THRIPS MANAGEMENT IN MANGO ORCHARDS

by

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Dissertation presented for the degree

DOCTOR OF PHILOSOPHY

at the

University of Stellenbosch

March 1999

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DECLARATION

I the undersigned hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

ABSTRACT

Thrips associated with mango trees {*Mangifera indica* L. (Anacardiaceae)} were collected over a five year period in the main mango production areas of South Africa. Fifteen species were identified, eleven belonging to the family Thripidae and four to the family Phlaeothripidae. The citrus thrips, *Scirtothrips aurantii* Faure and the red banded thrips, *Selenothrips rubrocinctus* (Giard) were the only two species found to cause lesions on the fruit. *Scirtothrips aurantii* was the economically most important species found.

There was a tendency for lesions caused by *S. aurantii* to decrease in prominence as the fruit matured. Some lesions that were prominent at the beginning of the season appeared less clearly defined at the end of the season. However, badly marked fruit did not recover to the extent that it could be exported.

Sticky traps (140mm X 76mm X 0.2mm) of various colours were tested in mango orchards for the attraction of *S. aurantii* adults. Yellow was superior to blue, white, red and green. Yellow traps can be used effectively for assessing activity levels of *S. aurantii* in mango orchards.

Cumulative insect-days were computed for *S. aurantii* on the traps and on the fruit and were correlated with the percentage fruit with lesions making it unacceptable for export. Fruit with such lesions should not exceed 5%. Chemical intervention should be used when *S. aurantii* on the traps exceed 2326 cumulative insect-days and when numbers on the fruit exceed 24 cumulative insect-days.

By using a two stage sampling system for determining *S. aurantii* population levels in mango orchards, the optimum combination of the number of trees per orchard (primary

units) and fruit per tree (secondary units) was estimated. The recommendation is to sample 5 fruit from 10 trees.

Hoerl's function ($Y = aX^b e^{cX}$) was used to describe the relationship between the number of *S. aurantii* on the fruit and fruit size, as well the number on the traps and fruit size. Fruit size when the maximum numbers of *S. aurantii* occurred ranged from 20.22mm to 40.33mm, while the fruit size at maximum numbers on the traps was from 2.94mm to 36.82mm. Therefore, for the management of thrips *S. aurantii* it is essential that they are monitored until fruit are at least 40mm in length.

Scirtothrips aurantii numbers started to build up during September which is the end of the flowering period and reached a peak usually during October or November when small fruit were present. *Scirtothrips aurantii* was only present on the fruit for a short period and the population survived on new growth that was present throughout the year. Low numbers were present from June until August. The highest number of *S. aurantii* was observed on the cultivar Sensation.

Different insecticides were evaluated in the field for control of *S. aurantii* on mango fruit. The insecticides tested were formetanate, formetanate plus sugar, tartar emetic plus sugar, methamidophos, sulphur, phenthoate, cypermethrin, fipronil, fenthion, isophenfos and prothiofos and an extract of Syringa [*Melia azedarach* L. (Meliaceae)]. A non-toxic, garlic based insect repellent and feeding depressant was also evaluated. The best control was obtained with formetanate and fipronil. The garlic based substance showed potential, but not the Syringa extract.

OPSOMMING

Blaaspootjies wat op mango bome {*Mangifera indica* L. (Anacardiaceae)} voorkom, is oor 'n tydperk van 5 jaar in die belangrikste mango produksie gebiede van Suid-Afrika versamel. Vyftien spesies is geïdentifiseer, waarvan elf behoort aan die familie Thripidae en vier aan die familie Phlaeothripidae. Die sitrusblaaspootjie, *Scirtothrips aurantii* Faure en die rooibandblaaspootjie, *Selenothrips rubrocinctus* (Giard) was die enigste twee spesies wat letsels op die vrugte veroorsaak het. *Scirothrips aurantii* was die ekonomiese belangrikste spesie wat voorgekom het.

Letsels veroosaak deur *S. aurantii* het 'n afname in prominensie getoon namate die vrugte volwasse geword het. Sommige letsels wat prominent aan die begin van die seisoen was, was ligter en nie so duidelik aan die einde van die seisoen gedefinieer nie. Vrugte met letsels het egter nie in so 'n mate herstel dat dit vir uitvoer aanvaarbaar was nie.

Taai kaartvalle (140mm X 76mm X 0.2mm) van verskillende kleure is in mangoboorde getoets vir die aanlokking van volwasse *S.aurantii*. Geel het meer aangelok as blou, wit, rooi en groen. Geel valle kan effektief aangewend word vir die bepaling van die aktiwiteitsvlak van *S. aurantii* in mangoboorde.

Kumulatiewe insek-dae is vir *S. aurantii* op die vrugte en op die valle bereken en met die persentasie vrugte met letsels wat dit onaanvaarbaar vir uitvoer maak, in verband gebring. Vrugte met sulke letsels moet nie 5% oorskry nie. Chemiese ingryping moet geskied wanneer *S. aurantii* op die valle 2326 kumulatiewe insek-dae en op vrugte 24 kumulatiewe insek-dae oorskry.

Deur gebruik te maak van 'n twee stadium mosternemingstel is die optimum kombinasie

van die aantal bome per boord en vrugte per boom bereken. Die aanbeveling is om 5 vrugte van 10 bome te monster.

Hoerl se funksie ($Y = aX^be^{cX}$) is gebruik om die verhouding tussen die aantal *S. aurantii* op die vrugte en die vruggrootte asook aantal op die valle en die vruggrootte te beskryf. Die vruggroote waarby die maksimum aantal *S. aurantii* op die vrugte teenwoordig was, was vanaf 20.22mm tot 40.33mm, terwyl die die vruggroote waarby die maksimum aantal op die valle teenwoordig was, gewissel het van 2.94mm tot 36.82mm. Vir die bestuur van blaaspootjies is dit dus belangrik om te moniteer vanaf vrugset tot vrugte ten minste 40mm in lengte is.

Scirtothrips aurantii se getalle het begin opbou gedurende September, wat die einde van die blomperiode is, en het gewoonlik 'n piek gedurende Oktober of November bereik wanneer klein vrugte teenwoordig was. *S. aurantii* was slegs vir 'n kort periode gedurende die seisoen op die vrugte teenwoordig en die bevolking het oorleef op nuwe groei wat reg deur die jaar teenwoordig was. Lae getalle het vanaf Junie tot Augustus voorgekom. Die hoogste getal *S. aurantii* is op die kultivar Sensation waargeneem.

Verskillende insekdoders vir die beheer van *S. aurantii* op mango vrugte is in die veld geëvalueer. Die insekdoders wat uitgetoets is, was formetanaat, formetanaat plus suiker, braakwynsteen plus suiker, metamidofos, swael, fentoaat, sipermetrin, fipronil, fention, isofenfos and protiofos en 'n ekstraksie van Sering [*Melia azedarach* L. (Meliaceae)]. 'n Nie-toksiese knoffel insek-afweermiddel en voedingsdepressant is ook geëvalueer. Die beste beheer is verkry met formetanaat and fipronil. Die knoffelsubstraat het potensiaal getoon, maar nie die Sering ekstrak nie.

ACKNOWLEDGEMENTS

The author extends her gratitude to the following:

Dr P.H. Joubert, the head of the pest management section at the ARC-Institute for Tropical and Subtropical Crops, for his support.

All my colleagues in the pest management department for their encouragement, support and interest.

The South African Mango Growers' Association for funding the project.

Prof. J.H. Giliomee for supervision of the study.

Dr K.L. Pringle who provided valuable statistical advice and constructive criticism.

Messrs M.C. Welding, R.L.J. Coetzer and A.J. Toerien for help with analyses of data.

Mr M. Stiller who did a tremendous job in identifying the thrips.

Mmes S. Dreyer, M. Maritz, C. Neethling and M.S. De Beer for technical assistance. Special thanks to Mrs M.S. De Beer for help with drawing the graphs.

My husband and parents for their continual support throughout the years.

This study was conducted in dependance on God, through whose grace I live.

CONTENTS

INTRODUCTION

Production of mango (*Mangifera indica* L.) in South Africa began in the Ofcolaco area in the Northern Province and near Malelane in the Mpumalanga Province in 1920 (Schroeder, 1991). Only seedlings, primarily of the cultivars Peach and Sabre, were planted. Improved fibreless cultivars such as Kent, Haden and Zill were later introduced from Florida. At present, approximately half of the total number of trees in South Africa consist of fibreless cultivars, mainly from Florida, with a few local selections being cultivated (Mullins, 1987; Amm, 1991). Processing absorbs 60% of the total tonnage, local fresh fruit 30% and export 10% (Amm, 1993). During the 1992/93 season, 1.1 million cartons were exported. The South African Mango Growers' Association (SAMGA) encourages the exploitation of new markets and therefore mango production and export from South Africa are escalating.

The most important insect pests, against which insecticides are regularly used on a preventative basis, are the mango seed weevil *Sternochetus mangiferae* (F.), the mango scale *Aulacaspis tubercularis* Newstead and fruit flies (De Villiers & Labuschagne, 1992; Botha, 1993). Three fruit fly species, namely the marula fruit fly *Ceratitis cosyra* (Walker), the Natal fruit fly *Ceratitis rosa* (Karsch) and the Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) are known to attack mango fruit in South Africa (De Villiers & Du Toit, 1979). *C. cosyra* and *C. rosa* are indigenous to Africa and phytosanitary measures are taken to prevent accidental exportation of these species (Labuschagne *et al.*, 1995). Since morphological differentiation between the maggots and eggs of the three species is difficult, infestation of fruit by any of the three species is liable to lead to rejections (Labuschagne *et al.*, 1994). According to the new regulations drawn up by the European Economic Community, it is possible for a whole consignment to be rejected if only one fruit fly maggot is found in the fruit.

Other potential economically important pests listed on mango are mango shield scale *Milviscutulus mangiferae* (Green), pink wax scale *Ceroplastes rubens* (Maskell), the coconut bug *Pseudotherapterus wayi* Brown and the South African citrus thrips *Scirtothrips aurantii* Faure (De Villiers & Labuschagne, 1992). The latter is the subject of this dissertation.

Earlier workers briefly mentioned the economic importance of *S. aurantii.* Annecke & Moran (1982) stated that *S. aurantii* severely scars young mango fruit, while Botha (1993) warned that the importance of *S. aurantii* on mango should not be underestimated, considering the problems the citrus industry is experiencing with this insect. As in citrus, feeding of *S. aurantii* causes lesions on the mango fruit (Fig. 1), leaf malformation (Fig. 2) and stunting of new growth. The damage on the fruit is only cosmetic and no harm is done to the fruit flesh. Mango fruit with larger lesions are not suitable for the export market. Criteria for the local market are not as strict, but the appearance of the fruit affects its marketability. Some mango producers chemically protect the foliage of their newly planted trees against *S. aurantii,* while on bearing trees it is often controlled preventatively. *Scirtothrips aurantii* also damages young mango trees in nurseries. The insect seems to be of greater importance in regions where citrus and mango trees are cultivated together. Thus the management of Letaba Estates near Tzaneen removed approximately 2 500 mango trees as the high population of *S. aurantii* they maintained was considered a threat to the citrus orchards in the vicinity. When the citrus trees came into production, it was impossible to control *S. aurantii* with the normal spray programme (Gilbert, M.J., personal communication). Some mango producers are concerned about the high numbers of *S. aurantii* and other thrips species occurring in mango inflorescences and are concerned about the effect of thrips feeding on fruit set, and control them with synthetic pyrethroids.

There were no registered thripicides for the control of thrips on mango trees prior to 1995. Methamidophos 500g/ℓ AL is currently registered for the control of *S. aurantii* on mango (Krause *et al.*, 1996). This organophosphate is also registered on citrus for the control of aphid, psylla, soft brown scale, citrus thrips, orange dog larvae and various mite species. The product is recommended for the control of *S. aurantii* and aphids on non-bearing and young mango trees up to three years of age. Methamidophos is a systemic pesticide and is applied as an undiluted stem treatment. The dosage rate is dependent on the trunk diameter. Methamidophos will control *S. aurantii* on young flush while limited efficacy is obtained on developing fruit. This thripicide is applied to the stems at the first indication of infestation or damage to young growth, and repeated at 21 day intervals if necessary. There are presently no registered insecticides for thrips control on older bearing trees.

The indigenous *S. aurantii* has been recognised as a pest on citrus since 1925 (Faure, 1929). Commercial damage is caused by the larvae and adults which feed on young fruit, producing a brown blemish on the rind (Bedford, 1943; Wentzel *et al.*, 1978; Kamburov, 1991, Gilbert & Bedford, 1998). Severely blemished fruit is not suitable for export. Citrus in South Africa is primarily produced for fresh fruit on the export market. Therefore it is important to prevent the external cosmetic damage. *Scirtothrips aurantii* is also abundant on tender new shoots, causing leaf malformation and stunted growth (Wentzel *et al.*, 1978; Kamburov, 1991; Gilbert, 1992; Gilbert & Bedford, 1998). The shape of the leaves may be distorted, with two parallel streaks of damaged tissue, one on each side of the midrib. In severe cases small apical shoots may die and multiple budding may follow. This can lead to crop reduction during the following season (Kamburov, 1991). The insecticides applied to control citrus thrips often interfere with the biological control of red scale, *Aonidiella aurantii* (Maskell), and other pests on citrus (Grout & Richards, 1991a, Bedford *et al.*, 1992).

Scirtothrips aurantii is of economic importance in most citrus producing areas of South Africa, but its pest status varies considerably (Bedford, 1943; Wentzel *et al.*, 1978, Gilbert & Bedford, 1998). The most severe outbreaks occur in Mpumalanga, the Northern Province and the Rustenburg areas, while in the Eastern and Western Cape Provinces the pest status is far lower (Gilbert & Bedford, 1998). *Scirtothrips aurantii* is also of economic importance in Zimbabwe (Hall, 1930) and Swaziland (Stassen & Catling, 1969), and also occurs in other African countries such as Egypt, Sudan, Nigeria and the Ivory Coast (Zur Strassen, 1960; Mound & Palmer, 1981). Outside the continent, its presence has been confirmed in the Cape Verde Islands, Yemen, Mauritius and Reunion (Mound & Palmer, 1981; Gilbert & Bedford, 1998). *Scirtothrips aurantii* occurs on a wide range of host plants and attacks many crops (Faure, 1929; Hall, 1930; Bedford, 1943; Stofberg, 1948; Georgala, 1967; Wentzel, 1971; Mound & Palmer, 1981; Gilbert, 1990; Grout & Richards, 1990a; Gilbert & Bedford, 1998). In Faure's (1929) list of host plants he also referred to the mango.

Traditionally preventative sprays of parathion were used in spring for combined control of this pest and scales on citrus (Georgala, 1982). In the development of an integrated control programme *S. aurantii* was a key factor, since at present there is not sufficient biological control of this species in most production areas and insecticides have to be applied on a preventative basis.

The amount of damage caused by *S. aurantii* to citrus fluctuates widely from year to year; it also varies in different localities, in different orchards and on different citrus cultivars. The efficacy of different thripicides also varies. Therefore is it essential that any thrips programme is based on thorough scouting and monitoring. Monitoring systems were therefore developed for thrips on citrus (Samways *et al.*, 1986; Grout & Richards, 1990b).

Interest is starting to be focused on the possible resistance of *S. aurantii* to organophosphate pesticides as a result of field observations indicating failures in control (Gilbert, 1992). Variable susceptibility of different populations to parathion has been demonstrated under controlled conditions (Grout & Richards, 1991b). Tolerance to tatar emetic bait was demonstrated in Swaziland (Grout *et al.*, 1996). In view of the damage caused to citrus and the problems experienced with chemical control, Botha's (1993) contention that *S. aurantii* should not be underestimated as a pest on mango can be supported.

A few predators of *S. aurantii* have been recorded on citrus (Bedford, 1943; Wentzel *et al.*, 1978). Due to the fact that *S. aurantii* pupates in the ground, Milne (1977) speculated that predacious ground mites might play an important role in regulating the population. Predacious mites in the genus *Euseius* evidently play an important role in regulating *S. aurantii* populations (Schwartz, 1983; Grout & Richards, 1992; Grout, 1994). Seven *Euseius* spp. have been recorded on citrus in Zimbabwe, Swaziland and South Africa (Grout, 1994). In the Eastern Cape *E. addoensis addoensis* (McMurtry) occurs commonly in citrus orchards and reduces scarring caused by *S. aurantii* (Grout & Richards, 1992). *Euseius citri* (Van der Merwe & Ryke) plays a role in reducing the numbers of *S. aurantii* in citrus orchards in Mpumalanga, the Northern Province, the North West Province and Swaziland but it does not occur in sufficiently high numbers to be commercially effective (Grout, 1994). *Euseius citri* feeds on immature and adult *S. aurantii* (Grout & Stephen, 1993). Recently *Goetheana incerta* Annecke, an eulophid parasitic wasp, was recovered from *S. aurantii* on citrus in Swaziland and Mpumalanga (Grout & Stephen, 1995). This was the first record of a parasitoid of *S. aurantii*. Approximately 2% of larvae collected from citrus during February and March were parasitized.

Several other thrips species have been found to damage mango in various parts of the world, some of them occurring in South Africa. The pine tree thrips, *Heliothrips haemorrhoidalis* (Bouché) and the red banded or cacao thrips, *Selenothrips rubrocinctus* (Giard) are cosmopolitan species which also attack mango (Avidov & Harpaz, 1969; Hill, 1975; Wysoki *et al.*, 1993). Both *H. haemorrhoidalis* and *S. rubrocinctus* occur in South Africa and are sporadic pests on avocado (Annecke & Moran, 1982; De Villiers & Van den Berg, 1987; De Villiers, 1990; Dennill & Erasmus, 1992). The extent of the damage caused by these species to mango in South Africa is not known. The Mediterranean mango thrips, *Scirtothrips mangiferae* Priesner, attack mango in Egypt and also occurs in Israel, Greece, Aden, Sudan and Lybia, but not in South Africa (Priesner, 1932; Venezian & Ben-Dov, 1982; Wysoki *et al.*, 1993). *Scirtothrips dorsalis* Hood occurs on *Mangifera* in India (Mound & Palmer, 1981). It was recorded from castor-oil plant *Ricinus communis* L. in South Africa (Gilbert, 1986). The Western flower thrips or Californian thrips *Frankliniella occidentalis* (Pergande) is an economically important pest of mango in Israel (Ben-Dov *et al.*, 1992; Wysoki *et al.*, 1993). It was first recorded in South Africa in 1987 (Giliomee, 1989). The threat of the latter two species to mango in South Africa is not yet known. The castor thrips *Retithrips syriacus* (Mayet) is listed as a mango pest in Israel (Wysoki *et al.*, 1993) and is commonly found in Africa, India and South America (Palmer *et al.*, 1989), but has not yet been recorded from mango in South Africa. *Thrips hawaiiensis* (Morgan) occurs on mango in Thailand (Palmer *et al.*, 1989).

Even though a considerable amount of information is available on the occurrence and control of *S. aurantii* on citrus, very little is known of this species as a pest on mango. In view of the increasing importance of mango as a commercial agricultural crop and the uncertainties regarding the impact, phenology and control of *S. aurantii* on mango, this study was undertaken. The overall objective was to contribute towards the management of *S. aurantii* on mango. The latter requires basically the availability of reliable monitoring techniques for the insect, an understanding of the relationship between insect numbers and the damage they cause, knowledge of the biology of the insect and information on control measures. Each of the chapters that follow will focus on more specific objectives within this broad framework. These specific objectives are:

1) To identify the Thysanoptera present in mango orchards and to determine if *S. aurantii* is the only species causing damage to mango.
2) To determine the correlation between *S. aurantii* numbers and the percentage damaged fruit.
3) To develop a monitoring system for thrips on mango and in particular to determine the suitability of different coloured sticky traps for monitoring *S. aurantii* in mango orchards.
4) To determine the stage of the fruit susceptible to thrips damage and to assess the level of damage.
5) To determine the seasonal occurrence of *S. aurantii* in mango orchards.
6) To determine the efficacy of different insecticides for controlling *S. aurantii* in mango orchards.
7) To develop an integrated pest management strategy for thrips in mango orchards.

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FIGURE 1 Lesions on mango fruit caused by *Scirtothrips aurantii*

FIGURE 2 Leaf malformation caused by *Scirtothrips aurantii*

CHAPTER 1

SPECIES OF THRIPS (ORDER: THYSANOPTERA) ASSOCIATED WITH MANGO TREES IN SOUTH AFRICA

ABSTRACT

Thrips were collected on mango trees {*Mangifera indica* L. (Anacardiaceae)} from 1992 to 1996 in the main mango production areas in South Africa to identify the complex of species associated with this crop. Thrips were collected from the flowers, fruit and leaves. Fifteen species were identified, eleven belonging to the family Thripidae and four to the family Phlaeothripidae. The citrus thrips, *Scirtothrips aurantii* Faure and the red banded thrips, *Selenothrips rubrocinctus* (Giard) were the only two species found to cause lesions on the fruit. Numbers of *S. rubrocinctus* were usually low in mango orchards and did not seem to be of economic importance. *Scirtothrips aurantii* was abundant on new growth causing stunting of growth and leaf malformation. *Aleurodothrips fasciapennis* (Franklin) and *Haplothrips bedfordi* Jacot-Guillarmod were the only two predatory thrips found. The Western flower thrips, *Frankliniella occidentalis* (Pergande), was collected from mango flowers in the Letsitele area. *Thrips acaciae* Trybom, *Thrips tenellus* Trybom and *S. aurantii* were found to be the most abundant in the flowers.

INTRODUCTION

The number of described species in the order Thysanoptera totals more than 5 000, divided between two sub-orders, the Tubulifera and the Terebrantia (Zur Strassen, 1960). Thrips are mostly between 1 and 2mm in length and nearly all black, brown or yellow. Different species vary greatly in habits. Most thrips feed on vascular plants, fungi or mosses, some are predatory and a few are omnivorous (Lewis, 1973). Flowers are particularly favoured by many species (Kirk, 1984; 1987). Flower living species are sometimes useful as pollinators (Syed, 1979; Kirk, 1984), but they can also cause flowers to drop prematurely, causing poor fruit set (Lewis, 1973). Where thrips feed on cultivated crops, they can be serious pests, not only because of the feeding damage but also because they are important as the transmitters of various plant viruses (Amin & Palmer, 1985). Some thrips are predators of small insects, many of which are pests, in which case thrips are beneficial (Palmer & Mound, 1989). The life history of thrips involves an egg, two active larval instars that feed, followed by two (or three) relatively inactive pupal instars and the adult (Palmer *et al.*, 1989). Because thrips have a short life cycle and a high innate capacity of increase, several generations can be produced per year. Therefore it is not surprising that when conditions are favourable their numbers can multiply rapidly.

A few thrips species are known to attack the mango {*Mangifera indica* L.(Anacardiaceae)}. The pine tree thrips, *Heliothrips haemorrhoidalis* (Bouché), is a cosmopolitan species which is known to attack mango in Israel (Avidov & Harpaz, 1969; Wysoki *et al.*, 1993). The red banded or cacao thrips, *Selenothrips rubrocinctus* (Giard), is also a cosmopolitan species which attacks mango (Hill, 1975). Both *H. haemorrhoidalis* and *S. rubrocinctus* are sporadic but potentially serious pests on avocado fruit in South Africa (Dennill & Erasmus, 1992). By feeding on the pericarp, these thrips extract chlorophyll and cause bronzing of the surface of the fruit, while the skin of severely damaged fruit may crack (Annecke & Moran, 1982; De Villiers & Van den Berg, 1987; De Villiers, 1990). *Selenothrips rubrocinctus* usually damages young mango trees and trees in nurseries, but rarely mature trees (Hill, 1975). The extent of damage caused by these two species to mango in South Africa is not known. The South African citrus thrips, *Scirtothrips aurantii* Faure, was found to have severely scarred young mango fruit (Annecke & Moran, 1982). *Scirtothrips dorsalis* Hood occurs on *Mangifera* in India (Mound & Palmer, 1981) and was recorded from the Castor oil plant, *Ricinus communis* L. in South Africa (Gilbert, 1986). The Mediterranean mango thrips, *Scirtothrips mangiferae* Priesner, attacks mango in Egypt and Israel (Priesner, 1932; Venezian & Ben-Dov, 1982; Wysoki *et al.*, 1993). It can be a severe pest mainly on young trees, causing the young leaves to curl and drop prematurely. Twigs of infested shoots are much shorter than those of uninfested ones. No damage to fruit has yet been recorded. The Western flower thrips or Californian thrips, *Frankliniella occidentalis* (Pergande), is an economically important pest of mango in Israel and causes serious damage consisting of skin silvering and heavy skin cracking (Ben-Dov *et al.*, 1992; Wysoki *et al.*, 1993). *F. occidentalis* was first documented in South Africa in 1987. This insect possibly entered the country on cut flowers imported from Europe (Giliomee, 1989), but has not previously been recorded from mango in South Africa. The castor thrips, *Retithrips syriacus* (Mayet), is listed on mango in Israel but is not considered to be of economic importance (Wysoki *et al.*, 1993). This species is found in South Africa but has not been collected from mango (Zur Strassen, 1960). *Thrips hawaiiensis* (Morgan) occurs on mango in Thailand (Lee & Wen, 1982), but is not known from South Africa.

The objective of this study was to identify the Thysanoptera associated with mango trees in South Africa and to make observations on the abundance of species.

MATERIALS AND METHODS

Thrips survey

Thrips occurring on mango leaves, flowers and fruit were collected from 1992 to 1996 in different production areas of Mpumalanga (Friedenheim, Kaapmuiden, Malelane, Nelspruit) and the Northern Province (Hoedspruit, Letsitele, Nondweni). Leaves, flowers and fruit were examined and any thrips present were removed with a fine brush. Inflorescences were also shaken over a tray and the thrips picked up with an aspirator. The thrips were stored in a mixture of 9 parts 60% ethyl alcohol and 1 part acetic acid.

Monitoring thrips in the flowers and on young fruit

To determine the diversity of thrips found in the flowers of the mango, they were collected from the time of budding (14 August 1995) until fruit were on average 71mm in length (6 November 1995). This was done in a mango orchard (no. F3) at the Institute for Tropical and Subtropical Crops (ITSC) Nelspruit Experimental Farm. This orchard consisted of different mango selections. Inflorescences at the same stage of development were marked and sampled weekly by shaking five inflorescences and collecting thrips with an aspirator. This was repeated in Zill and Sensation orchard (no. V6) at the ITSC Friedenheim Experimental Farm during 1996. Ten inflorescences were sampled in each cultivar. Sampling commenced on 12 August 1996 and was terminated on 7 October 1996 when flowers started dropping and the fruit was setting.

Monitoring thrips with yellow card traps

In a Sensation orchard (no. K8) at the ITSC Nelspruit Experimental Farm, three yellow card traps were used for the monitoring of adult thrips from August 1992 until March 1993. Traps were also placed in a Zill orchard (no. V6) and a Fascell orchard (no. V7) at the ITSC Friedenheim Experimental Farm from August to November 1992. From September until November 1996 traps were placed in a Zill and Sensation orchard (no. V6) on the ITSC Friedenheim Experimental Farm. The traps consisted of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2mm). Both sides of the traps were coated with a sticky adhesive, Fly-tac®. Traps were suspended 1.5 m to 2m above the ground on the northern side of the tree. The traps were placed along a diagonal across the orchard with one trap in the centre and the other two traps near the opposing corners. Every week traps were changed and covered with clear polyethylene plastic wrap. Thrips were counted using a stereo microscope.

Monitoring thrips with dispersal/emergence traps

Dispersal/emergence (D/E) traps sample mature thrips larvae as they drop to the ground to pupate and adults emerging from the soil. Each trap consisted of a square glass plate (250mm X 250mm X 3mm) placed on top of a polyvinyl chloride irrigation pipe with a diameter of 130mm and a height of 100mm. The glass plate was covered with a sticky adhesive, Fly-tac®, and served as the trapping surface. D/E traps were used by Reed & Rich (1975) and Tanigoshi & Moreno (1981) for monitoring *Scirtothrips citri* (Moulton) in citrus orchards and Gilbert (1992) for monitoring *S. aurantii* in citrus orchards. These traps were used for monitoring *S. aurantii* and other thrips from 1996 in the Zill and Sensation orchard (no. V6) at the ITSC Friedenheim Experimental Farm from 26 August to 4 November 1996. Three traps per orchard were used and placed 300mm from the tree trunks as suggested by Reed & Rich (1975) and Gilbert (1992). Traps were placed on the northern side. Traps were changed weekly and covered with clear polyethylene plastic wrap and taken to the laboratory where counting was conducted using a stereo microscope. As it is difficult to distinguish between the larvae of the different species, only the adults were counted on both sides of the glass plate.

RESULTS AND DISCUSSION

Thrips survey

Thirteen species were identified from the flowers (Table 1), five from the leaves (Table 2) and three from the fruit (Table 3).

Aleurodothrips fasciapennis (Franklin) was collected at two localities from the leaves and is known as a predatory thrips feeding on scale insects (Palmer & Mound, 1989). This species is known to prey on the mango scale, *Aulacaspis tubercularis* Newstead (Labuschagne, 1993). *Haplothrips bedfordi* Jacot-Guillarmod, a predatory thrips occurred on the flowers, leaves and fruit and was collected at five localities. *Haplothrips bedfordi* was found in association with *S. aurantii* on the fruit. It is a predator of *S. aurantii* on citrus and both larvae and adults feed on *S. aurantii* (Bedford, 1943). *Haplothrips clarisetis* Priesner was collected from mango flowers and on one occasion from the leaves. It occurred at five localities. *Haplothrips gowdeyi* (Franklin) was collected from the flowers at four localities. *Haplothrips clarisetis* and *H. gowdeyi* are known plant feeders and appear on a wide range of host plants (Zur Strassen, 1960; Gilbert, 1990).

Florithrips dilutus (Hood) was only collected at one locality from the flowers. *Frankliniella occidentalis* was collected for the first time on mango flowers in this study. It was only found in Letsitele but it may expand its range as it is a recent introduction (Giliomee, 1989). This species is highly polyphagous and has been recorded on numerous hosts (Badenhorst, 1993). It remains to be seen whether or not this species can cause the kind of damage observed in Israel (Ben-Dov *et al.*, 1992; Wysoki *et al.*, 1993).

Frankliniella schultzei (Trybom), also known as the kromnek thrips, occurred in mango flowers at four localities. It has a world-wide distribution but is particularly common in Africa. This polyphagous and flower living species, can damage young leaves within the bud. It is known to carry spores of mildews, moulds and rusts from infected plants (Palmer *et al.*, 1989) and is also a vector of tomato spotted wilt virus. *Frankliniella schultzei* also occurs in citrus flowers but does not cause damage (Gilbert, M.J., personal communication).

Megalurothrips sjostedti (Trybom) was collected from the flowers at four localities. This species is known as the bean thrips of Africa and is a major pest of cowpeas. Mechanical damage to the cowpea flowers may result in yield loss (Palmer *et al.*, 1989; Alghali, 1992). *Ramaswamiahiella subnudula* Karny was collected from the flowers at three different localities.

Scirtothrips aurantii was collected from the flowers, leaves and fruit and occurred at all the locations where collecting was done. This species was only collected from new leaves and young fruit and it seemed that feeding did not take place on mature leaves and fruit. It was observed to cause lesions on the fruit, leaf malformation and stunting of new growth. The lesions on the fruit consisted of silvering and cracking of the skin. Both adults and larvae were seen to feed. This species is a well documented pest on citrus in South Africa (Gilbert & Bedford, 1998).

Sericothrips occipitalis Hood was only collected on one occasion. It is known to occur on a wide rage of host plants, including legumes (Zur Strassen, 1960; Palmer *et al.*, 1989).

Selenothrips rubrocinctus was collected from leaves and fruit at four localities. This species fed on both young and mature leaves and fruit. Characteristically associated with the feeding damage on the fruit and the leaves were numerous small, shiny black spots of excreta. *Selenothrips rubrocinctus* fed on both sides of the leaves and caused rusty marks as well as curled leaf edges. Greyish lesions were caused on the mango fruit. Although *S. rubrocinctus* can become a severe pest on young mango plantings (Hill, 1975), numbers in the orchards were usually low and seemed to be under good biological control. The phytoseiid mites, *Euseius* near *rhusi*, *Iphiseius degenerans* (Berlese), *Typhlodromus vescus* Van der Merwe and *Euseius citri* (Van der Merwe & Ryke) were found in association with *S. rubrocinctus*.

Taeniothrips gowdeyi (Bagnall) was collected from the flowers at three localities. This species also occurs commonly within citrus flowers but their numbers are low in comparison with *Thrips tenellus* Trybom (Gilbert, 1990).

Thrips acaciae Trybom was collected from the flowers at two localities and is also known to occur in the flowers of *Acacia karroo* (Zur Strassen, 1960). *Thrips tenellus* was found very commonly in the mango flowers and occurred at all the locations where collecting was done. It is also commonly found in citrus flowers and in the flowers of *Acacia* spp. (Gilbert, 1990). Both *T. acaciae* and *T. tenellus* probably feed on pollen.

Except for thrips, there was a large complex of other insects and mites present in the flowers. *Orius* spp. (Anthocoridae) were commonly found in the flowers preying on the thrips.

Monitoring thrips in the flowers and on young fruit

Scirtothrips aurantii was the most abundant species found in the flowers and on the young fruit at the ITSC Nelspruit Experimental Farm mango orchard (no. F3) during 1995 (Tables 4 and 7). *Haplothrips gowdeyi* and *T. tenellus* were also found in high numbers during the flowering period. *Scirtothrips aurantii* was the only species found on the fruit as it developed beyond 9mm. This was the only orchard where *S. aurantii* was found in such high numbers in the flowers. The orchard consisted of different selections and the population probably built up on the fruit of early flowering selections. By the time the majority of trees started to flower, *S. aurantii* was already present in high numbers.

In contrast with the Nelspruit orchard, *T. acaciae* was the most abundant species in the Zill and Sensation orchard (no. V6) at the ITSC Friedenheim Experimental Farm during 1996

(Tables 5, 6 and 7), while *S. aurantii* was absent. *Thrips tenellus* was also present in fairly high numbers.

Monitoring thrips with yellow card traps

Yellow sticky card traps were an effective method for monitoring thrips species and numbers. The traps were easy to use and handle. The thrips trapped were mainly *S. aurantii* and *T. tenellus;* while other species were very low in numbers and were omitted from the results. *Thrips acaciae* was abundant at Friedenheim during 1996 and was included. The abundance of *T. tenellus* and *S. aurantii* in Sensation orchard (no. K8) at Nelspruit during 1992/93 is given in Fig. 1. The numbers of *T. tenellus* were high during the flowering period, but declined sharply when fruit were setting and virtually none were present during the fruiting period. The numbers of *S. aurantii* increased when fruit were setting and declined towards the end of the fruiting period. Similar results were obtained in the Zill and Fascell orchards at Friedenheim during 1992 (Figs 2 and 3).

During 1996, at Friedenheim, in both the Zill and Sensation orchards high numbers of *T. tenellus* and *T. acaciae* were present during the flowering period and declined when fruit were setting and developing (Figs 4 and 5). Very low numbers of *S. aurantii* were present during the flowering period and when fruit were setting.

Monitoring thrips with D/E traps

The D/E traps yielded similar patterns to yellow card traps, with high numbers of *T. tenellus* and *T. acaciae* present during the flowering period which declined when fruit were setting and developing (Figs 6 and 7). However, in the Zill orchard, numbers peaked about three weeks earlier in the card traps than on the D/E traps. Very low numbers of *S. aurantii* were present during the flowering period and when fruit were small.

CONCLUSION

Fifteen Thysanoptera species were found on mango, eleven belonging to the family Thripidae and four to the family Phlaeothripidae. Thirteen species were identified from the flowers, with *S. aurantii, T. acaciae* or *T. tenellus* occurring the most abundantly. The abundance of thrips species in the flowers varied from orchard to orchard and from season to season. *Frankliniella occidentalis*, a recent introduction to South Africa and a pest of many crops, was collected from mango flowers in the Letsitele area but its possible threat for mango production in South Africa is not yet known. *Scirtothrips aurantii* and *S. rubrocinctus* were the only two species observed to cause lesions on the fruit. *Selenothrips rubrocinctus* numbers were usually low in mango orchards and did not seem to be of economic importance. *Scirtothrips aurantii* was also abundant on new growth, causing stunting of growth and leaf malformation. It appeared to be the most economically important thrips species on the mango. *Haplothrips bedfordi* and *A. fasciapennis* were two predatory thrips found.

ACKNOWLEDGEMENTS

The author thanks Mmes M. Maritz, C. Neethling, M.S. De Beer and S. Dreyer for assistance in the study. Thrips were identified by Mr M. Stiller and mites by Dr E.A. Ueckermann. This project was funded by the South African Mango Growers' Association and by the Agricultural Research Council.

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TABLE 1 Thrips collected from mango flowers

Thrips	**Locality**
Suborder: Tubulifera	
Haplothrips bedfordi Jacot-Guillarmod (Phlaeothripidae)	Friedenheim Kaapmuiden Nelspruit Nondweni
Haplothrips clarisetis Priesner (Phlaeothripidae)	Friedenheim Kaapmuiden Letsitele Nelspruit Malelane
Haplothrips gowdeyi (Franklin) (Phlaeothripidae)	Friedenheim Hoedspruit Kaapmuiden Nelspruit
Suborder: Terebrantia	
Florithrips dilutus (Hood) (Thripidae)	Letsitele
Frankliniella occidentalis (Pergande) (Thripidae)	Letsitele
Frankliniella schultzei (Trybom) (Thripidae)	Friedenheim Kaapmuiden Letsitele Nelspruit
Megalurothrips sjostedti (Trybom) (Thripidae)	Friedenheim Hoedspruit Kaapmuiden Nelspruit
Ramaswamiahiella subnudula Karny (Thripidae)	Hoedspruit Letsitele Nelspruit
Scirtothrips aurantii Faure (Thripidae)	Friedenheim Hoedspruit Kaapmuiden Letsitele Nelspruit Malelane Nondweni
Sericothrips occipitalis Hood (Thripidae)	Nelspruit
Taeniothrips gowdeyi (Bagnall) (Thripidae)	Kaapmuiden Hoedspruit Letsitele
Thrips acaciae Trybom (Thripidae)	Friedenheim Nelspruit
Thrips tenellus Trybom (Thripidae)	Friedenheim Hoedspruit Kaapmuiden Letsitele Malelane Nelspruit Nondweni

TABLE 2 Thrips collected from mango leaves

Thrips	Locality
Suborder: Tubulifera	
Aleurodothrips fasciapennis Franklin (Phlaeothripidae)	Friedenheim Nelspruit
Haplothrips bedfordi Jacot-Guillarmod (Phlaeothripidae)	Friedenheim Kaapmuiden Letsitele Nelspruit
Haplothrips clarisetis Priesner (Phlaeothripidae)	Letsitele
Suborder: Terebrantia	
Scirtothrips aurantii Faure (Thripidae)	Friedenheim Hoedspruit Kaapmuiden Letsitele Malelane Nelspruit
Selenothrips rubrocinctus (Giard) (Thripidae)	Nondweni Friedenheim Nelspruit

TABLE 3 Thrips collected from mango fruit

Thrips	
Suborder: Tubulifera	
Haplothrips bedfordi Jacot-Guillarmod (Phlaeothripidae)	Friedenheim Nelspruit
Suborder: Terebrantia	
Scirtothrips aurantii Faure (Thripidae)	Friedenheim Hoedspruit Kaapmuiden Letsitele Malelane Nelspruit
Selenothrips rubrocinctus (Giard) (Thripidae)	Friedenheim Nondweni Hoedspruit Nelspruit

TABLE 4 Thrips species collected at weekly intervals from mango flowers in a selection orchard at Nelspruit by sampling five inflorescences from budding until fruit were on average 71mm long

Date	Species (numbers in brackets)
1995-08-14 All flowers on panicle closed	*H. gowdeyi* (2) *Haplothrips* sp. (2) *S. aurantii* (24) Larvae (3)
1995-08-21 15% of flowers on panicle open	*H. gowdeyi* (14) *S. aurantii* (1) Larvae (1)
1995-08-28 85% of flowers on panicle open	*H. clarisetis* (10) *F. schultzei* (6) *S. aurantii* (14) *T. tenellus* (5) Larvae (2)
1995-09-04 100% of flowers on panicle open	*H. gowdeyi* (2) *S. aurantii* (14) *T. tenellus* (4)
1995-09-11 Small fruit setting	*S. aurantii* (10) *T. tenellus* (8) Larvae (15)
1995-09-18 Average fruit length 3mm	*H. bedfordi* (2) *H. gowdeyi* (2) *S. aurantii* (14) *T. tenellus* (4)
1995-09-26 Average fruit length 9mm	*S. aurantii* (18) Larvae (3)
1995-10-02 Average fruit length 12mm	*S. aurantii* (34) Larvae (12)
1995-10-09 Average fruit length 22mm	*S. aurantii* (20) Larvae (16)
1995-10-16 Average fruit length 39mm	*S. aurantii* (1)
1995-10-23 Average fruit length 58mm	*S. aurantii* (1) Larvae (1)
1995-10-30 Average fruit length 58mm	-
1995-11-06 Average fruit length 71mm	-

TABLE 5 Thrips species collected at weekly intervals from flowers of the cultivar Zill at Friedenheim by sampling ten inflorescences from budding until the fruit were on average 9mm long

Date	Species (numbers in brackets)
1996-07-22 All flowers on panicle closed	-
1996-07-29 All flowers on panicle closed	-
1996-08-05 10% of flowers on panicle open	-
1996-08-12 70% of flowers on panicle open	-
1996-08-19 100% of flowers on panicle open	-
1996-08-26	*H. gowdeyi* (1) *T. acaciae* (1)
1996-09-02	*T. acaciae* (2)
1996-09-09	*H. clarisetis* (1) *H. gowdeyi* (1) *T. tenellus* (1)
1996-09-16	*H. clarisetis* (2) *H. gowdeyi* (1) *T. acaciae* (10) *T. tenellus* (11)
1996-09-23	*H. gowdeyi* (2) *T. acaciae* (13) *T. tenellus* (9)
1996-09-30	*H. gowdeyi* (1) *T. acaciae* (30) *T. tenellus* (13) Larvae 8
1996-10-07 Average fruit length 9mm	*H. gowdeyi* (1) *T. acaciae* (2)

TABLE 6 Thrips species collected at weekly intervals from flowers of the cultivar Sensation at Friedenheim by sampling ten inflorescences from budding until the fruit were on average19mm long

Date	Species (numbers in brackets)
1996-07-22 All flowers on panicle closed	-
1996-07-29 5% of flowers on panicle open	*H. bedfordi* (1) *H. gowdeyi* (3) *S. occipitalis* (1)
1996-08-05 30% of flowers on panicle open	-
1996-08-12 50% of flowers on panicle open	-
1996-08-19 90% of flowers on panicle open	-
1996-08-26 90% of flowers on panicle open	Larvae (1)
1996-09-02 100% of flowers on panicle open	*T. acaciae* (1)
1996-09-09	*T. acaciae* (4) *T. tenellus* (3)
1996-09-16	*H. clarisetis* (1) *H. gowdeyi* (2) *T. acaciae* (13) *T. tenellus* (2)
1996-09-23	*H. gowdeyi* (1) *T. acaciae* (95) *T. tenellus* (2)
1996-09-30	*T. acaciae* (28) *T. tenellus* (52)
1996-10-07 Average fruit length 19mm	*H. gowdeyi* (1)

TABLE 7 The cumulative number (n) from each species collected from the flowers and small fruit, the percentage contribution (P) of each of those species to the total number collected, the abundance ranking (AR) and the occurrence frequency (OF)

Thrips species collected from orchard no. F3 at Nelspruit (1995-08-14 to 1995-11-13)				
Species	**n**	**P**	**AR**	**OF**
H. bedfordi	2	0.9	6	7.1
H. clarisetis	10	4.7	4	7.1
H. gowdeyi	20	9.4	3	28.6
Haplothrips sp.	2	0.9	6	7.1
F. schultzei	6	2.8	5	7.1
S. aurantii	151	71.2	1	78.5
T. tenellus	21	9.9	2	28.6
TOTAL	212			
Thrips species collected from Zill orchard no. V6 at Friedenheim (1996-07-22 to 1996-10-07)				
Species	**n**	**P**	**AR**	**OF**
H. clarisetis	3	2.9	4	50.0
H. gowdeyi	7	6.9	3	8.3
T. acaciae	58	56.9	1	50.0
T. tenellus	34	33.3	2	33.3
TOTAL	102			
Thrips species collected from Sensation orchard no. V6 at Friedenheim (1996-07-22 to 1996-10-07)				
Species	**n**	**P**	**AR**	**OF**
H. bedfordi	1	0.5	4	8.3
H. clarisetis	1	0.5	4	8.3
H. gowdeyi	7	3.3	3	33.3
T. acaciae	141	67.1	1	41.6
T. tenellus	59	28.1	2	33.3
S. occipitalis	1	0.5	4	8.3
TOTAL	210			

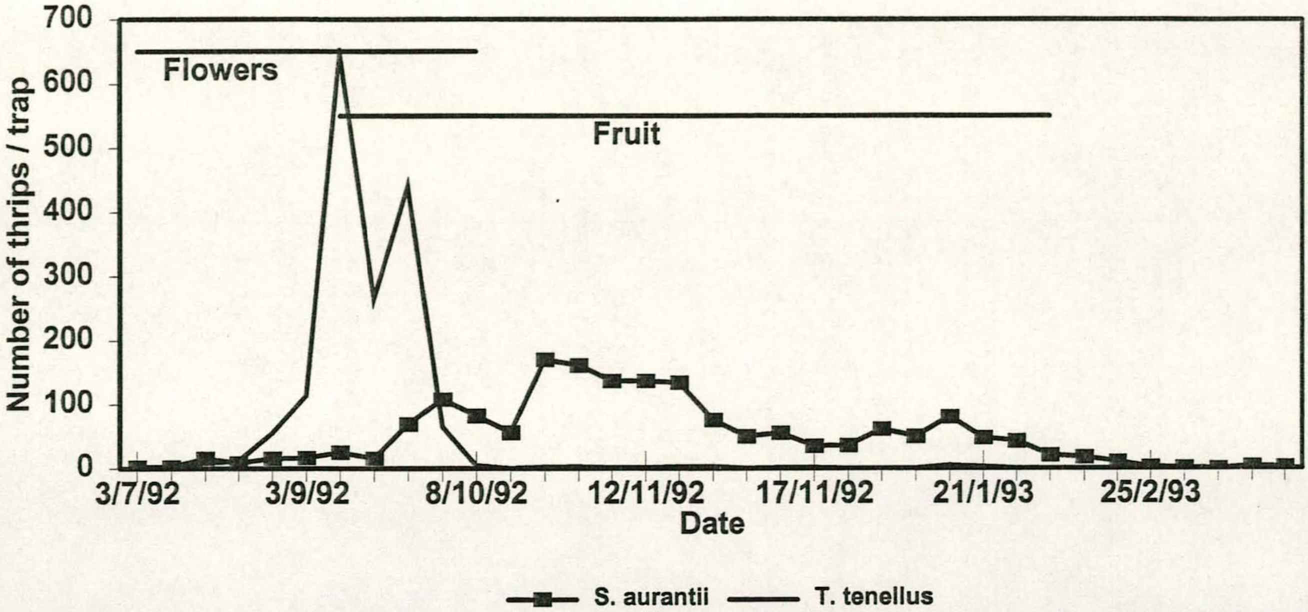

FIGURE 1 *Scirtothrips aurantii* and *Thrips tenellus* on yellow card traps in a Sensation orchard (no. K8) at Nelspruit during 1992-1993

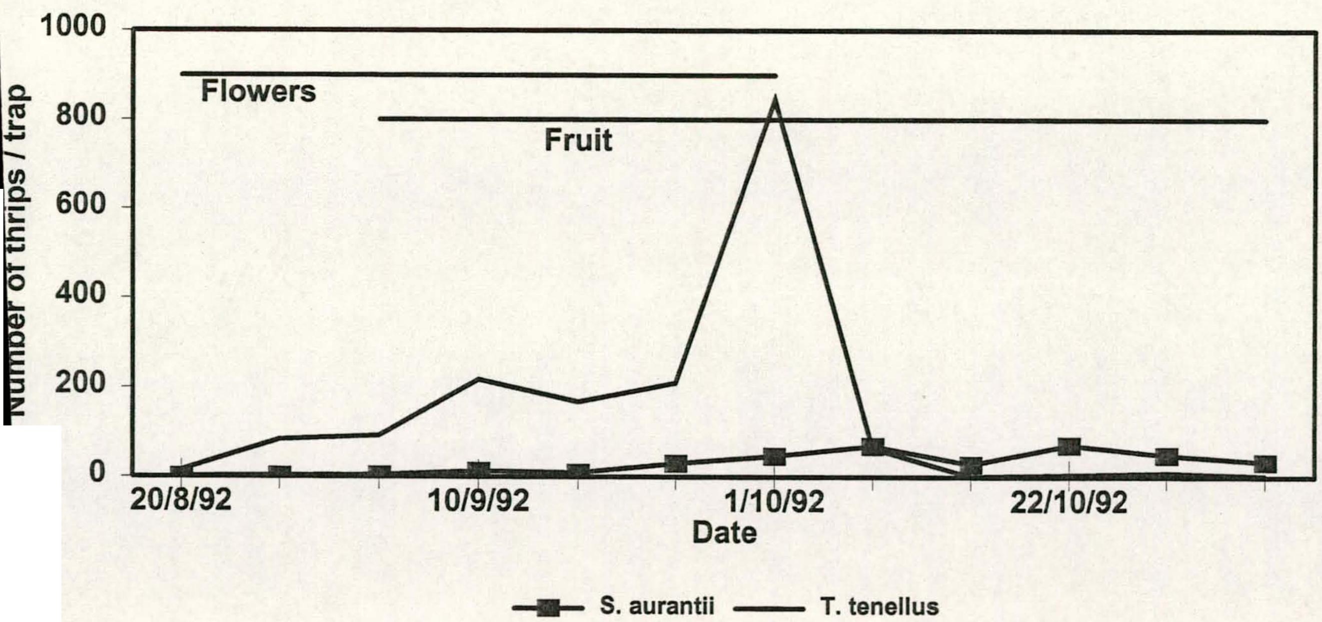

FIGURE 2 *Scirtothrips aurantii* and *Thrips tenellus* on yellow card traps in a Zill orchard (no. V6) at Friedenheim during 1992

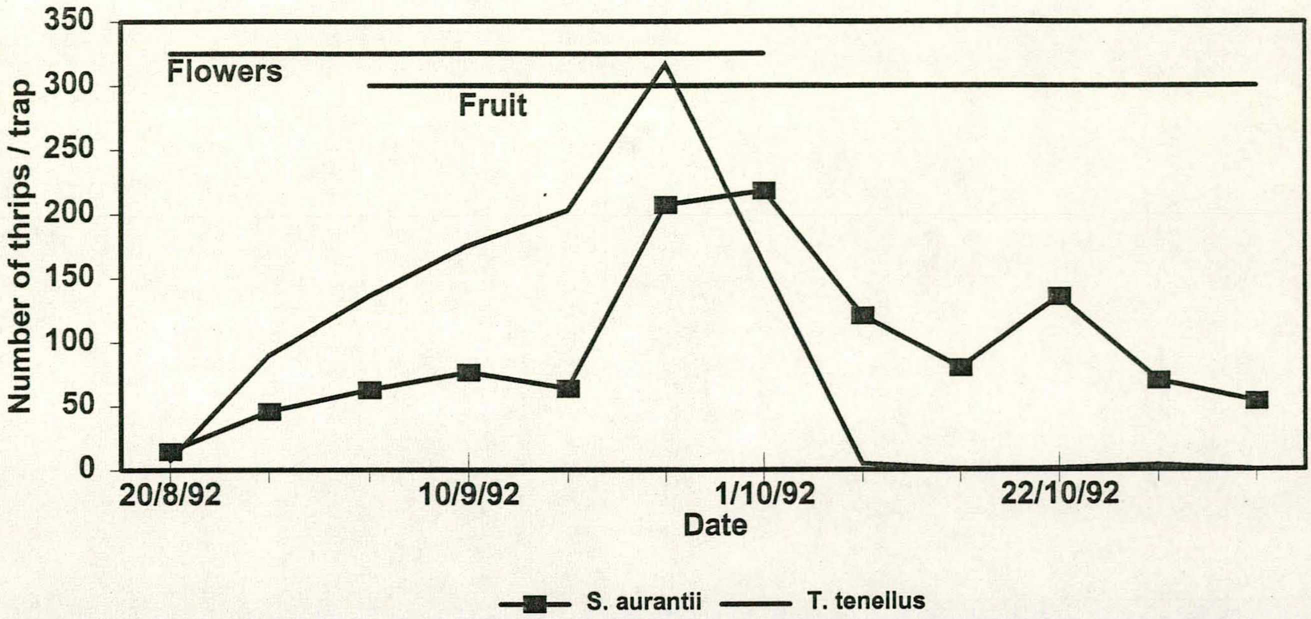

FIGURE 3 *Scirtothrips aurantii* and *Thrips tenellus* on yellow card traps in a Fascell orchard (no. V7) at Friedenheim during 1992

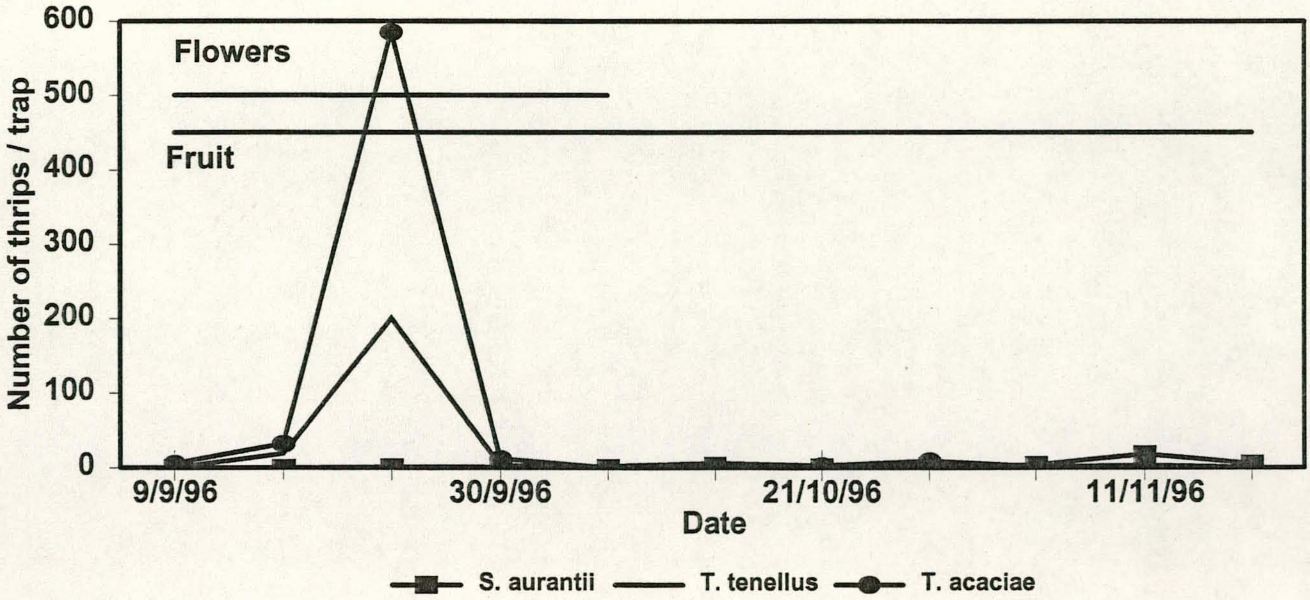

FIGURE 4 *Scirtothrips aurantii*, *Thrips acaciae* and *Thrips tenellus* on yellow card traps in a Zill orchard (no. V6) at Friedenheim during 1996

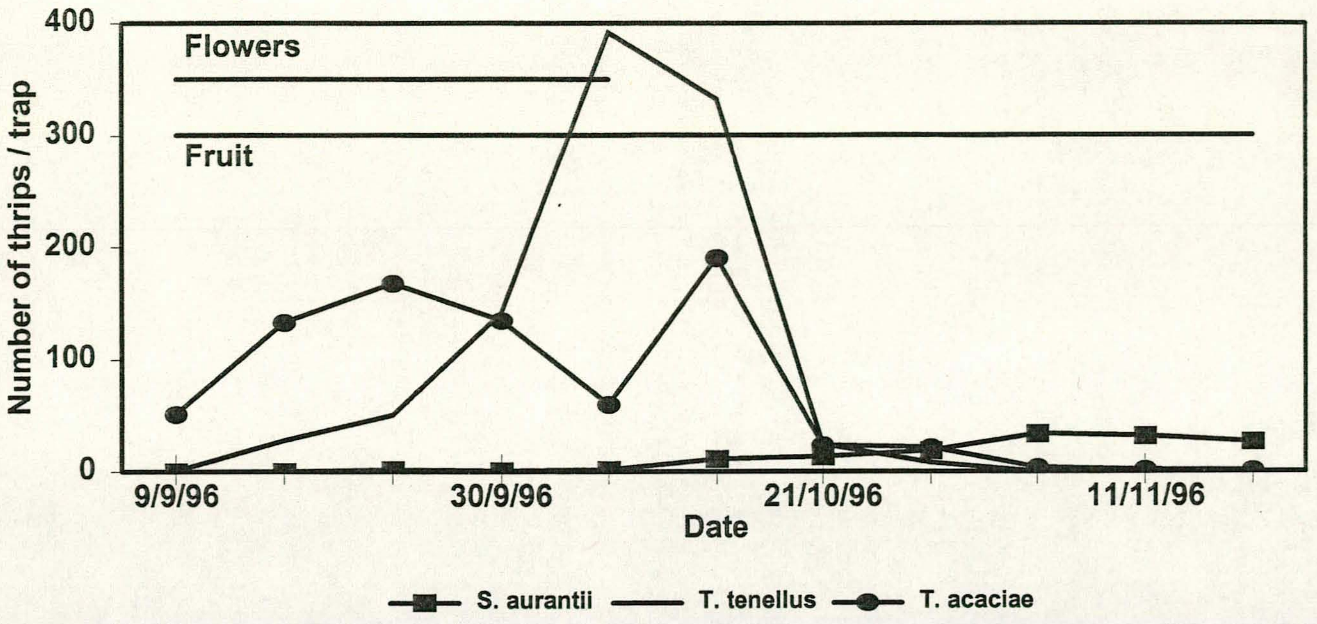

FIGURE 5 *Scirtothrips aurantii*, *Thrips acaciae* and *Thrips tenellus* on yellow card traps in a Sensation orchard (no. V6) at Friedenheim

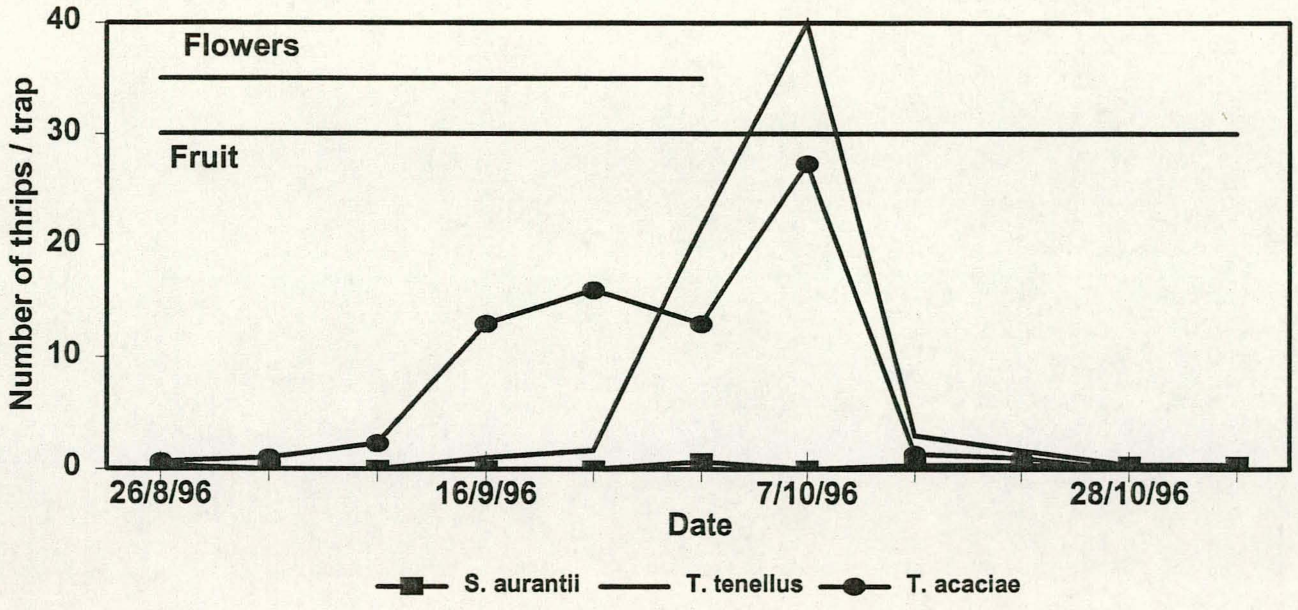

FIGURE 6 *S. aurantii*, *Thrips acaciae* and *Thrips tenellus* on D/E traps in a Zill orchard (no. V6) at Friedenheim during 1996

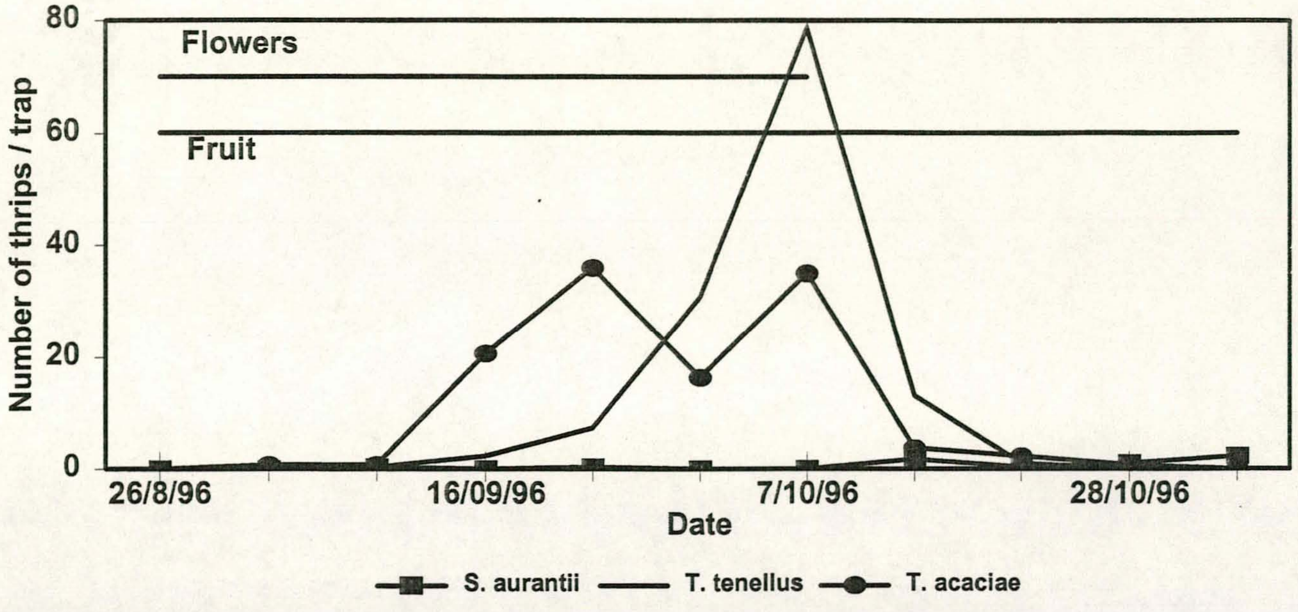

FIGURE 7 *Scirtothrips aurantii*, *Thrips acaciae* and *Thrips tenellus* on D/E traps in a Sensation orchard (no. V6) at Friedenheim during 1996

CHAPTER 2

LESIONS CAUSED BY THE CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) ON MANGO FRUIT

ABSTRACT

The citrus thrips *Scirtothrips aurantii* (Thysanoptera: Thripidae) causes lesions on mango fruit rendering them unsuitable for export. Mango fruit which were severely scarred at the beginning of the season appeared less heavily damaged towards the end of the season. Therefore, the fruit appeared to repair the damage caused by *S. aurantii*. This was investigated by weekly recording the percentage fruit with lesions at different sites in the Mpumalanga Province. With one exception, the percentage fruit with lesions at harvest was significant lower than the highest percentage prior to harvest in the ten orchards investigated. Some lesions that were prominent at the beginning of the season were less clearly defined at the end of the season and the fruit was acceptable for export. However, badly marked fruit did not recover to the extent that it could be exported.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) is not only an important pest of citrus in southern Africa, but it also malforms leaves and scars young fruit of the mango (*Mangifera indica* L.) (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978; Annecke & Moran,1982; Brink, 1993). The damage on mango fruit is merely cosmetic, but fruit with large lesions is not suitable for the export market. According to the export standards of the South African Mango Growers' Association, lesions larger than $400mm^2$ for count 7-14 and $500mm^2$ for count 4-6 fruit are not acceptable for export.

Scirtothrips aurantii is known to cause permanent superficial scarring to the epidermis of citrus fruit. A number of different blemish patterns are caused, depending upon the time of the year, the size of the fruit, whether the fruit is borne in bunches or not and the severity of the infestation (Kamburov, 1991; Gilbert & Bedford, 1998). During field studies in mango orchards, it was noticed that fruit with severe scarring early in the season appeared less scarred as the season progressed. Therefore, it seemed that the mango fruit repair the damage caused by *S. aurantii*. The objective of this study was to investigate the decrease in the prominence of the lesions as the season progressed.

MATERIALS AND METHODS

Observations were made at four different sites in the Mpumalanga Province of South Africa. At Kaapmuiden (25.26S, 31.30E) data were collected in Keitt, Sensation and Tommy Atkins orchards and at the Institute for Tropical and Subtropical Crops Nelspruit Experimental Farm (25.26S, 30.58E) data were collected in a Sensation orchard (no. K8). Data were collected from a Fascell orchard (no. V7), two Sensation orchards (nos T4 and V6) and a Zill orchard (no. V6) at the ITSC Friedenheim Experimental Farm (25.27S, 30.58E) . The last site was at Hazyview (25.02S, 31.08E) and data were collected from a Zill and Sensation orchard. The orchards were commercially productive and fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot. Bait sprays were used against fruit flies (Tephritidae). At Kaapmuiden two sprays of fenthion were used against the mango weevil, *Sternochetus mangiferae* (F.) (Curculionidae) and at Hazyview different insecticides were used against *S. aurantii*.

In each orchard ten fruit on each of ten trees were visually inspected and the percentage of fruit with lesions noted. Trees and fruit were chosen randomly. Small and not clearly visible lesions were ignored because export standards permit small lesions to be present. Observations were made weekly from fruit set until just prior to harvest during the 1994/95 season.

In addition, 20 small mango fruit with distinct lesions were marked and photographed at the beginning of October 1994. These fruits were 20mm to 30mm in length and from different selections. The same fruits were photographed at the end of January 1995, prior to harvest, to compare the severity of the lesions.

RESULTS AND DISCUSSION

In all the orchards, with the exception of the Zill orchard at Hazyview, the number of fruit with lesions increased to reach a peak in the middle of the season and then declined towards harvest (Figs. 1 to 4). In the Zill orchard at Hazyview the number of affected fruit did not decline as the fruit matured, but remained between 27 and 38%.

Of the twenty fruits photographed at the beginning of the season only five were still present at the end of the season, the rest had dropped. Lesions at the beginning of the seasons were distinct, silver in colour and contrasted with fruit colour (Fig. 5). At the end of the season the lesions contrasted less with fruit colour and lesions were transparent, but the fruits were still unacceptable for export (Fig. 5).

From the data and the photographs it was evident that there was a tendency for lesions to decrease in prominence as the season progressed, although there was a lot of variation in the data. Some lesions that were prominent at the beginning of the season were less clearly defined at the end of the season and acceptable for export. However, badly marked fruit did not recover to the extent that it could be exported.

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer, M. Maritz and M.S. De Beer for assistance in the study and Ms K. De Jager for photographing the fruit. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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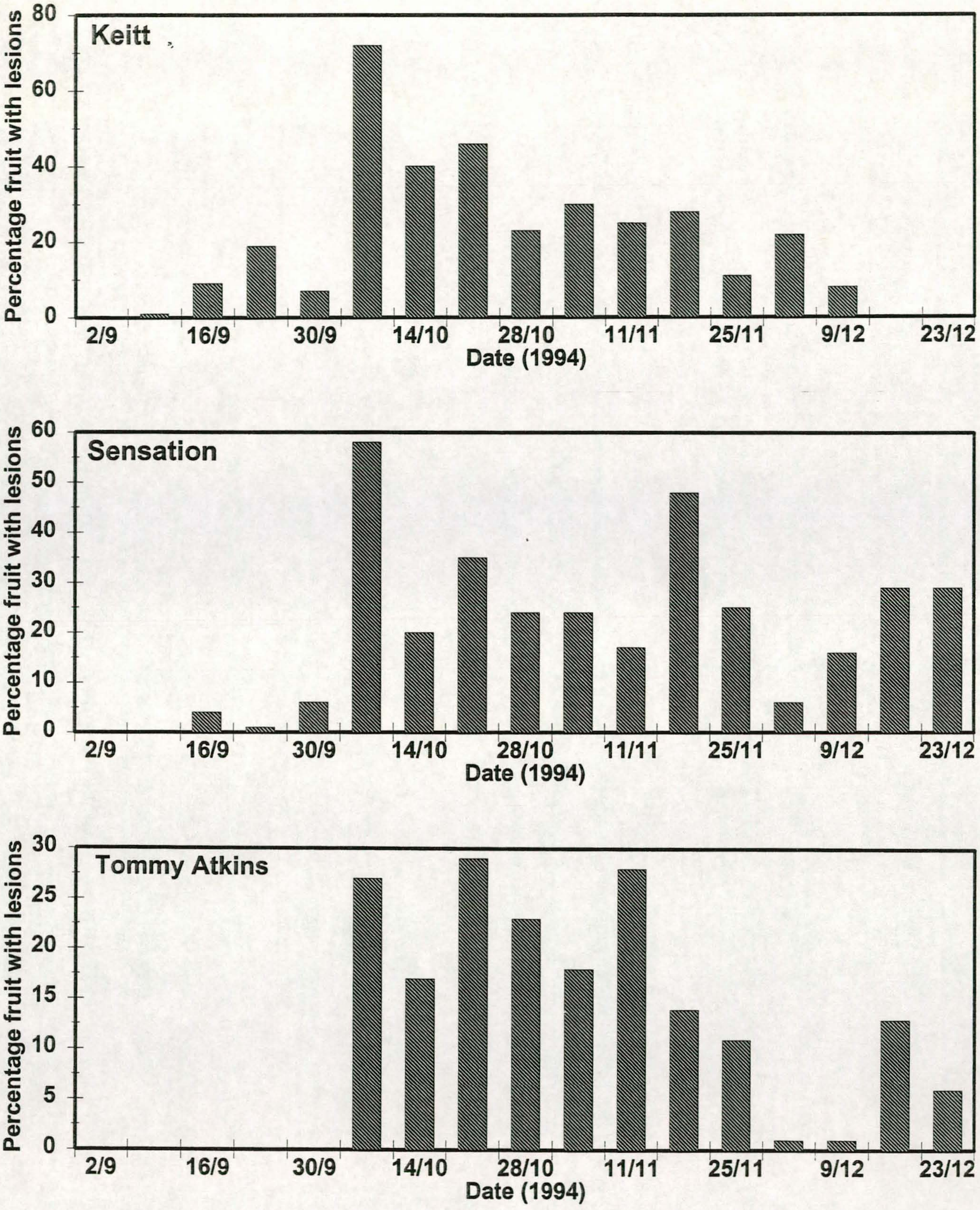

FIGURE 1 Weekly percentage fruit with lesions in orchards at Kaapmuiden

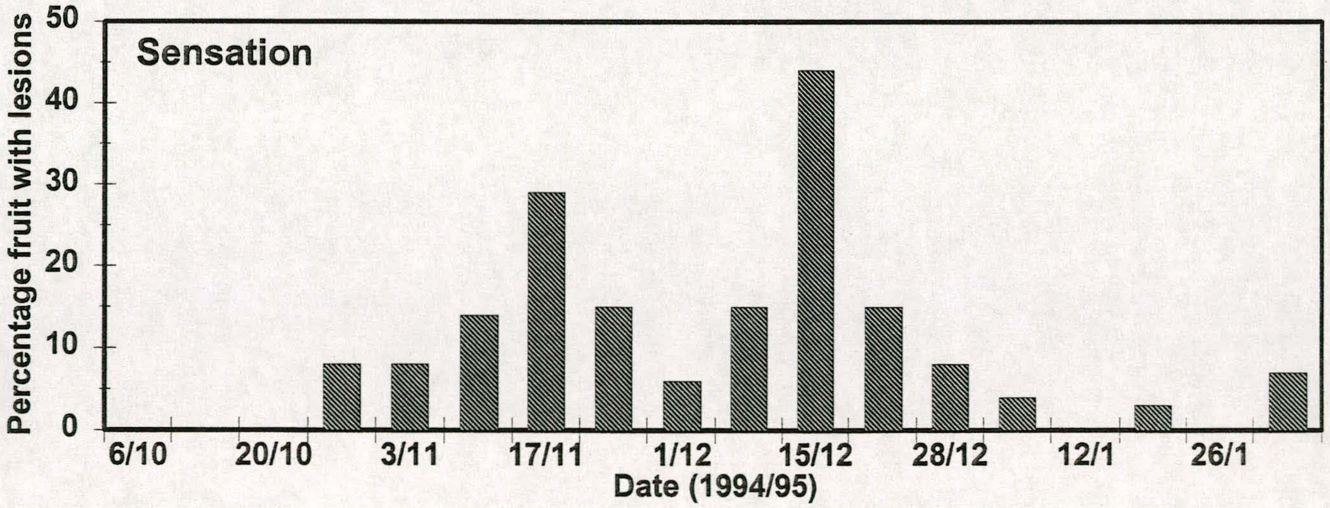

FIGURE 2 Weekly percentage fruit with lesions in a orchards at Nelspruit

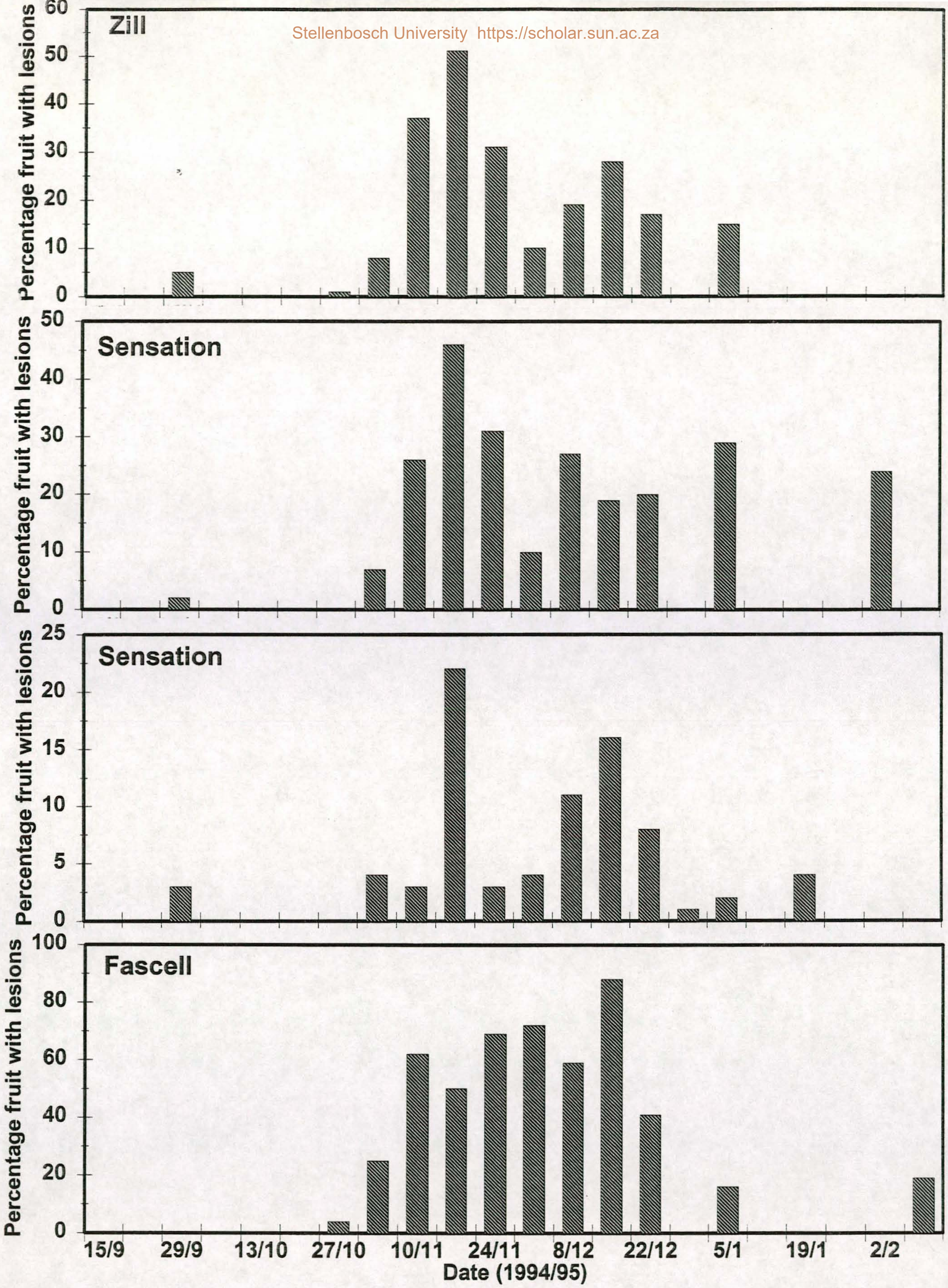

FIGURE 3 Weekly percentage fruit with lesions in orchards at Friedenheim

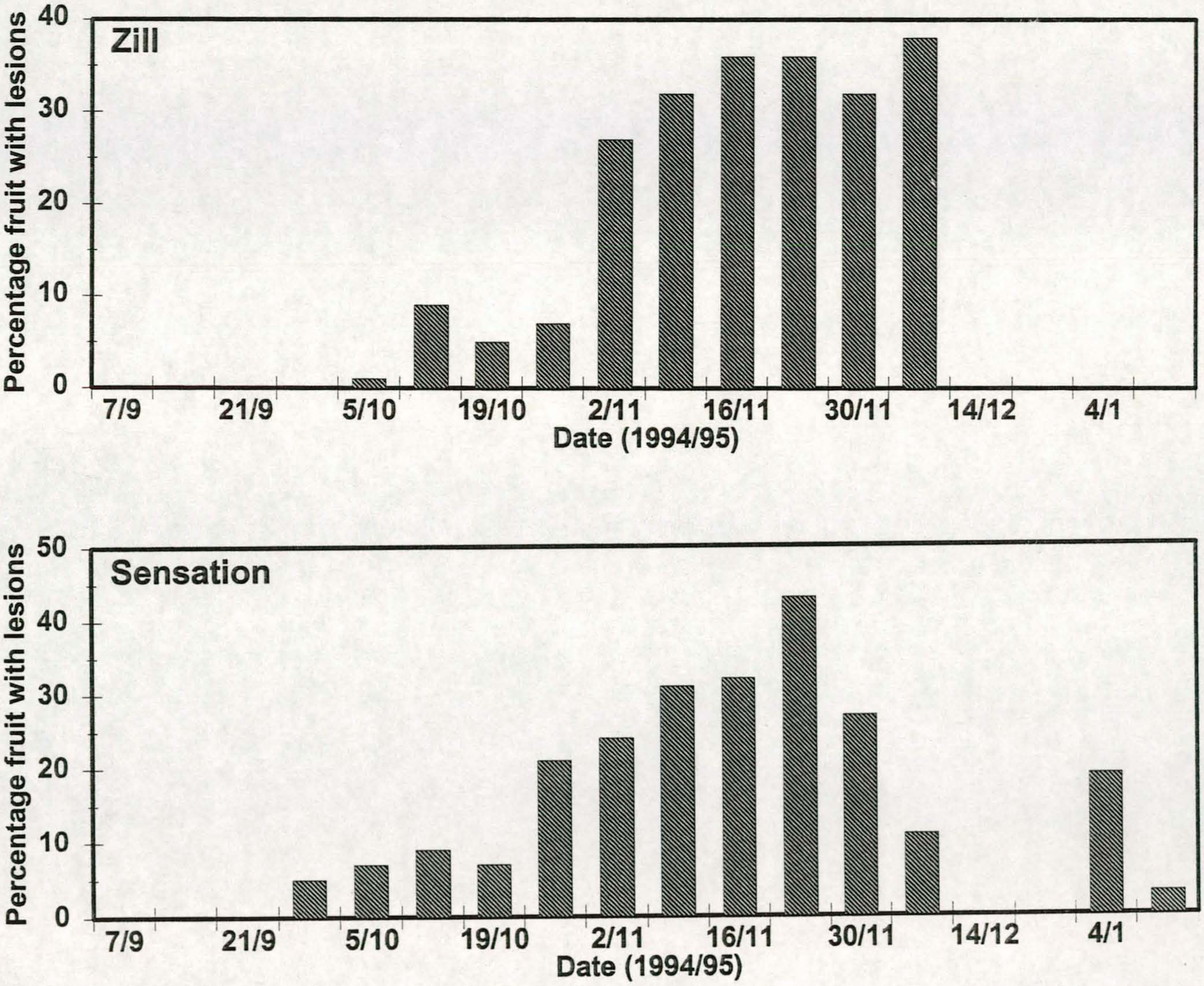

FIGURE 4 Weekly percentage fruit with lesions in orchards at Hazyview

FIGURE 5 Mango fruit with lesions photographed at the beginning of the season and prior to harvest

CHAPTER 3

ATTRACTION OF THE CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) TO STICKY TRAPS OF DIFFERENT COLOURS IN MANGO ORCHARDS

ABSTRACT

Sticky traps of various colours were tested in mango orchards in Nelspruit (South Africa) for their attraction of adult citrus thrips, *Scirtothrips aurantii* (Thysanoptera: Thripidae) Faure. Yellow was superior to blue, white, red and green. Blue, white, red and green traps attracted similar numbers of thrips although *S. aurantii* tended to respond more to green than red, white and blue in this sequence. Yellow traps can be used effectively for assessing activity levels of *S. aurantii* in mango orchards.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) is an important pest of citrus in southern Africa (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978). Annecke & Moran (1982) mentioned that *S. aurantii* caused lesions to young fruit of the mango (*Mangifera indica* L.) and its status as a pest of this crop has increased over the past number of years (Brink, 1993). Fruit with large lesions are not suitable for the export market although the damage is merely cosmetic. The damage to young mango growth results in leaf malformation and stunted growth.

Before integrated pest management can successfully be implemented against *S. aurantii* in mango orchards an effective technique for monitoring population numbers must be available in order to determine whether the application of control measures is required, to determine the correct timing of control applications and for gauging their effect. Monitoring thrips using coloured sticky traps is well documented (Moffit, 1964; Beckham, 1969; Beavers *et al.*, 1971; Walker, 1974; Yudin *et al.*, 1987; Brodsgaard, 1989; Gillespie & Vernon, 1990; Gaum & Giliomee, 1994), but it has not yet been used in mango orchards.

When white, yellow, blue, red, green and black sticky traps were used to capture *Scirtothrips citri* (Moulton) on navel oranges in California, the white traps caught greater numbers (Beavers *et al.*, 1971). Moreno *et al.* (1984) suggested the use of yellow to monitor *S. citri* . The fluorescent Saturn yellow trap was developed for monitoring *S. aurantii* in citrus orchards in South Africa (Samways, 1986; Samways *et al.*, 1986). These traps are not commonly used because they are expensive and cumbersome (Grout & Richards, 1989). Grout & Richards (1990) found that smaller non-fluorescent yellow card traps on the sunny side of trees were more attractive to *S. aurantii* than Saturn yellow traps used on the shady side. Yellow card traps were also less expensive and easier to use. Citrus producers were therefore encouraged to use them. As sticky traps could also be useful for monitoring population fluctuations of *S. aurantii* in mango orchards, the attraction of traps of different colours for *S. aurantii* was evaluated in this study.

MATERIALS AND METHODS

To determine the colour preferences of *S. aurantii*, five different colours were used: blue, yellow, green, red and white. Blue was included because certain thrips species are attracted to blue, for example the western flower thrips *Frankliniella occidentalis* (Pergande) (Brodsgaard, 1989; Gaum & Giliomee, 1994). Blue sticky traps are used for monitoring thrips in nectarine orchards in South Africa (Jacobs, 1996). Yellow traps were included because yellow is the preferred trap colour for monitoring *S. aurantii* in citrus orchards in South Africa (Grout & Richards, 1990). Red and green were used because they resemble the young mango leaves while white traps were included because white is highly attractive to some thrips species (Lewis, 1973; Yudin *et al.*, 1987).

The yellow traps consisted of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2mm) obtained from Outspan International. The white, blue, red and green traps were cut from coloured cardboard. The spectral reflectance characteristics of the colours were determined at 10nm intervals from 380 tot 790nm, using a Perkin Elmar Lambda spectrophotometer; $BaSO_4$ (compressed powder supplied by Merck) standard = 100% (Fig. 1). Traps were coated on both sides with a sticky adhesive, Fly-tac®.

Field work was carried out in mango orchards at the Insitute for Tropical and Subtropical Crops Nelspruit Experimental Farm (25.26S, 30.58E) in the Mpumalanga Province of South Africa. One set of the five different colours was placed at four different localities on the farm. A set consisted out of one trap of each colour. The first set of traps was placed in a Sensation orchard (no. K8), the second in a mango orchard consisting of different selections (no. F3), the third in a Tommy Atkins orchard (no. F7) and the last set in mango trees grown from seed. All trees used were older than 10 years. In the first two orchards fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot. Bait sprays were used against fruit flies (Tephritidae). At the last two locations no pesticides were applied.

Traps were hung on the outside of five randomly chosen trees and rotated every week. They were placed on the sunny northern side of the trees, 1.5 m from the ground and changed weekly. After removal, each trap was wrapped in clear polyethylene plastic and brought to the laboratory. The number of *S. aurantii* present on both sides of the traps was counted using a stereo microscope. The trapping period was from April 1995 until March

1996.

Data (cumulative number) were analysed using an analysis of variance. Tukey's multiple range test was used to separate treatment differences.

RESULTS AND DISCUSSION

Scirtothrips aurantii adults were present in mango orchards throughout the year (Fig 2). During August numbers started to increase and reached a peak from the end of August to September. This corresponded with the period when the fruit started setting and when many small fruit were present in the tree. *Scirtothrips aurantii* feeds on small fruit and adult females lay their eggs in the fruit. High numbers also occurred at the beginning of November and during January which corresponded with flushing periods. *Scirtothrips aurantii* is known to feed and breed on soft new growth. During February to July their numbers remained low.

Adult *S. aurantii* responded more to yellow than any other colour (Table 1). Similar numbers were caught on blue, white, red and green traps, but there was a tendency for *S. aurantii* to respond more to green traps rather than red, white, and blue. These results support the recommendation of Grout & Richards (1990) for monitoring *S. aurantii* with yellow card traps in citrus orchards. Similar results were obtained by Moreno *et al.* (1984) with a closely related species, *S. citri*. This species responded more to fluorescent yellow than all other coloured card traps, and secondly to yellow. There was also a tendency for *S. citri* to respond more to green than to white, blue, clear, black and red, although these differences were not significant.

While searching for feeding or egg laying sites, flying insects receive various cues which stimulate or inhibit their behaviour. The colour of the substrate probably plays an important role in this regard. *Scirtothrips aurantii* must find succulent growth and small fruit where it can feed and lay eggs and the above results indicate that *S. aurantii* is attracted to the green-yellow region of the electromagnetic spectrum. Green traps showed peak reflectance at about 520nm (Fig. 1). Yellow traps did not have a well defined peak. There was little reflection below 490nm but there was a sharp rise at 500nm and the reflectance remained high thereafter (Fig. 1). Most plants are highly reflective in this region (500 - 600nm) (Moreno *et al.*, 1984)

This experiment confirms the importance of trap colour for effective monitoring and shows that yellow traps can be used effectively for assessing population activity of *S. aurantii* in mango orchards.

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer and M.S. De Beer for assistance in the study, Messrs K. van der Vyver and P. Stoffberg for reflection spectral analysis and Mr. M.C. Welding from ARC-Agrimetrics Institute for statistical analyses. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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TABLE 1 Average cumulative numbers of *Scirtothrips aurantii* caught on traps of different colours. Averages not followed by the same letter differ at the level of P=0.05.

Colour	Average cumulative number
Yellow	333.500**a**
Green	130.250**b**
Red	115.000**b**
White	68.500**b**
Blue	39.500**b**
Error mean square	2491.43
Error degrees of freedom	12

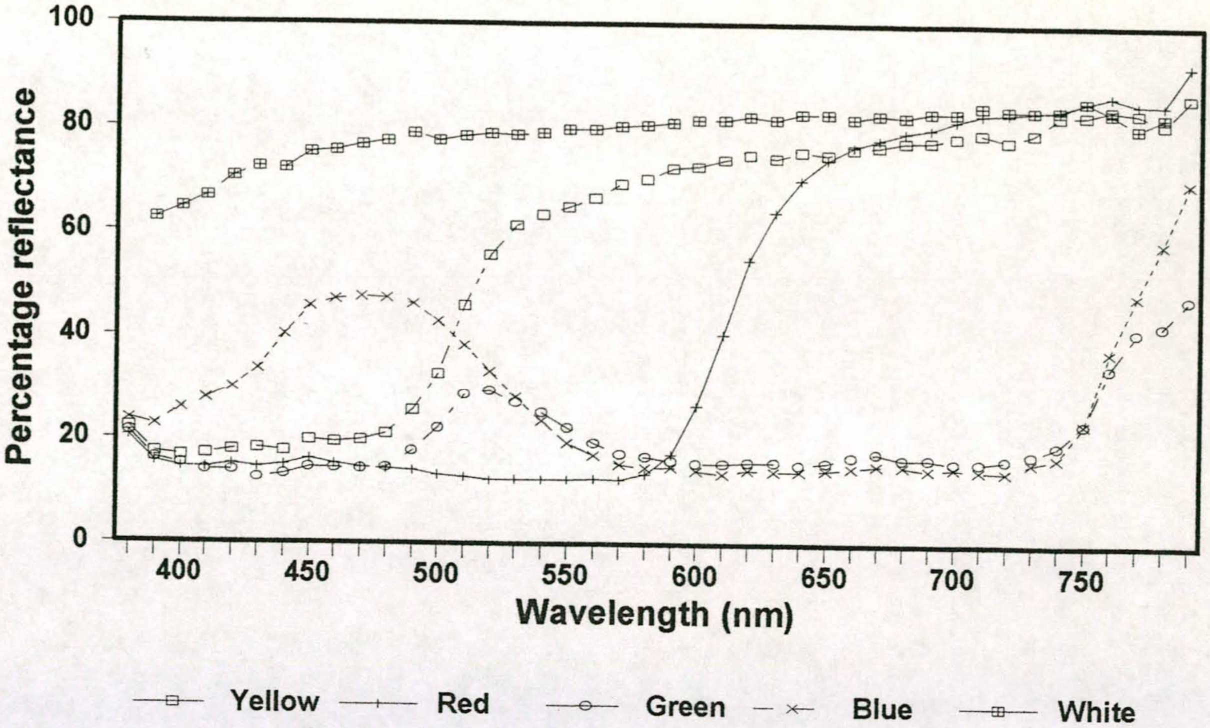

FIGURE 1 Percentage of reflectance of light from surfaces of colour traps as measured with a Perkin Elmer Lambda 9 spectrophotometer; $BaSO_4$ standard = 100%

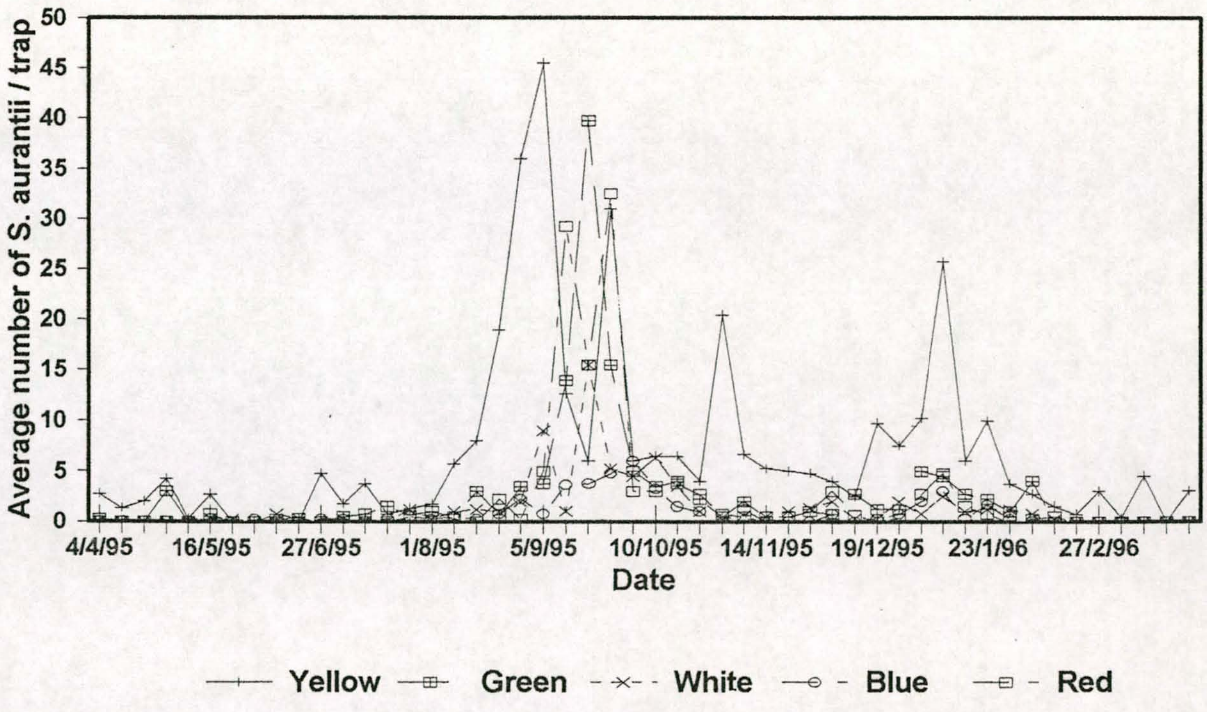

FIGURE 2 Weekly catches of *Scirtothrips aurantii* on coloured sticky traps in mango orchards from April 1995 to March 1996

CHAPTER 4

TREATMENT LEVELS FOR THE CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) IN MANGO ORCHARDS

ABSTRACT

The citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae), is a pest of mango and causes lesions on the fruit which render it unsuitable for export. Field work was carried out at three different sites in the Mpumalanga Province of South Africa to determine the correlation between *S. aurantii* numbers and the percentage damage caused. Adults of *S. aurantii* were monitored weekly by means of yellow sticky traps while fruits were visually inspected and the number of adults and larvae recorded. The percentage fruit unacceptable for export was determined prior to harvest. Cumulative insect-days were computed for *S. aurantii* on the traps and on the fruit and were correlated with the percentage fruit showing lesions unacceptable for export. The relationship between the number of *S. aurantii* on the traps (cumulative insect-days) and the percentage fruit culled was described by $Y = 0 + 0.002150X$ while the number on the fruit was described by $Y = 0 + 0.2099772X$. To keep the percentage culled fruit at a 5% or lower level producers should use chemical intervention when the number of *S. aurantii* on the traps exceeds 2326 cumulative insect-days or when the number on the fruit exceeds 24 cumulative insect-days.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae), has been known as a pest of citrus for more than 70 years (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978). Annecke & Moran (1982) mentioned that *S. aurantii* also severely scarred young fruit of the mango (*Mangifera indica* L.). Its status as a pest of this crop has increased over the past number of years (Brink, 1993). Adult thrips and larvae cause scarring by feeding on the fruit rind. Fruit with large lesions is not suitable for the export market. Damage in the form of leaf malformation and stunting of growth is caused to young mango growth.

In the management of this pest it is necessary to determine whether application of control measures is justified. The objective of this study was to monitor *S. aurantii* by means of yellow card traps and by visually inspecting the fruit and to correlate numbers on the traps and fruit with the percentage fruit with lesions unacceptable for export.

MATERIALS AND METHODS

Sites

Field work was carried out at three different sites in the Mpumalanga Province of South Africa. The first site was at Kaapmuiden (25.26S, 31.30E) where data were collected in Keitt, Sensation, Heidi and Tommy Atkins orchards. The second site was at the Insitute for Tropical and Subtropical Crops (ITSC) Nelspruit Experimental Farm (25.26S, 30.58E) where data were collected in a Sensation orchard (no. K8). The third site was at the ITSC Friedenheim Experimental Farm (25.27S, 30.58E) where data were collected from a Fascell orchard (no. V7), two Sensation orchards (nos T4 and V6) and a Zill orchard (no. V6). All orchards were commercially productive. In all orchards fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot and bait sprays were applied against fruit flies (Tephritidae). In the orchards at Kaapmuiden two sprays of fenthion were used against the mango weevil, *Sternochetus mangiferae* (F.) (Curculionidae).

Data were collected for two consecutive seasons (1993/1994 and 1994/1995) in all orchards except the Heidi orchard at Kaapmuiden where data were only collected during the 1993/94 season.

Fruit infestation

In each orchard, ten fruit on each of ten randomly chosen trees were visually inspected and the number of *S. aurantii* larvae and adults present on the fruit noted. This was conducted weekly from fruit set until harvest.

Trapping

Scirtothrips aurantii adults were monitored by using a method developed for this insect in citrus orchards (Grout & Richards, 1990). In each orchard three yellow card traps, consisting of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2mm), were used. Both sides of the traps were coated with a sticky adhesive, Fly-tac®. Traps were suspended 1.5m to 2m above the ground on the northern side of the tree. They were placed in a diagonal across the orchard with one trap in the centre and the other two traps near the opposing corners. Every week the traps were removed and covered in clear polyethylene plastic wrap and replaced. Individuals of *S. aurantii* on the trap were counted using a stereo microscope. The first traps were placed in the orchards prior to fruit set and the last were removed at harvest.

Lesions on the fruit

In each orchard ten fruit from ten randomly chosen trees were inspected for the occurrence of lesions prior to harvest. The percentage fruit unacceptable for export was determined. According to the South African Mango Growers' Association export standards, lesions larger than 400mm^2 for count 7-14 and 500mm^2 for count 4-6 fruit are not acceptable for export. The count refers to the number of fruit packed per box with a net weight of 4.2 to 4.3 kg.

Relationship between *S. aurantii* on the traps and fruit and percentage cull at harvest

Cumulative insect-days were computed as described by Ruppel (1983). This was done for *S. aurantii* adults on the traps and for adults and larvae on the fruit. These were correlated with the percentage fruit showing lesions unacceptable for export.

RESULTS AND DISCUSSION

The *S. aurantii* population on the traps and fruit peaked during September or October and then declined. Towards the end of each season virtually no *S. aurantii* were present on the fruit. On the traps, numbers declined after September or October, but some were still caught because flush was present in the orchards enabling feeding and breeding to take place. The number of *S. aurantii* varied considerably between the different orchards with the highest population levels in the Sensation orchard (V6) at Friedenheim during 1993/94. The percentage culled fruit varied from to 1 to 97%.

A positive relationship existed between the cumulative insect-days computed on the traps and the percentage cull (r^2 = 0.8949) (Fig. 1) and also on the fruit and the percentage cull (r^2 = 0.9627) (Fig. 2). This information provides producers with a tool for decision making. When mango fruit is sold on the local market lesions are accepted although the appearance affects the marketability. Fruit with larger lesions are not acceptable for export and are culled. To keep the percentage of culled fruit at a 5% level, producers should use chemical intervention when the number of *S. aurantii* on the traps exceeds 2326 cumulative insect-days or when the number on the fruit exceeds 24 cumulative insect-days. Using the regression equations given in Figs. 1 and 2 the population levels in cumulative insect-days can be estimated for any desired infestation level (percentage fruit with lesions).

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer, M. Maritz and M.S. De Beer for assistance in the study and Mr R.L.J. Coetzer for statistical analyses of data. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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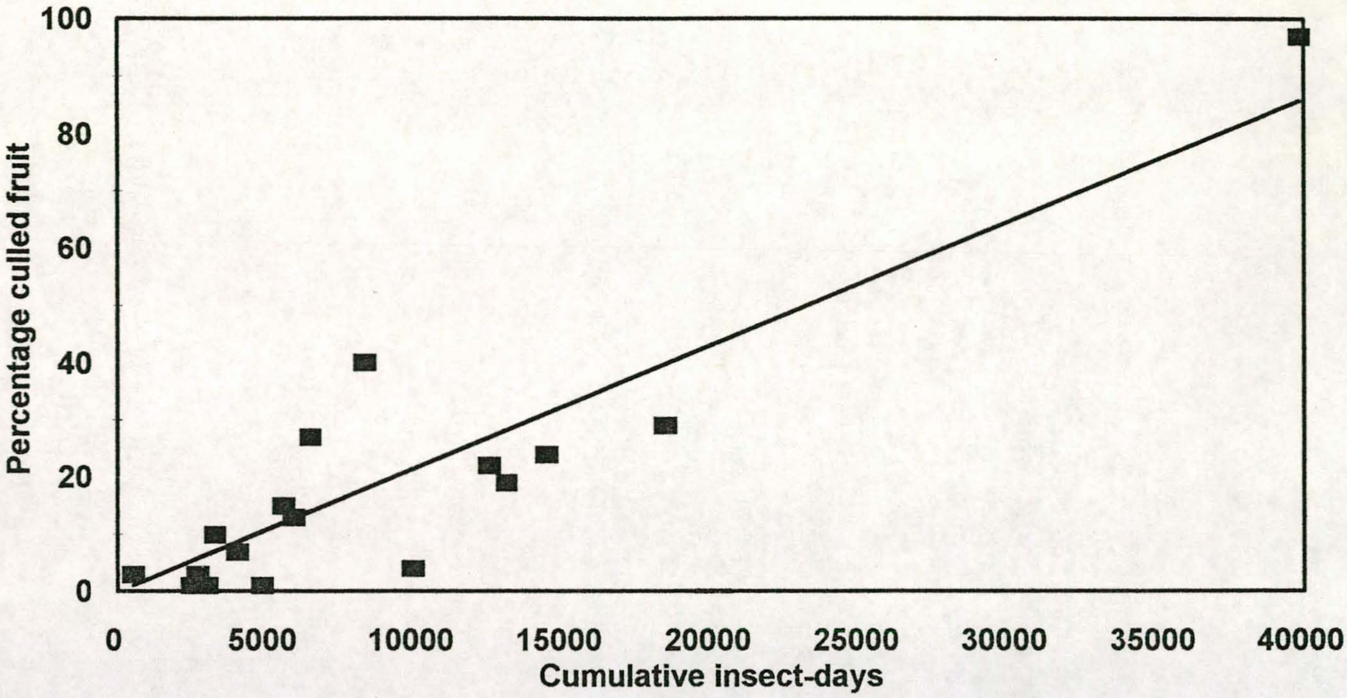

FIGURE 1 Relationship between number of *Scirtothrips aurantii* on the traps (cumulative insect-days) and the percentage culled fruit ($Y = 0 + 0.002150X$; $r^2 = 0.8949$)

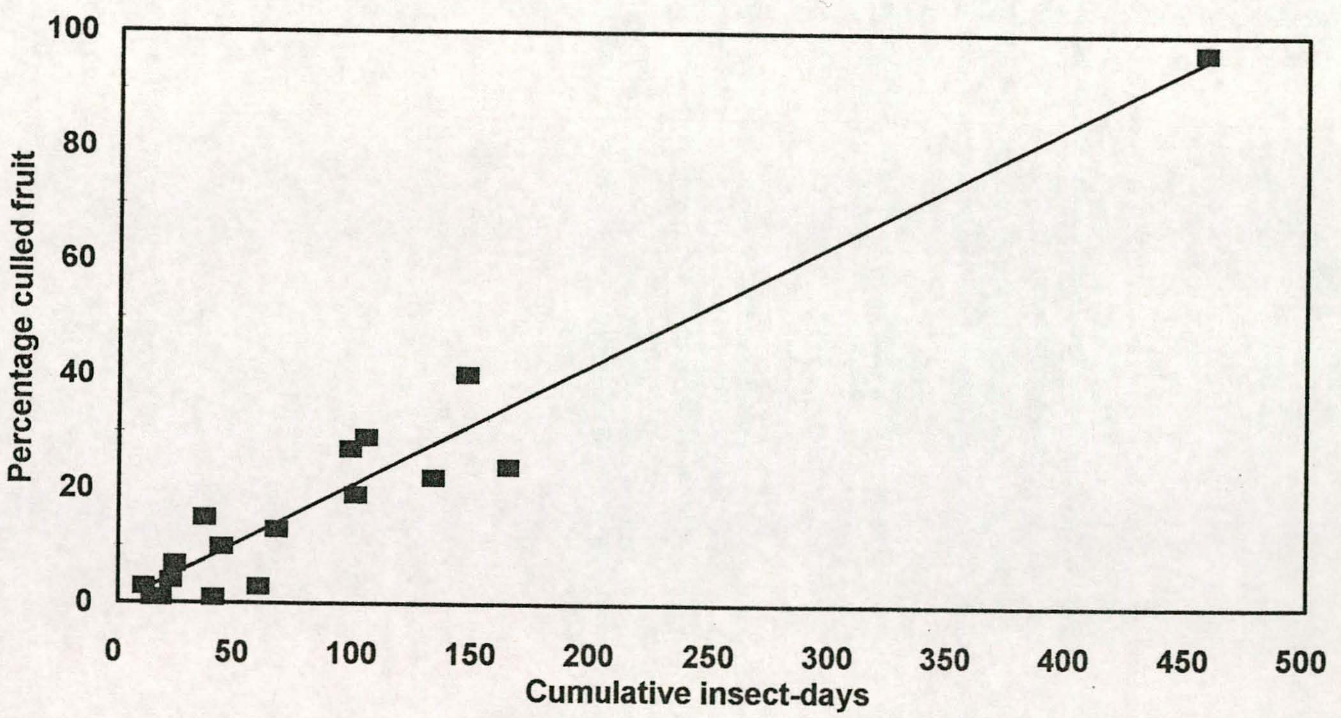

FIGURE 2 Relationship between number of *Scirtothrips aurantii* on the fruit (cumulative insect-days) and the percentage culled fruit ($Y = 0 + 0.209772X$; $r^2 = 0.9627$)

CHAPTER 5

SAMPLING PRECISION FOR ESTIMATING POPULATION LEVELS OF THE CITRUS THRIPS, *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE), IN MANGO ORCHARDS

ABSTRACT

To formulate a sampling technique for monitoring population levels of the citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) in mango orchards, data were collected for a two year period at four different localities in the Mpumalanga Province of South Africa. Using a two stage sampling system for determining population levels, the optimum combination of the number of trees per orchard (primary units) and fruit per tree (secondary units), was estimated. Taylor's regression of log s^2 on log $\overline{x}_{..}$ provided a good fit for both the within tree (r^2 = 0.887) and between tree (r^2 = 0.746) data. The value for the aggregation coefficient, b, in both cases was >1, indicating a clumped distribution. Sampling precision (D) was determined for $\overline{X}_{..}$ = 0.5, different values for the number of trees (N = 5, 10, 15, 20 and 25) and number of fruit per tree (n = 2, 5,10 and 20). The standard error relative to the mean, D, decreased more rapidly when the number of trees sampled was increased than when the number of fruit per tree was increased. For sampling *S. aurantii* populations in mango orchards it is recommended that 5 fruit be taken from each of 10 trees. This will give a sampling precision of D = 14%.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) causes lesions on the mango fruit rendering them unsuitable for export (Annecke & Moran, 1982; Brink, 1993). As the research on *S. aurantii* on mango step towards developing a system for managing this pest, a sampling system for monitoring population levels must be developed. This will enable producers to determine whether the application of control measures is required.

The objective of this study was to determine how many units (primary and secondary) should be sampled to obtain a reliable estimate of the field population. *Scirtothrips aurantii* was monitored by visually inspecting the fruit from different trees. From these counts the dispersion pattern and the optimum sample size necessary for monitoring *S. aurantii* populations levels in mango orchards in South Africa were estimated.

MATERIALS AND METHODS

Sites

Field work was carried out at four different sites in the Mpumalanga Province of South Africa. The first site was at Kaapmuiden (25.26S, 31.30E) where data were collected in Keitt, Sensation, Heidi and Tommy Atkins orchards. The orchards were from 1 to 1.5 hectares in area. The second site was at the Institute for Tropical and Subtropical Crops (ITSC) Nelspruit Experimental Farm (25.26S, 30.58E) where data were collected in a Sensation orchard (no. K8). The third site was at the ITSC Friedenheim Experimental Farm (25.27S, 30.58) and data were collected from a Fascell orchard (no. V7), two Sensation orchards (nos T4 and V6) and a Zill orchard (no. V6). Orchards at Nelspruit and Friedenheim were 1 hectare. The fourth site was at Hazyview (25.02S, 31.08E) and data were collected from a Zill orchard of approximately 1 hectare. All orchards were commercially productive and fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot. Bait sprays were used against fruit flies (Tephritidae). At Kaapmuiden two sprays of fenthion were used against the mango weevil, *Sternochetus mangiferae* (F.) (Curculionidae) and at Hazyview different insecticides were used against *S. aurantii.*

Counts on fruit

Data were collected weekly from fruit set until harvest for two consecutive seasons (1993/1994 and 1994/1995) in all orchards except the Heidi orchard at Kaapmuiden where data were only collected during the 1993/94 season. In each orchard ten fruit on each of ten trees were visually inspected while moving around the tree and the number of *S. aurantii* larvae and adults present on each fruit recorded. Trees were chosen randomly.

Sampling size estimates

Using a two stage sampling system for determining *S. aurantii* population levels in mango orchards, the optimum combination of the number of trees per orchard (primary units) and fruit per tree (secondary units) was estimated by a method described by Pringle (1987). Regarding trees as treatments and fruit within trees as replicates the random effects analysis of variance model was used to estimate SSB, SSW and $\overline{X}_{..}$, where SSW = sum of squares within primary units (trees), SSB = sum of squares between secondary units (fruit) and $\overline{X}_{..}$ = mean number of *S. aurantii* per fruit for the whole sample.

The variance within trees and between trees was determined as follows:

$S_W^2 = \frac{SSW}{nN-N}$ (within trees) and

$S_B^2 = \frac{\frac{SSB}{N-1} - S_W^2}{n}$ (between trees),

where N is the number of trees and n the number of fruit.

Taylor's power law is a general index for clumping and is based on the principle that the variance and the mean are positively correlated (Taylor,1961). Taylor showed that this relationship obeys a power law and is expressed by:

$s^2 = a\overline{x}^b$, or $\log S^2 = \log a + b \log \overline{x}$

where the intercept, a, is a sampling constant and the slope, b, an aggregation index (Taylor, 1961; 1971). A value for b significantly > 1 indicates a clumped distribution, for b = 1 a random distribution, and for b < 1 a regular distribution.

By fitting the regression model,

$\log s_k^2 = \log a_k + b \log \overline{x}_{..}$, k = W or B,

expressions relating the between and within tree variance to mean *S. aurantii* per fruit, $x_{..}$, could be obtained.

The sampling precision (D) was determined as follows:

$$D = \frac{1}{\overline{X}_{..}} \sqrt{\frac{n a_B \overline{X}_{..}^{bB} + a_W \overline{X}_{..}^{bw}}{Nn}}$$

where a and b are coefficients obtained from Taylor's power law regression.

From, this the degree of precision (D), in terms of the standard error relative to the mean could be obtained for any combination number of trees (N) per orchard and number of fruit per tree (n).

Sampling in the beginning of the fruiting period showed that in 93% of cases the value of $\overline{X}_{..}$ was between 0.1 and 15, and population levels of $\overline{X}_{..} = 0.5$ to $\overline{X}_{..} = 5$ occurred most frequently. The beginning of the fruiting period is the most critical time for making a decision whether or not spraying is necessary. Therefore, for determining the number of trees and number of fruit that needed to be sampled, a value of $\overline{X}_{..} = 0.5$ was chosen. The sampling precision was determined for different number of trees (N) and fruits per tree (n).

RESULTS AND DISCUSSION

Taylor's regression of log s^2 on log $x_{..}$ provided a good fit for both the within tree variance, S_W^2, (r^2 = 0.887) and between tree variance, S_B^2, (r^2 = 0.746) (Figs. 1 and 2). The value for the aggregation coefficient, b, in both cases was >1, indicating a clumped distribution (b = 1.3669 for between tree samples; b = 1.5499 for within tree samples).

The standard error relative to the mean, D, decreased more rapidly when the number of trees sampled was increased than when the number of fruit per tree was increased. Therefore, increasing the number of trees and decreasing the number of fruit per tree resulted in improved precision. By sampling 10 trees and 5 fruit per tree the value of D was 0.14 while by sampling 5 trees and 10 fruit per tree the value obtained for D was 0.16 (Fig. 3). Although moving between trees may be time consuming, the most time is spent on examining fruit because *S. aurantii* is small and a very careful examination is needed.

Therefore for sampling *S. aurantii* populations in mango orchards it is recommended that 5 fruit be taken from 10 trees. This will lead to a sampling precision of D = 14% which is an acceptable level. The total number of 50 fruit inspected for *S. aurantii* is a manageable number for mango producers - in citrus orchards it is a common practice to use a sample size of 100 fruit per orchard for monitoring population levels of this insect.

ACKNOWLEDGEMENTS

The authors thank Mmes S. Dreyer, M.S. De Beer and M. Maritz for assistance in the study and Mr M.C. Welding from ARC-Agrimetrics Institute for statistical analyses. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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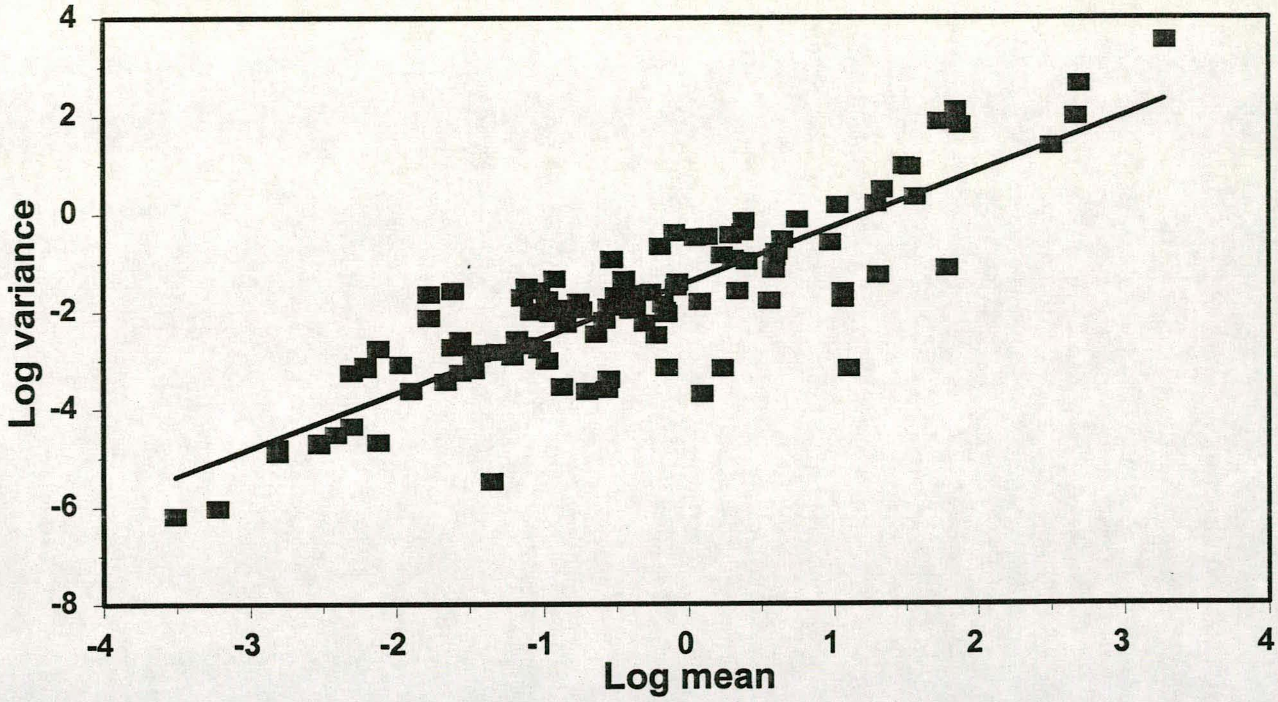

FIGURE 1 Taylor's power law relationship between the log variance and log mean for *Scirtothrips aurantii* (between trees). Log S_W^2 = -1.3973 + 1.13670 log$\overline{X}_{..}$; r^2 = 0.7456

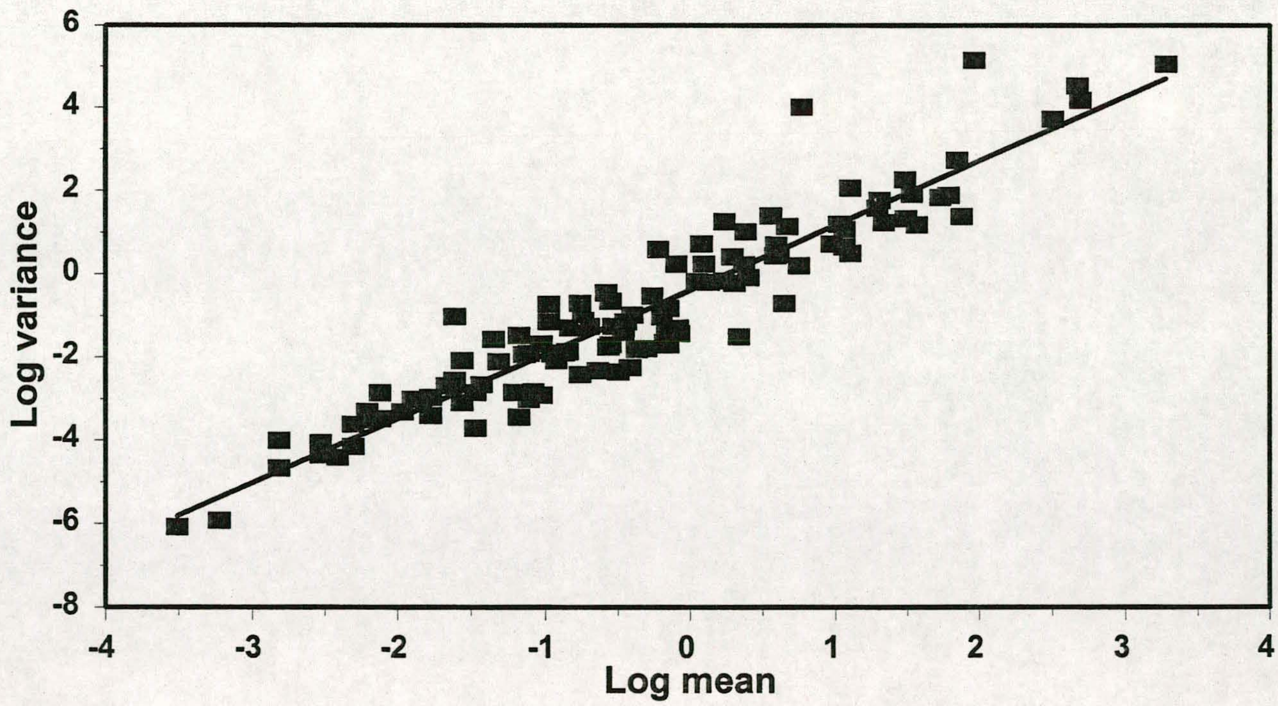

FIGURE 2 Taylor's power law relationship between the log variance and log mean for *Scirtothrips aurantii* (within trees). Log S_B^2 = -0.3875 + 1.5500 log$\overline{X}_{..}$; r^2 = 0.8866

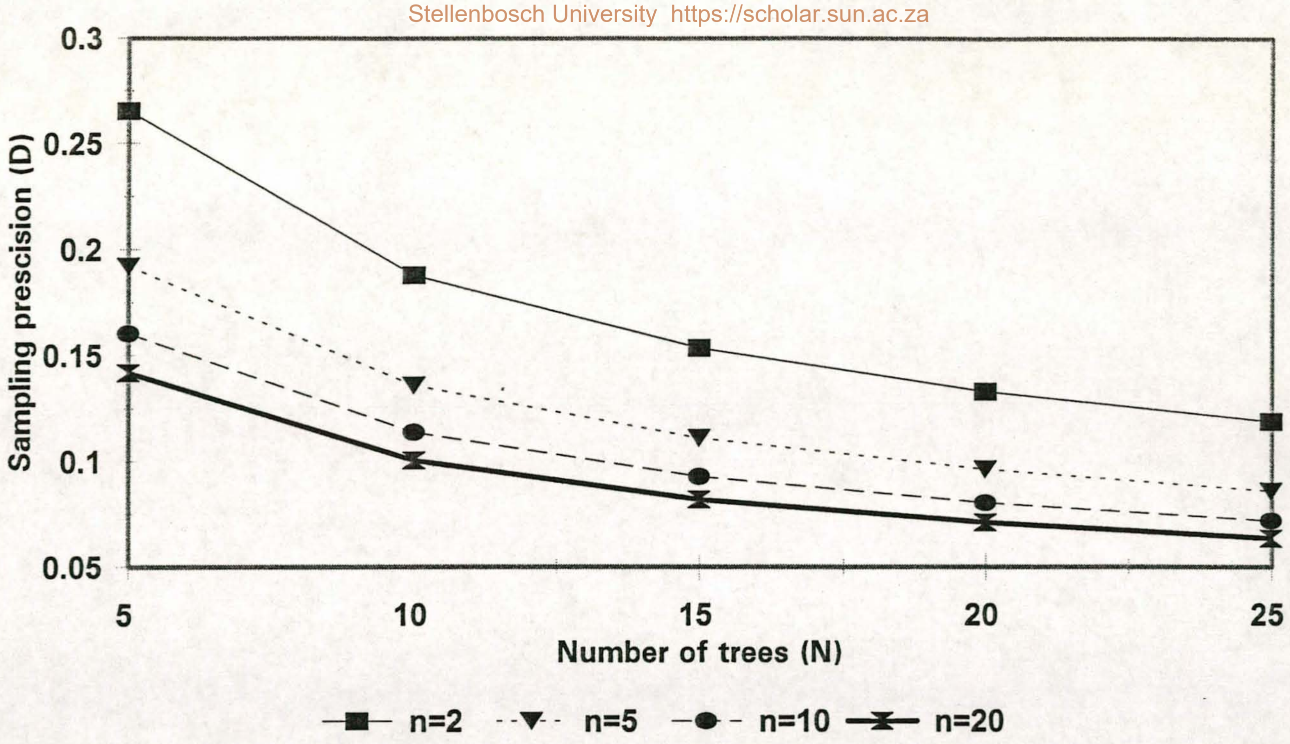

FIGURE 3 Sampling precision (D) measured as the standard error relative to the mean versus the number of fruit sampled for N = 5, N = 10, N = 15, N = 20, N = 25 trees for $X_{..}$ = 0.50 thrips per fruit

CHAPTER 6

THE RELATIONSHIP BETWEEN NUMBERS OF *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) AND FRUIT SIZE IN MANGO ORCHARDS IN SOUTH AFRICA

ABSTRACT

Population levels of the citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) were monitored for two consecutive seasons in mango orchards in the Mpumalanga Province of South Africa. Yellow sticky card traps were used to monitor adult numbers, while counts on the fruit were conducted to monitor numbers of adults and larvae. Fruit size was measured throughout the season. Hoerl's function ($Y = aX^b e^{cX}$) was used to describe the relationship between the number of *S. aurantii* on the fruit and fruit size, as well the number on the traps and fruit size. A notable feature in the population dynamics of *S. aurantii* was the rapid decline in numbers after the population peak had been reached. The highest number of *S. aurantii* was present between fruit set and when fruit reached 40mm in length.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) attacks both citrus and mango in southern Africa (Annecke & Moran, 1982; Brink, 1993; Gilbert & Bedford, 1998). The scarring that *S. aurantii* causes can make the fruit unsuitable for export. The critical period during which *S. aurantii* damages citrus fruit depends on several factors, including blossom time, weather and geographical location (Samways, 1986). Bedford (1943), working in the North West Province of South Africa, suggested that the sensitive period for fruit injury was from 12 days after petal fall until

December, when the fruit was approximately 44mm in diameter. This was supported by Quilici *et al.* (1988) working on Reunion Island. The period during which *S. aurantii* can cause damage to citrus fruit in Mpumalanga Province was divided into an early risk period, a central critical period and a longer risk period (Samways, 1986).

In recent years the status of *S. aurantii* as a pest of mango has increased (Brink, 1993). *Scirtothrips aurantii* is particularly abundant on the young mango fruit and then virtually disappears from the fruit towards the end of the season. The present study was therefore conducted to identify the critical stage when the highest numbers were present on the fruit and traps and to determine the relationship between the number of *S. aurantii* and fruit size. This information would enable producers to use fruit size as an indicator of potentially damaging numbers of *S. aurantii,* and to determine at which stage of fruit development chemical control measures should be applied.

MATERIALS AND METHODS

Sites

Field work was carried out at three sites in the Mpumalanga Province of South Africa. The first site was at Kaapmuiden (25.26S, 31.30E) where data were collected in Keitt, Sensation and Tommy Atkins orchards. The second site was at Institute for Tropical and Subtropical Crops (ITSC) Nelspruit Experimental Farm (25.26S, 30.58E) where data were collected in a Sensation orchard (no. K8). The third site was at the ITSC Friedenheim Experimental Farm (25.27S, 30.58E) and data were collected from a Fascell orchard (no. V7), two Sensation orchards (nos T4 and V6) and a Zill orchard (no. V6). All sites were commercially productive orchards. In all orchards, fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot. Bait sprays were applied against fruit flies (Tephritidae). In the orchards at Kaapmuiden two sprays of fenthion were used against the mango weevil, *Sternochetus mangiferae* (F.) (Curculionidae). The first fenthion spray was applied during the beginning of October and the second, four weeks later.

Counts on fruit

In each orchard, ten fruit randomly chosen on each of ten trees were visually inspected and the number of *S. aurantii* larvae and adults present on the fruit recorded. Trees were chosen randomly on a diagonal transect in the orchard. The length of ten randomly chosen fruit was measured with a calliper. Data were collected weekly from fruit set until harvest for two consecutive seasons (1993/1994 and 1994/1995).

Trapping

Scirtothrips aurantii was monitored using a method developed for this insect in citrus orchards (Grout & Richards, 1990). In each orchard three yellow card traps, consisting of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2 mm), were used. Both sides of the traps were coated with a sticky adhesive. Traps were suspended 1.5 m to 2m above the ground on the northern side of the tree. The traps were placed diagonally across the orchard with one trap in the centre and the other two traps near the opposing corners. Every week, traps were removed and covered in clear polyethylene plastic wrap and replaced with new ones. *Scirtothrips aurantii* on the traps were counted using a stereo microscope. The first traps were placed in the orchards prior to fruit set and the last were removed at harvest. In all the above mentioned orchards, observations were made during two consecutive seasons (1993/1994 and 1994/1995).

Statistical analysis

Hoerl's function ($Y = aX^b e^{cX}$) (Daniel & Wood, 1980) was used to describe the relationship between the number of *S. aurantii* on the fruit and fruit size, as well as the number on the traps and fruit size.

y	=	number of *S. aurantii* on the fruit or on the traps,
x	=	fruit size (mm) ,
a, b and c	=	constants estimated by non-linear regression and
e	=	base of natural logarithms.

The fruit size at which peak numbers were recorded was estimated by setting the second derivative of Hoerl's function to zero. Graphs for instances where this function did not provide good fit and where the correlation co-efficients, R^2, were less than 0.6, are not given.

RESULTS

Population fluctuations

Fluctuations in the population levels of *S. aurantii* on the fruit are shown in Figs 1 to 3 for the three different sites while the numbers trapped are given in Figs 4 to 6. In general, the population of *S. aurantii* on the fruit peaked between September and November and then declined rapidly to zero. At Kaapmuiden during the early part of the season the numbers of *S. aurantii* on both the traps and the fruit were higher during the 1994/1995 season than during 1993/94 (Figs 1 and 4). At Nelspruit the population levels during the two seasons were fairly similar (Figs 2 and 5), while at Friedenheim the numbers were slightly higher during 1993/1994 than during 1994/95 season (Figs 3 and 6).

The highest infestation levels at Kaapmuiden occurred on the cultivar Sensation. At the ITSC Friedenheim Experimental Farm the highest infestation level was present in the Sensation orchard (no. V6) while the Sensation orchard (no. T4) had a low infestation as did the Sensation orchard at ITSC Nelspruit.

Numbers on fruit in relation to fruit size

The relationship between the number of *S. aurantii* on 100 fruit and fruit size was described by Hoerl's function in 12 out of the 16 data sets (Tables 1 and 2). *Scirtothrips aurantii* numbers in the Keitt orchard reached a peak when the fruit was 25.56mm and 25.69mm in the 1993/94 and 1994/95 seasons respectively (Fig. 7). After the peak numbers had been reached, the population declined. Towards the end of the fruiting period virtually no *S. aurantii* were present. This tendency was present in all the other orchards (Figs 8 to 12).

Numbers on the traps in relation to fruit size

The relationship between the number of *S. aurantii* on the traps and fruit size was described by Hoerl's function in 7 out of the 16 data sets (Table 3 and 4). In the Keitt orchard at Kaapmuiden the highest number of *S. aurantii* on the traps was present at the beginning of the fruiting period and subsequently declined (Fig. 13). This same tendency was present in the Tommy Atkins orchard during the 1993/94 (Fig. 14), while during the 1994/95 season the numbers built up and reached a peak when fruit was 19.16mm (Fig. 14). Numbers in the Sensation orchard (no. K8) increased and reached a peak when the fruit size was 28.93mm and then declined (Fig. 15). In the Fascell orchard (no. V7) the highest number of *S. aurantii* on the traps was present at the beginning of the fruiting period (Fig. 16). In the Sensation orchard (no. V6) the highest number of *S. aurantii* was present when fruit was 37.64mm. The numbers decreased after this peak had been reached (Fig. 17). The same tendency was observed in the Zill orchard (no. V6) (Fig. 18).

DISCUSSION

The numbers of *S. aurantii* present in mango orchards fluctuated widely from season to season, varied among different localities, between different orchards at the same locality and different cultivars. Therefore *S. aurantii* on mango can be considered as a sporadic pest and it is essential that any control program for this insect be based on thorough and regular inspections and monitoring.

A possible explanation for the high numbers in the Sensation orchard (no. V6) and the Keitt and Sensation orchards at Kaapmuiden could be that these orchards were cultivated in close proximity to other mango cultivars such as Zill, Fascell and Tommy Atkins. Sensation and Keitt are late cultivars, while Zill is an early one. Tommy Atkins is regarded as an early mid-season cultivar and Fascell is a late mid season cultivar (Snyman & Schroeder, 1992). *Scirtothrips aurantii* may have built up on early cultivars and have moved over to adjacent orchards where the fruit were smaller and more vulnerable to scarring. Late cultivars such as Sensation and Keitt cultivated in close proximity to early cultivars may therefore be more prone to attack (Figs 1, 3, 4 and 6).

A noticeable feature in the population dynamics of *S. aurantii* is the rapid decline in numbers after the population peak had been reached. This occurred whether orchards were sprayed with fenthion or not and whether peak numbers were high or low. A similar decline in the numbers of *S. aurantii* was also observed on citrus fruit and it was suggested that when the fruit is large, the skin is too tough for penetration of the mouthparts (Gilbert, 1992). In the case of citrus, *S. aurantii* is also, to a certain extent, attracted away from the fruit onto new flush. The skin of the mango fruit also gets thicker as the fruit expands and it may be that the fruit becomes too tough for the mouthparts and the ovipositor to penetrate, with the result that *S. aurantii* may move to new flush.

Differences in results for the same orchards in the same season were observed with the two different monitoring techniques. This can be explained by the fact that counts on the traps measure only flying adults while counts on the fruit were based on both larvae and adults. The former is a relative estimate and the latter an absolute one (Dent, 1991). Trap catches are also influenced by the number of *S. aurantii* present on new growth where feeding and breeding take place and are also more likely to be influenced by weather patterns. Since traps measure the flying adults, they have a potential use in the early warning of infestations.

Based on Hoerl's function, the fruit size at the maximum *S. aurantii* number on the fruit was estimated to range from 20.22mm to 40.33mm, while for the traps it ranged from 2.94mm to 36.82mm. Therefore, for the management of thrips in mango orchards both yellow card traps and direct counts on the fruit can be used. The former can provide an early warning of high populations and the latter an accurate indication of whether or not sufficient numbers are present to cause the damage.

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer, M. Maritz, M. De Beer, C. Neethling and Mr W.P. Steyn for assistance in the study, Messrs D.J. Elphick and R.I. Elphick for access to their property and Messrs R.L.J. Coetzer and M.C. Welding for analyses of data. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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TABLE 1 F-values (with degrees of freedom) and their corresponding probability levels (P), correlation co-efficients (R^2) and the fruit size bearing the maximum number of thrips per fruit for Hoerl's function regressions of *S. aurantii* number /100 fruit on fruit size from different mango cultivars, localities and years.

Cultivar and orchard	Year	F(df.)	P	R^2	Fruit size at maximum *S. aurantii* number
Keitt Kaapmuiden	1993/94	9.647 (2; 4)	0.0295	0.8283	25.56
Keitt Kaapmuiden	1994/95	30.767 (2; 8)	0.0002	0.8849	25.69
Sensation Kaapmuiden	1993/94	8.114 (2; 8)	0.0119	0.6698	33.71
Sensation Kaapmuiden	1994/95	13.772 (2;10)	0.0013	0.7336	21.86
Tommy Atkins Kaapmuiden	1993/94	15.850 (2; 6)	0.0040	0.8409	20.22
Tommy Atkins Kaapmuiden	1994/95	5.501 (2; 7)	0.0367	0.6112	25.99
Nelspruit Sensation (no. K8)	1993/94	2.841 (2; 6)	0.1355	0.4864	not significant
Nelspruit Sensation (no. K8)	1994/95	2.845 (2; 11)	0.1004	0.3416	not significant
Friedenheim Fascell (no. V7)	1993/94	13.608 (2; 5)	0.0095	0.8448	23.42
Friedenheim Fascell (no. V7)	1994/95	5.393 (2; 7)	0.0382	0.6064	33.15
Friedenheim Sensation (no. T4)	1993/94	6.260 (2; 9)	0.0198	0.5818	correlation co-efficient low
Friedenheim Sensation (no. T4)	1994/95	3.041 (2;12)	0.0854	0.3364	not significant
Friedenheim Sensation (no. V6)	1993/94	62.336 (2; 7)	0.0001	0.9468	28.16
Friedenheim Sensation (no. V6)	1994/95	3.588 (2, 11)	0.0632	0.3948	not significant
Friedenheim Zill (no. V6)	1993/94	9.682 (2; 9)	0.0057	0.6827	42.21
Friedenheim Zill (no. V6)	1994/95	10.920 (2; 11)	0.0024	0.6651	40.52

TABLE 2 Regression constants estimated for Hoerl's function ($Y = aX^be^{cX}$) with the t-values and the probability levels in brackets for regressions of *S. aurantii*/100 fruit on fruit size from different mango cultivars, localities and years (for instances where $P < 0.05$ and $R^2 > 0.6$).

Cultivar and orchard	Year	a	t(P)	b	t(P)	c	t(P)
Keitt Kaapmuiden	1993/94	0.0357	-0.887 (0.4250)	3.9110	2.470 (0.0689)	-0.1530	-3.397 (0.0274)
Keitt Kaapmuiden	1994/95	0.0958	-1.890 (0.0954)	3.8563	6.404 (0.002)	-0.1501	-7.597 (0.0001)
Sensation Kaapmuiden	1993/94	0.0001	-0.954 (0.3680)	5.5044	1.718 (0.1242)	-0.1633	-2.635 (0.0299)
Sensation Kaapmuiden	1994/95	0.0792	-0.987 (0.3471)	3.8767	3.245 (0.0088)	-0.1773	-4.457 (0.0012)
Tommy Atkins Kaapmuiden	1993/94	2.4981	0.234 (0.8231)	1.4319	0.946 (0.3808)	-0.0708	-2.170 (0.0730)
Tommy Atkins Kaapmuiden	1994/95	0.2775	-0.519 (0.6198)	2.7368	2.526 (0.0395)	-0.1053	-3.176 (0.0156)
Friedenheim Fascell (no. V7)	1993/94	0.1391	-0.268 (0.7995)	3.8129	1.367 (0.2298)	-0.1628	-2.470 (0.0565)
Friedenheim Fascell (no. V7)	1994/95	0.0008	-2.049 (0.0796)	5.0525	3.269(0. 0137)	-0.1524	-3.032 (0.0191)
Friedenheim Sensation (no. V6)	1993/94	0.0087	-1.939 (0.0937)	5.3478	5.482 (0.0009)	-0.1899	-7.738 (0.0001)
Friedenheim Zill (no. V6)	1993/94	1.3×10^{-5}	-3.302 (0.0092)	6.1460	4.314 (0.0020)	-0.1456	-3.818 (0.0041)
Friedenheim Zill (no. V6)	1994/95	7.3×10^{-7}	-3.728 (0.0033)	6.7025	4.548 (0.0008)	-0.1654	-4.663 (0.0007)

TABLE 3 F-values (with degrees of freedom) and their corresponding probability levels (P), correlation co-efficients (R^2) and the fruit size bearing the maximum number of thrips per fruit for Hoerl's function regressions of *S. aurantii* number/trap on fruit size from different mango cultivars, localities and years.

Cultivar and orchard	Year	F(df.)	P	R^2	Fruit size at maximum *S. aurantii* number
Keitt Kaapmuiden	1993/94	10.063 (2; 16)	0.0015	0.5571	correlation co-efficient low
Keitt Kaapmuiden	1994/95	20.048 (2; 20)	0.0001	0.6672	no turning point
Sensation Kaapmuiden	1993/94	3.123 (2; 16)	0.0716	0.2807	not significant
Sensation Kaapmuiden	1994/95	10.589 (2; 22)	0.0006	0.4905	correlation co-efficient low
Tommy Atkins Kaapmuiden	1993/94	36.942 (2; 13)	0.0001	0.8504	10.81
Tommy Atkins Kaapmuiden	1994/95	65.979 (2; 16)	0.0001	0.8919	19.16
Nelspruit Sensation (no. K8)	1993/94	19.015 (2; 18)	0.0001	0.6787	28.93
Nelspruit Sensation (no. K8)	1994/95	3.520 (2; 18)	0.0513	0.2811	not significant
Friedenheim Fascell (no. V7)	1993/94	14.899 (2; 8)	0.0020	0.7884	2.94
Friedenheim Fascell (no. V7)	1994/95	8.586 (2; 13)	0.0042	0.5691	correlation co-efficient low
Friedenheim Sensation (no. T4)	1993/94	1.193 (2; 15)	0.3305	0.1372	not significant
Friedenheim Sensation (no. T4)	1994/95	4.705 (2; 22)	0.0199	0.2996	correlation co-efficient low
Friedenheim Sensation (no. V6)	1993/94	4.384 (2; 17)	0.0291	0.3403	correlation co-efficient low
Friedenheim Sensation (no. V6)	1994/95	17.841 (2; 22)	0.0001	0.6186	37.64
Friedenheim Zill (no. V6)	1993/94	48.450 (2; 16)	0.0001	0.8583	36.82
Friedenheim Zill (no. V6)	1994/95	9.553 (2; 17)	0.0017	0.5292	correlation co-efficient low

TABLE 4 Regression constants estimated for Hoerl's function ($Y = aX^be^{cX}$) with the t-values and the probability levels in brackets for regressions of *S. aurantii*/trap on fruit size from different mango cultivars, localities and years (for instances where $P < 0.05$ and $R^2 > 0.6$).

Cultivar and orchard	Year	a	t(P)	b	t(P)	c	t(P)
Keitt Kaapmuiden	1994/95	351.118 9	4.881 (0.0001)	-0.1441	-0.277 (0.7842)	-0.0264	-1.964 (0.0636)
Tommy Atkins Kaapmuiden	1993/94	39.9004	1.058 (0.3091)	0.6821	0.522 (0.6107)	-0.0632	-2.407 (0.0317)
Tommy Atkins Kaapmuiden	1994/95	11.0079	3.169 (0.0060)	1.2286	3.670 (0.0021)	-0.0641	-7.201 (0.0001)
Nelspruit Sensation (no. K8)	1993/94	0.2187	-0.421 (0.6789)	2.3548	1.809 (0.0872)	-0.0814	-3.126 (0.0058)
Friedenheim Fascell (no. V7)	1993/94	711.625 7	0.962 (0.3643)	0.2029	0.082 (0.9365)	-0.0689	-1.363 (0.2101)
Friedenheim Sensation (no. V6)	1994/95	3.5×10^{-19}	-2.961 (0.0072)	5.9885	4.441 (0.0002)	-0.1591	-5.334 (0.0001)
Friedenheim Zill (no. V6)	1993/94	0.0175	-3.534 (0.0028)	3.5384	7.781 (0.0001)	-0.0961	-9.246 (0.0001)

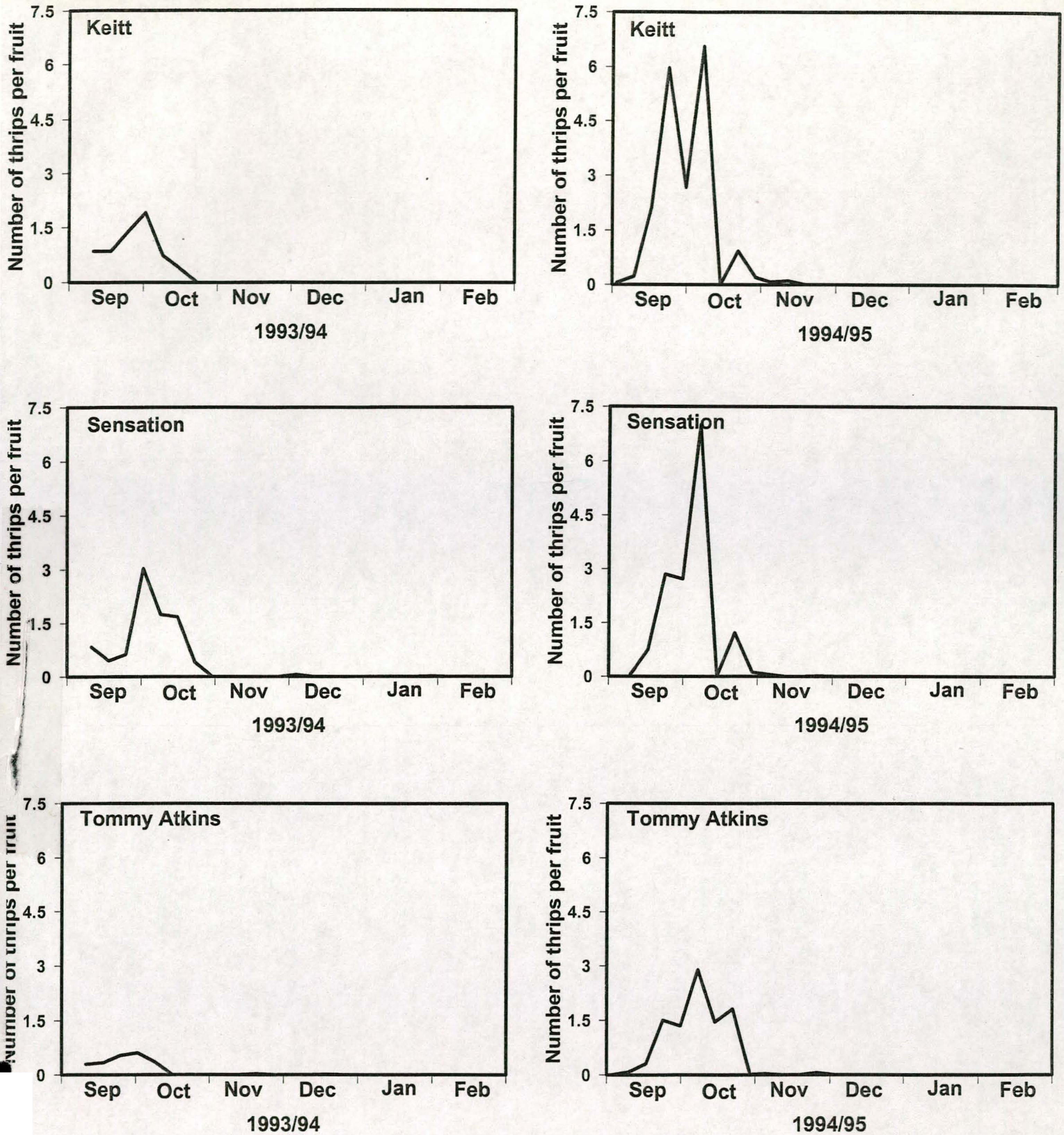


FIGURE 1 Seasonal abundance of *Scirtothrips aurantii* larvae and adults on mango fruit in orchards of various cultivars at Kaapmuiden

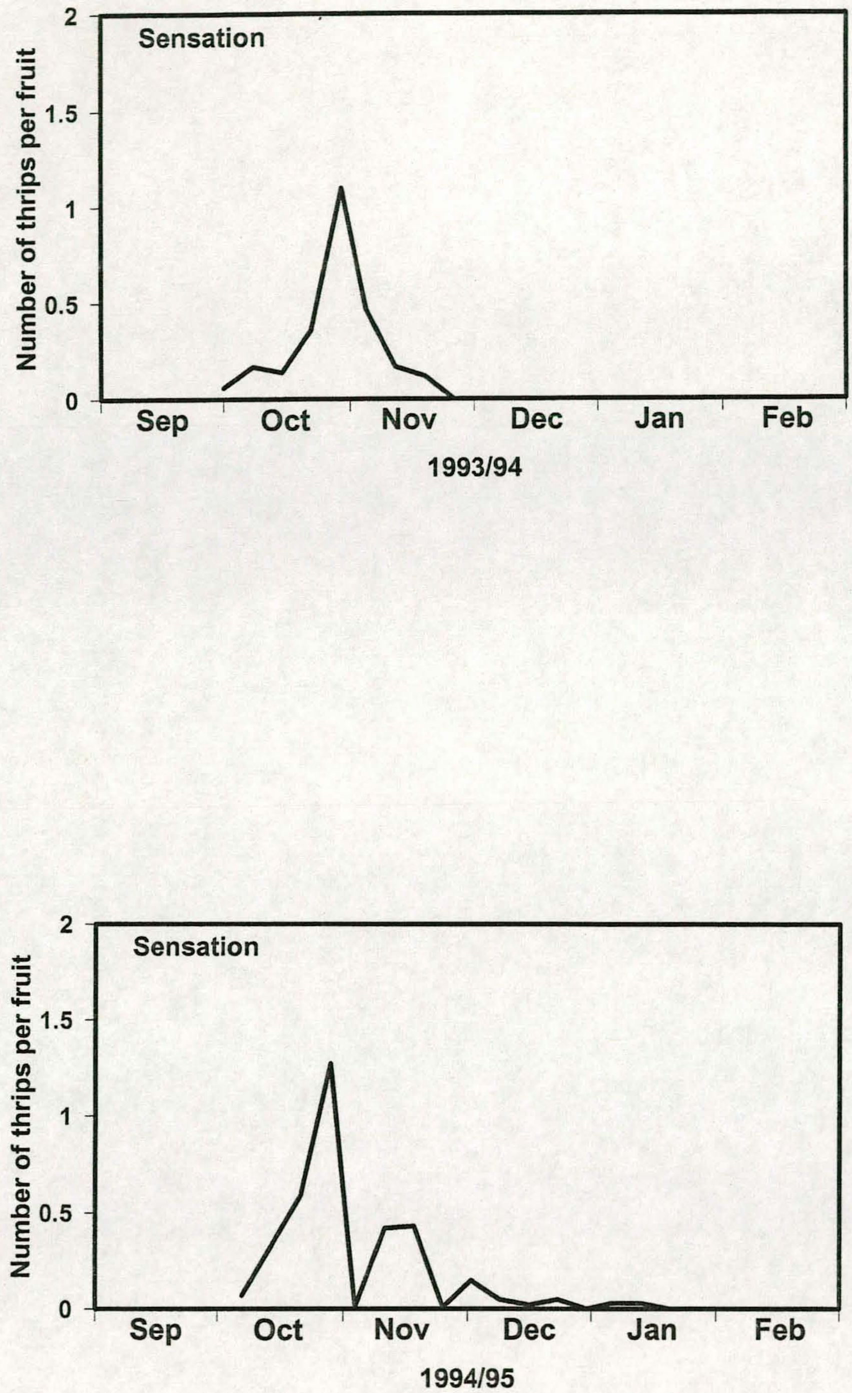


FIGURE 2 Seasonal abundance of *Scirtothrips aurantii* larvae and adults on mango fruit in an orchard at ITSC Nelspruit Experimental Farm

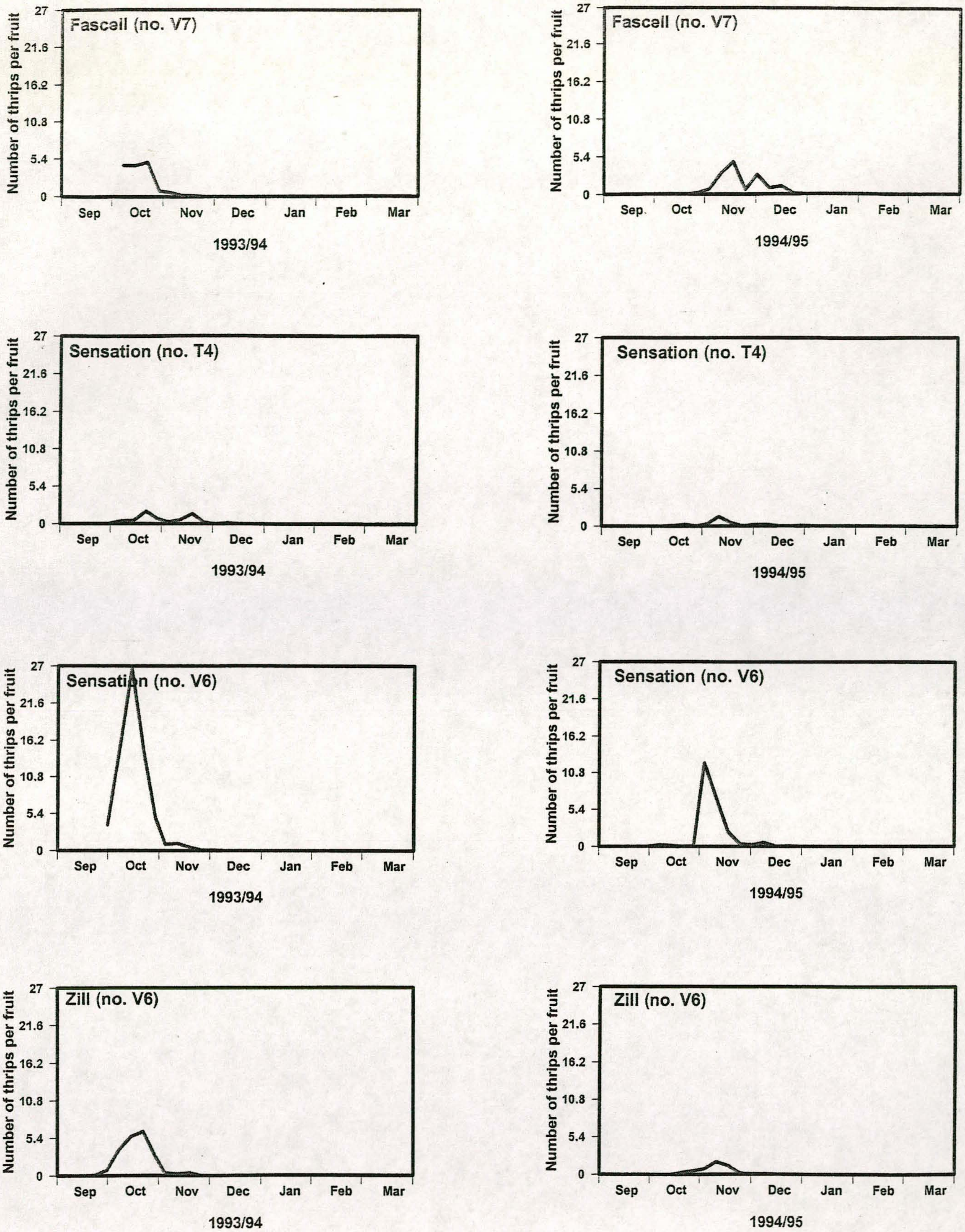


FIGURE 3 Seasonal abundance of *Scirtothrips aurantii* larvae and adults on mango fruit in orchards of various cultivars at ITSC Friedenheim Experimental Farm

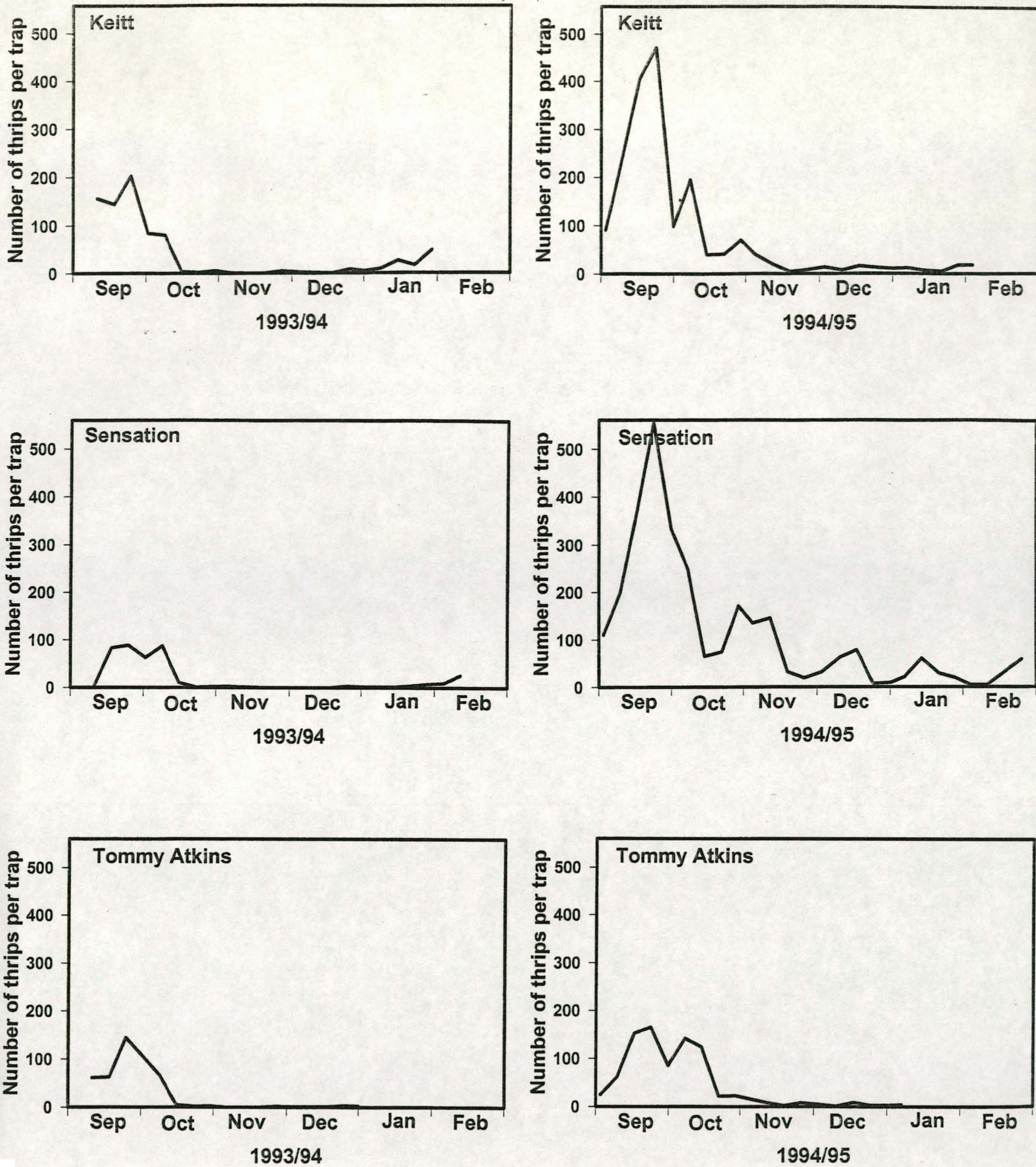
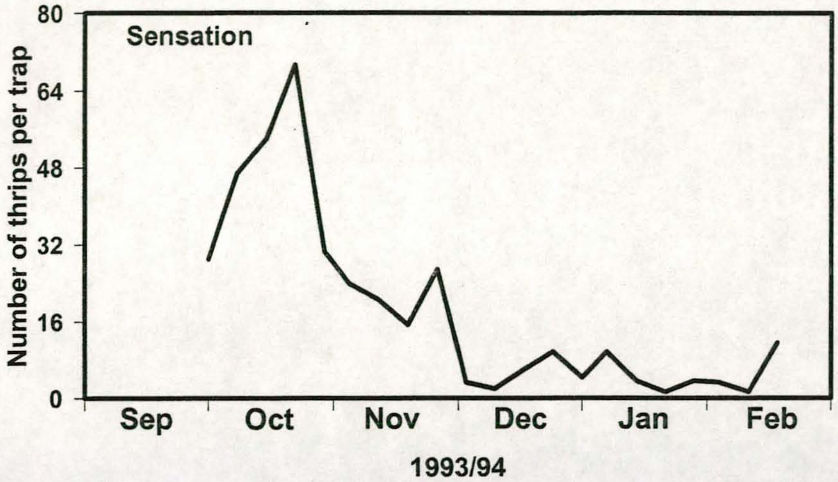


FIGURE 4 Mean number of adult *Scirtothrips aurantii* recorded on traps in mango orchards of various cultivars at Kaapmuiden



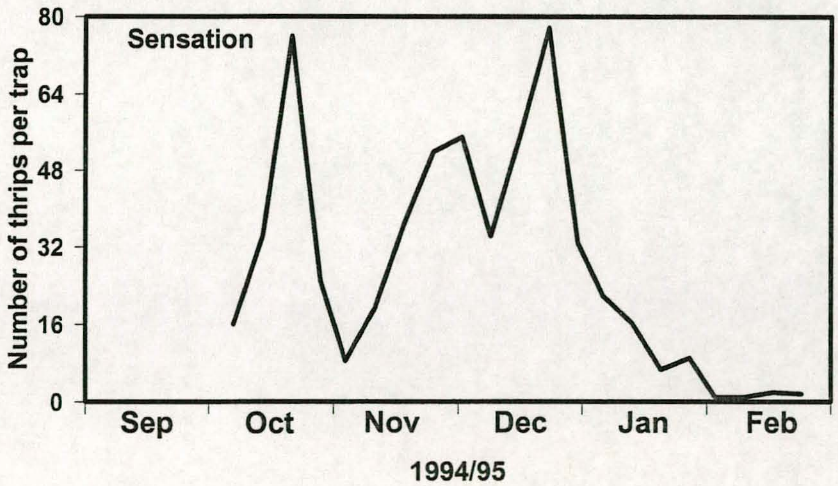


FIGURE 5 Mean number of adult *Scirtothrips aurantii* recorded on traps in an orchard at ITSC Nelspruit Experimental Farm

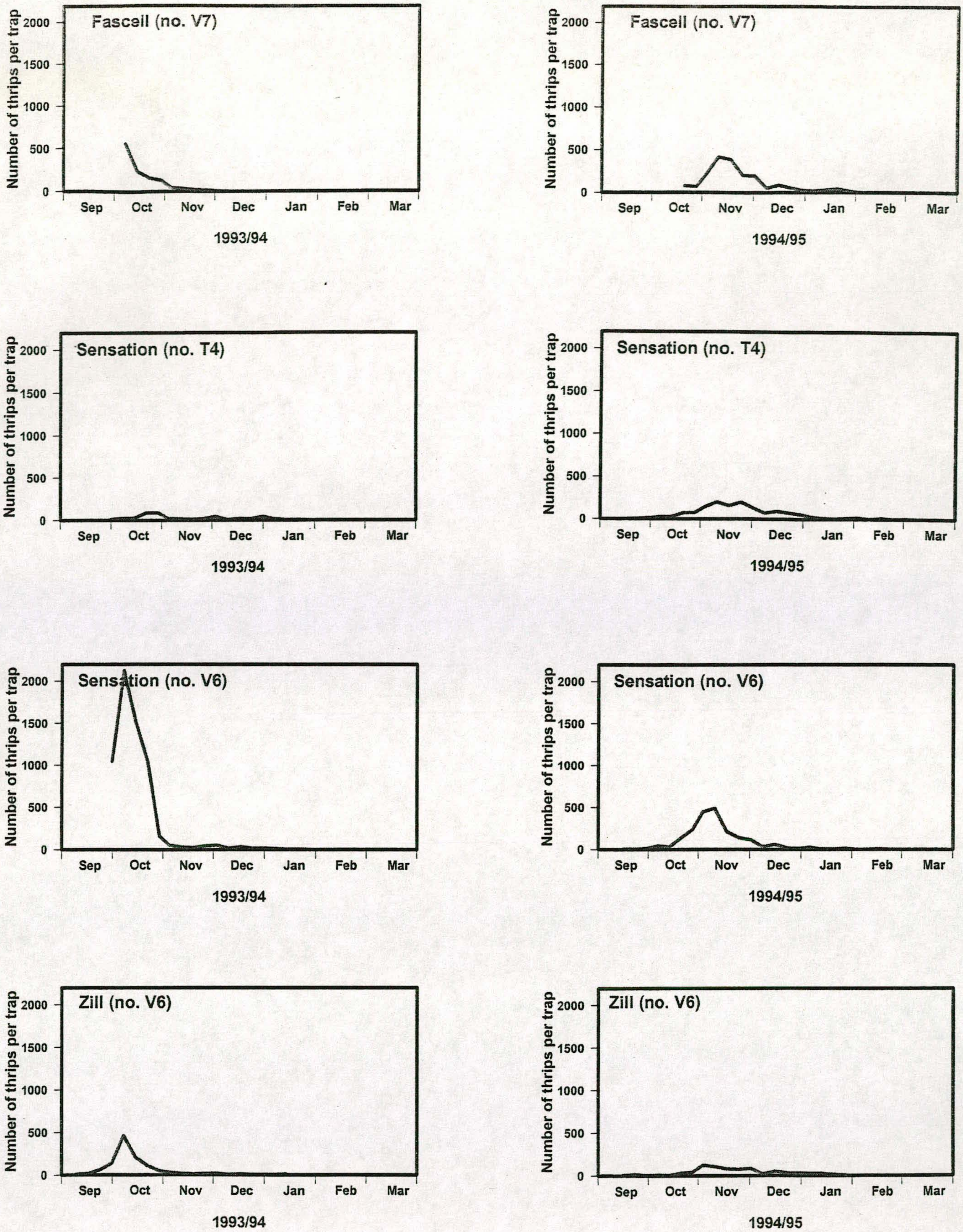


FIGURE 6 Mean number of adult *Scirtothrips aurantii* recorded on traps in orchards of various cultivars at ITSC Friedenheim Experimental Farm

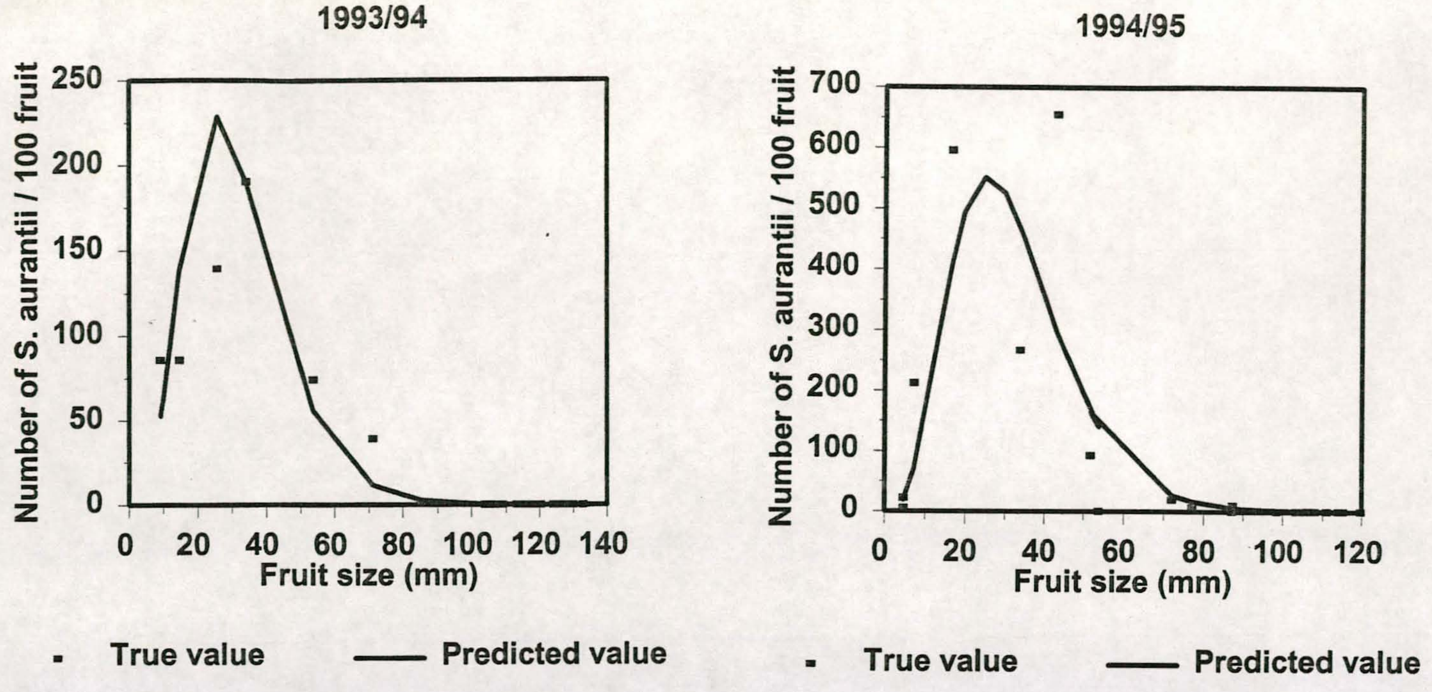


FIGURE 7 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Keitt orchard at Kaapmuiden

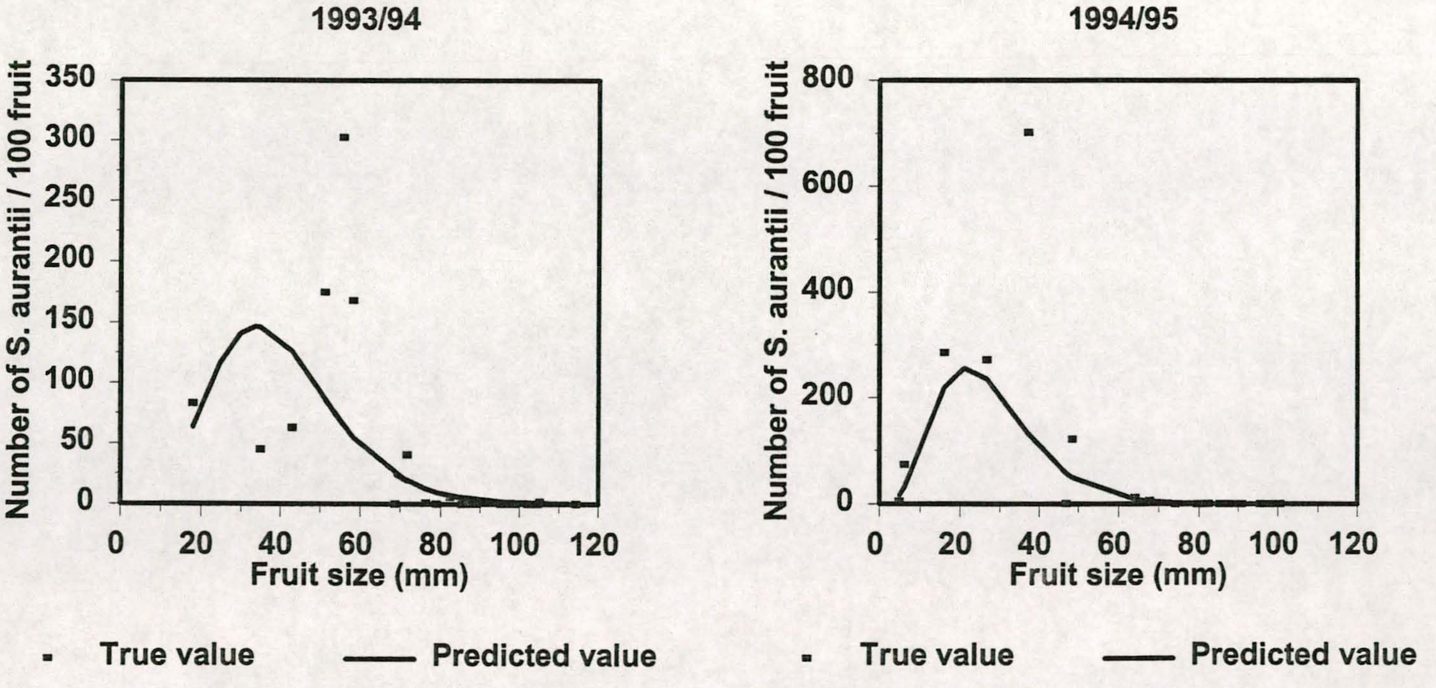


FIGURE 8 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Sensation orchard at Kaapmuiden

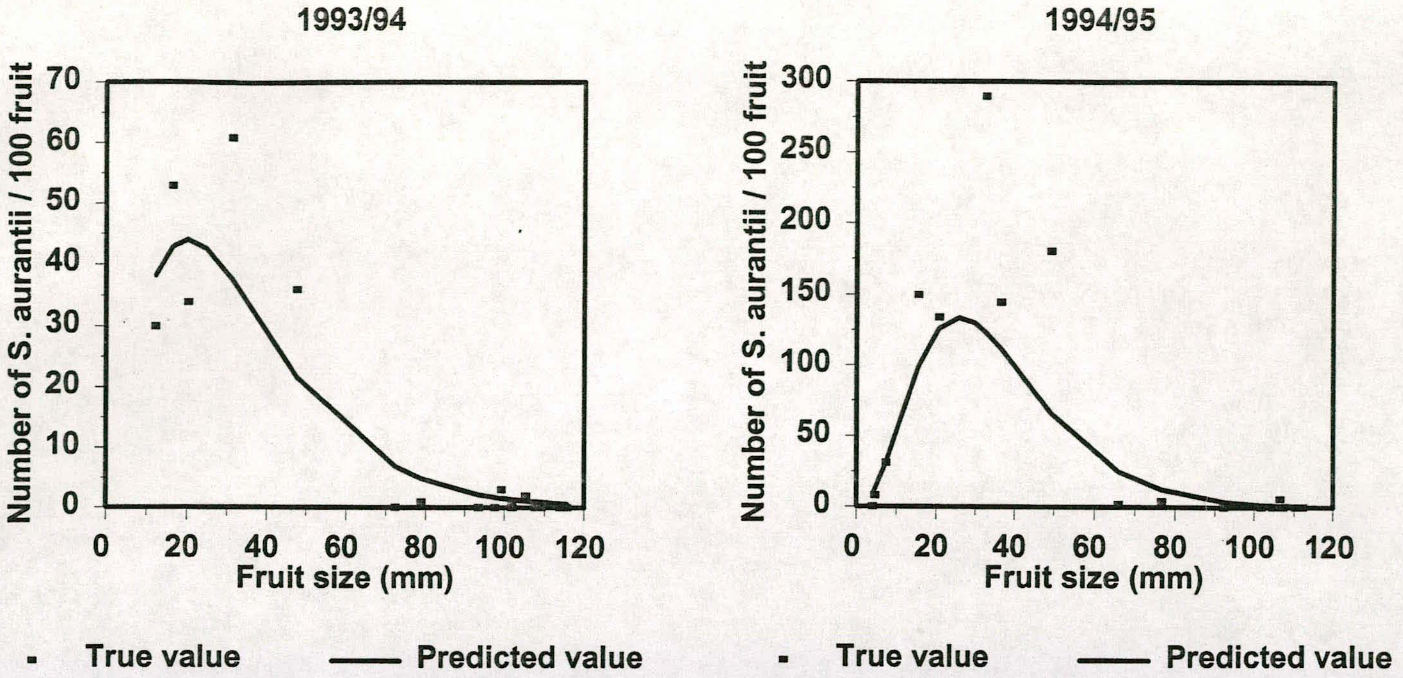


FIGURE 9 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Tommy Atkins orchard at Kaapmuiden

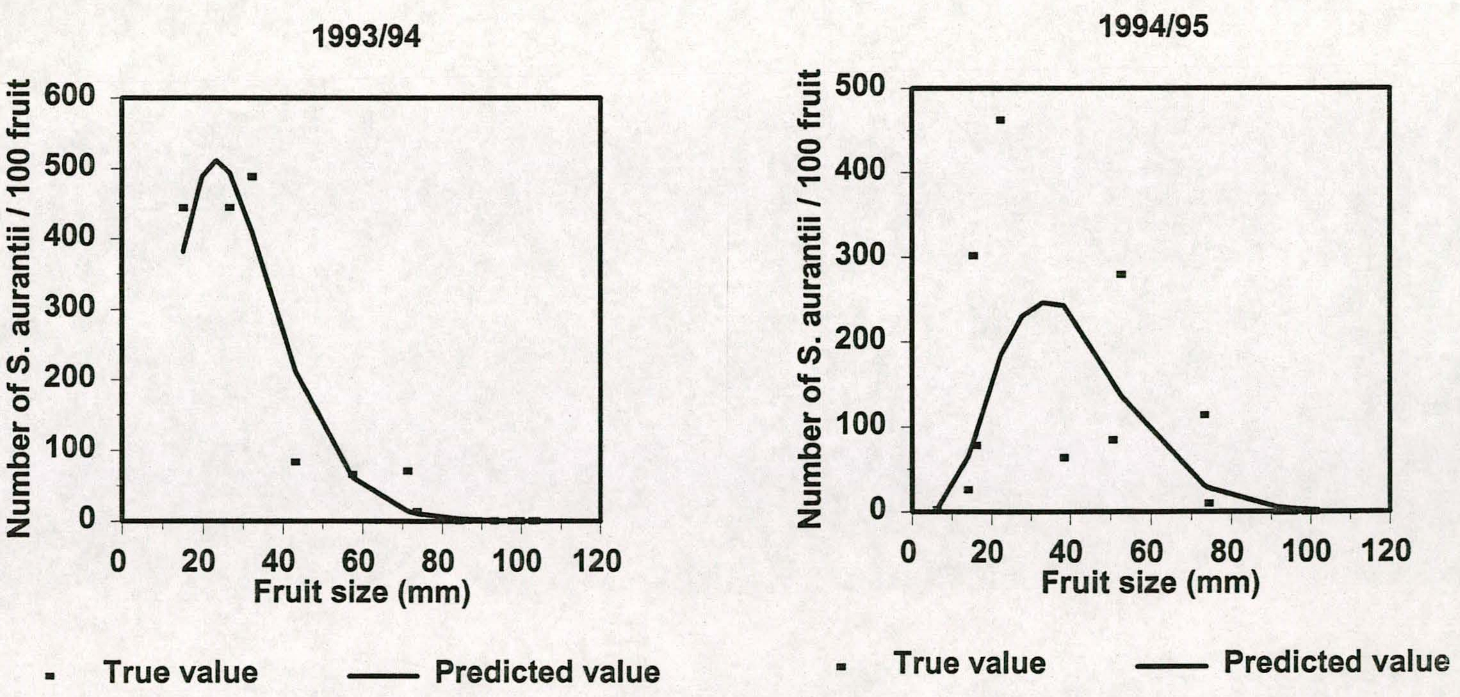


FIGURE 10 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Fascell orchard (no. V7) at Friedenheim

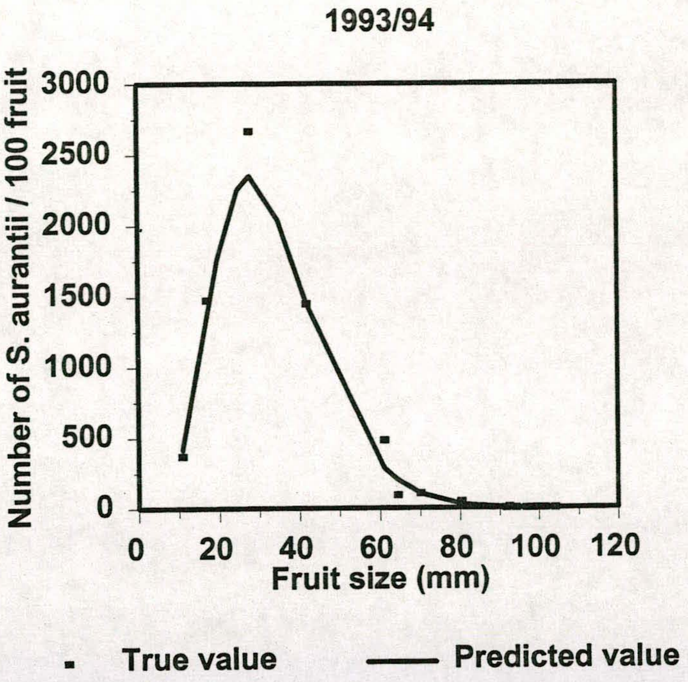


FIGURE 11 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Sensation orchard (no. V6) at Friedenheim

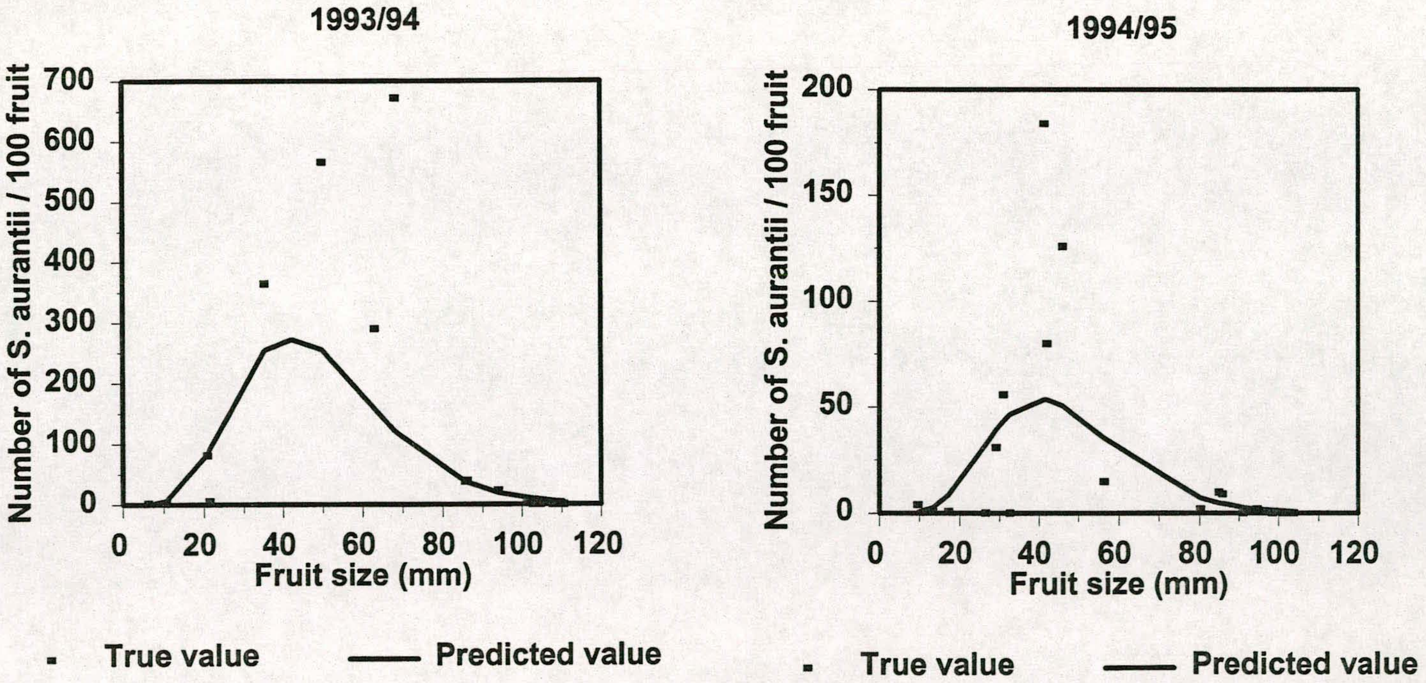


FIGURE 12 Number of *Scirtothrips aurantii*/100 fruit plotted against fruit size for the Zill orchard (no. V6) at Friedenheim

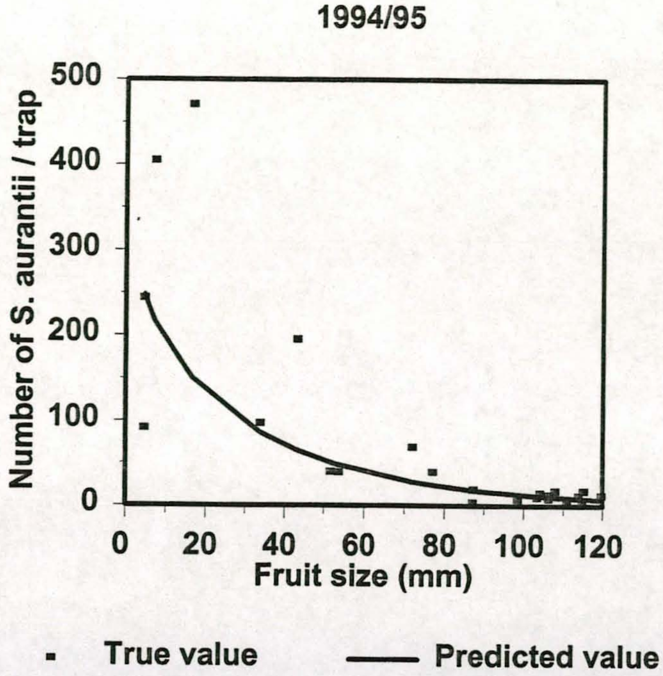


FIGURE 13 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Keitt orchard at Kaapmuiden

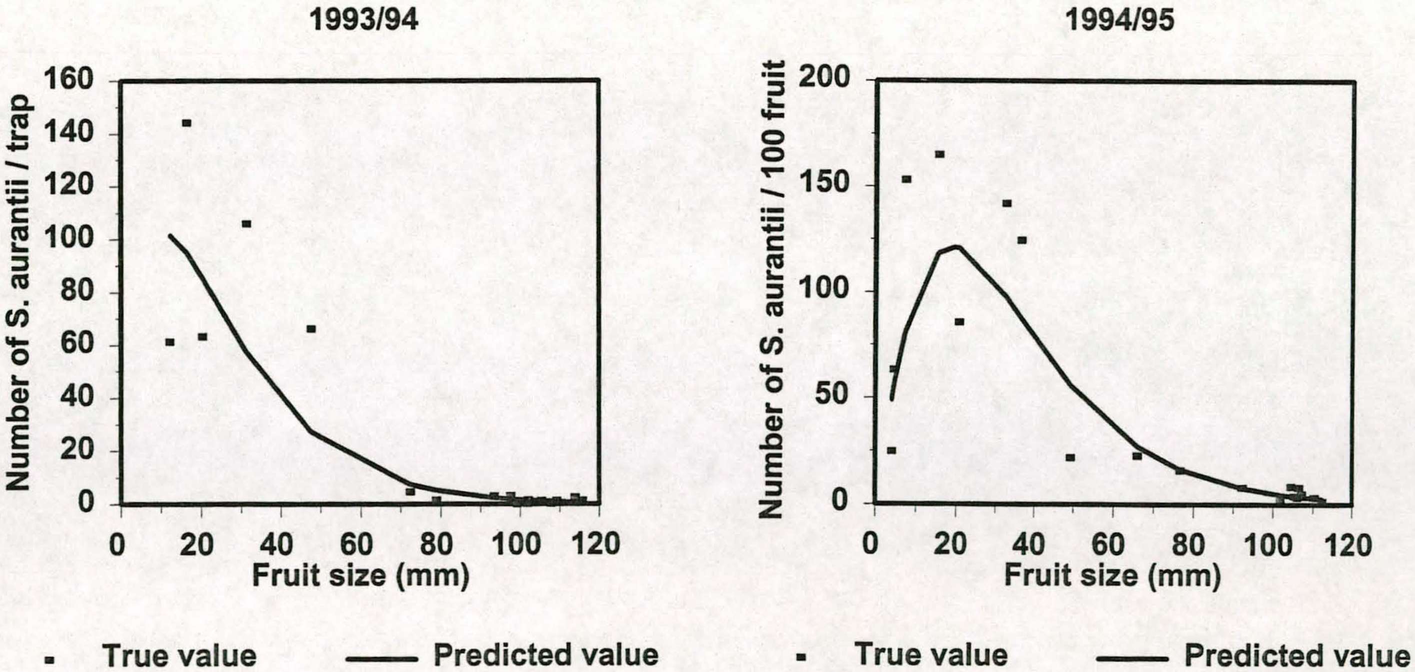


FIGURE 14 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Tommy Atkins orchard at Kaapmuiden

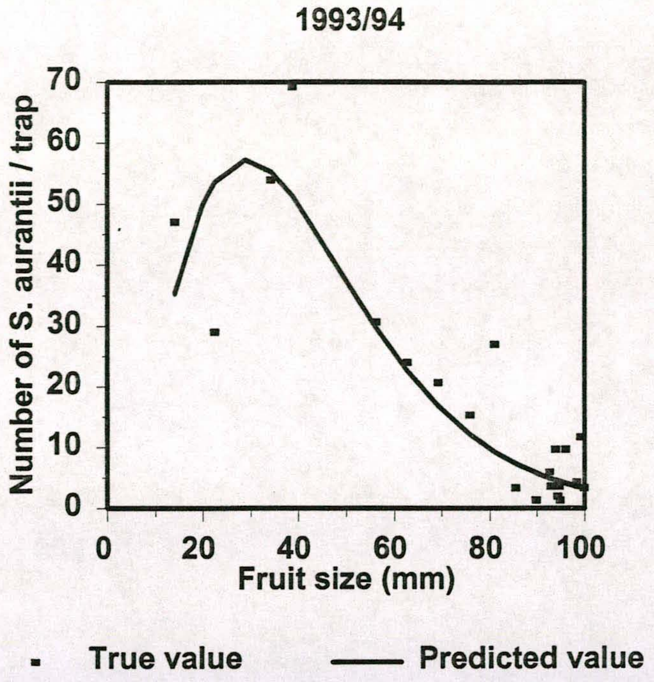


FIGURE 15 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Sensation orchard (no. K8) at Nelspruit

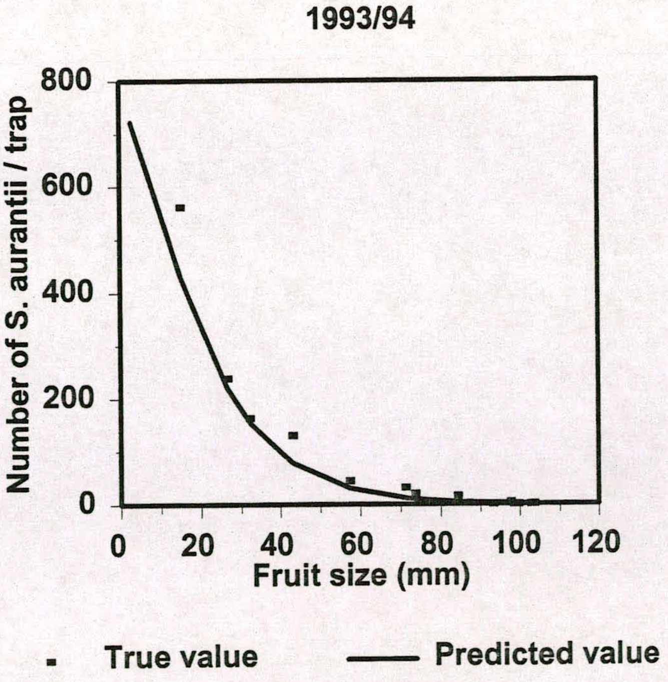


FIGURE 16 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Fascell orchard (no. V7) at Friedenheim

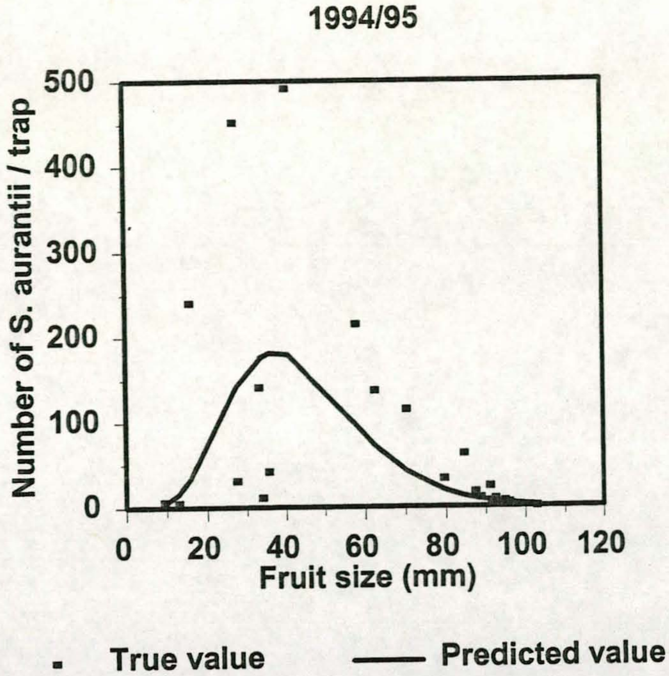


FIGURE 17 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Sensation orchard (no. V6) at Friedenheim

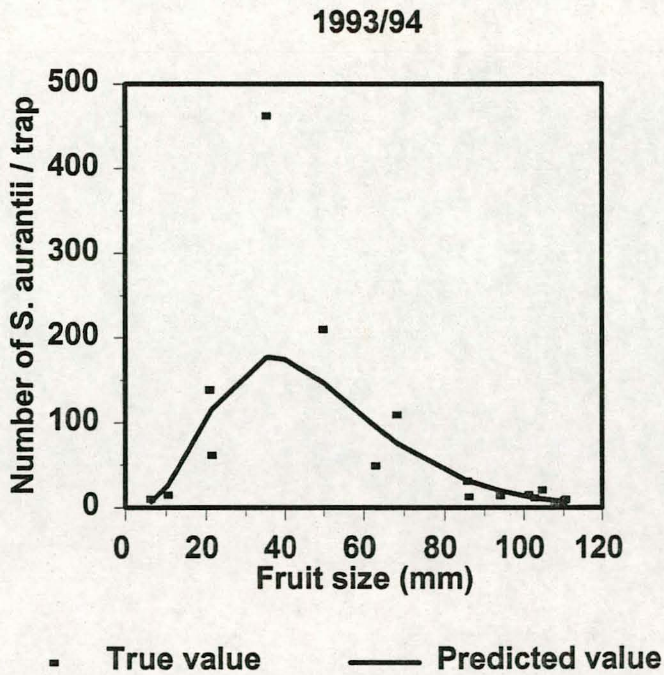


FIGURE 18 Number of *Scirtothrips aurantii*/trap plotted against fruit size for the Zill orchard (no. V6) at Friedenheim

CHAPTER 7

SEASONAL ABUNDANCE OF ADULT CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) NUMBERS IN SOUTH AFRICAN MANGO ORCHARDS

ABSTRACT

The seasonal abundance of adult citrus thrips *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) was studied over a three year period. Weekly monitoring using yellow card traps was conducted in different orchards in the Mpumalanga Province from 1992 - 1995. *Scirtothrips aurantii* numbers started to build up during September, which is the end of the flowering period, and reached a peak during October or November when small fruit were present on the trees. Low numbers were present from June until August.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) is a well documented and important pest of citrus in southern Africa (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978, Gilbert & Bedford, 1998). It is also a pest of mango (*Mangifera indica* L.) according to Annecke & Moran (1982). Its status as a pest of mango has increased over the past years (Brink, 1993). Adults and larvae feed on the fruit, causing lesions. The damage is cosmetic and mangoes with large lesions are not suitable for the export market. Leaf malformation and stunting of growth are also caused to young mango growth.

As with any species, the densities of *S. aurantii* populations vary at different times of the year and from year to year. A severe outbreak of *S. aurantii* on citrus in one year may be followed by one or more years with relatively low population levels in which even unsprayed orchards have little or no damage (Wentzel *et al.*, 1978). In citrus orchards numbers are generally highest during the six months from September to February (Gilbert & Bedford, 1998). According to Wentzel *et al.* (1978), the population declines from the end of April to the beginning of August due to cooler weather and a diminishing food supply. It was found that *S. aurantii* populations in citrus trees were clearly related to the flushing rhythm (Stassen & Catling, 1969). A study on Reunion Island revealed that *S. aurantii* on citrus increased during the end of the flowering period and maintained high levels until the end of the austral summer period and then began to decrease. No captures were registered from March until the beginning of September (Quilici *et al.*, 1988).

Although many studies have been conducted on citrus, no monitoring has been done in mango orchards. The aim of this study was to record the variation in adult *S. aurantii* numbers in mango orchards over a three year period.

MATERIALS AND METHODS

Sites

Field work was carried out at two different sites in the Mpumalanga Province of South Africa. At the Institute for Tropical and Subtropical Crops (ITSC) Nelspruit Experimental Farm (25.26S, 30.58E) data were collected in a Sensation orchard (no. K8). The second site was at the ITSC Friedenheim Experimental Farm (25.27S, 30.58E) and data were collected from a Fascell orchard (no. V7), two Sensation orchards (nos T4 and V6) and a Zill orchard (no. V6). All sites were commercially productive. In all orchards fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot. Bait sprays were applied against fruit flies (Tephritidae). The monitoring period commenced during August 1992 and continued until August 1995 except in the case of the Sensation orchard (no. V6) where monitoring started during March 1993.

Trapping of *S. aurantii*

In each orchard three yellow card traps were used for the monitoring of adult *S. aurantii.* The traps consisted of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2mm). These traps and monitoring system were developed for monitoring *S. aurantii* in citrus orchards (Grout & Richards, 1990a). Both sides of the traps were coated with a sticky adhesive, Fly-tac®. Traps were placed 1.5 m to 2m above the ground on the northern side of the tree and diagonally across the orchards with one trap in the centre and the other two traps near the opposing corners. Every week traps were changed and wrapped in clear polyethylene plastic wrap. *Scirtothrips aurantii* adults were counted using a stereo microscope.

RESULTS

Over the three year period a total number of 16 756, 8 496, 28 144, 8 607 and 9 955 adult *S. aurantii* was caught respectively on the traps in Fascell orchard (no. V7), Sensation orchard (no. T4), Sensation orchard (no. V6), Zill orchard (no. V6) and Sensation orchard (no. K8). Although the sampling period for the Sensation orchard (no. V6) was shorter, the highest total number was recorded in this orchard.

In the Fascell orchard (no. V7) at Friedenheim, the highest numbers during 1992 and 1993 were recorded in October, while the highest number during 1994 was in November (Fig.1). A similar pattern existed in the Sensation orchard (no. T4) and the Zill orchard (no. V6) (Figs 2 and 4). In the Sensation orchard (no. V6) numbers peaked during October in 1993 and during November in 1994 (Fig. 3). In the Sensation orchard (no. K8) the highest numbers were present during November in 1992, October in 1993 and December in 1994

(Fig. 5). In the Fascell orchard (no. V7) and Sensation orchard (no. K8) high numbers were also present during April 1993, which corresponded with the flushing of trees.

The year in the observation period where highest numbers were found was not the same for all the orchards. The highest number was present during the 1994/95 fruiting season for Fascell orchard (no. V7) and Sensation orchard (no.T4). In the Sensation orchard (no. V6) and Zill orchard (no. V6) highest numbers were present during 1993/94 while at Nelspruit it was 1992/93.

DISCUSSION

Numbers of *S. aurantii* usually started to increase during September, which is the end of the flowering period and reached a peak during October or November when small fruit were present on the trees. Low numbers were present from June until August. The results from this study are similar to those of Gilbert (1992) for citrus orchards in the Northern Province.

Great variation in *S. aurantii* numbers was observed in the same orchard from season to season. The numbers during each month are therefore highly unpredictable from year to year. The same cultivar at the same location also had different numbers as in the case of Sensation orchard (no. V6) and Sensation orchard (no. T4). The presence of alternative hosts of *S. aurantii* in the vicinity of orchards may influence the numbers in orchards (Gilbert, 1990; Grout & Richards, 1990b). The Sensation orchard (no. V6) was adjacent to a macadamia orchard which had high numbers of *S. aurantii*.

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer, M.S. De Beer and M. Maritz for assistance in the study. This project was funded by the Agricultural Research Council and the South African

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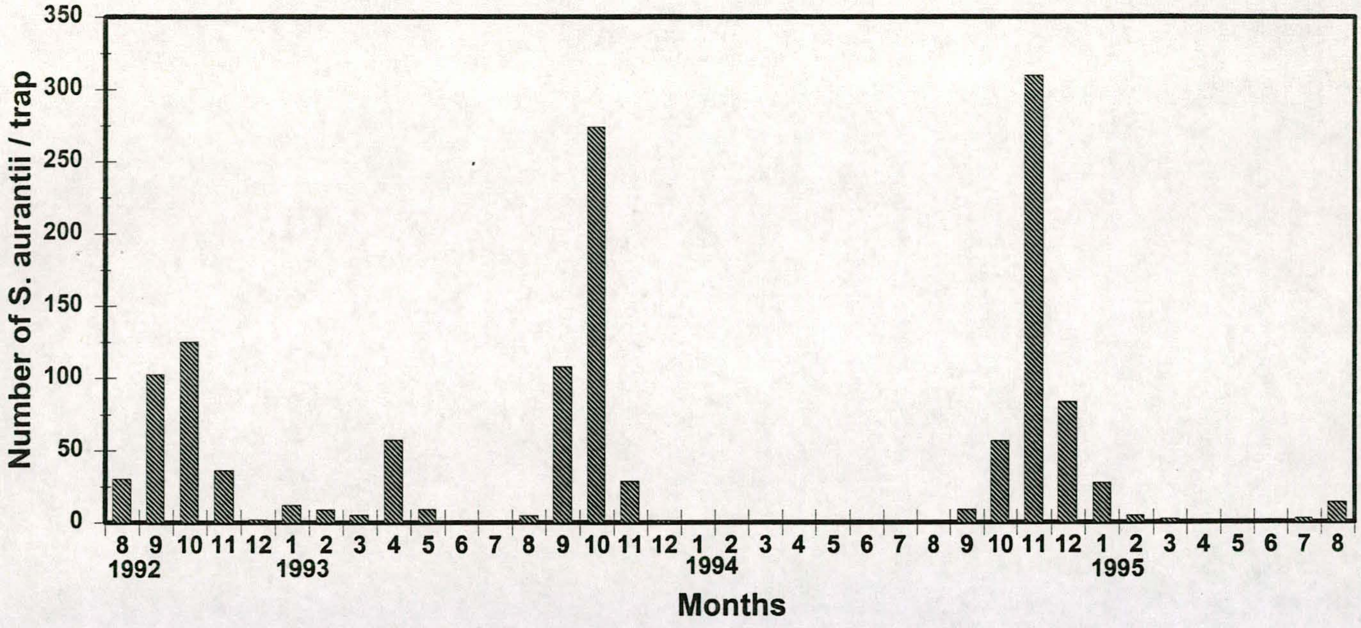

FIGURE 1 Mean number of adult *Scirtothrips aurantii* recorded on traps in a Fascell orchard (no. V7) at Friedenheim

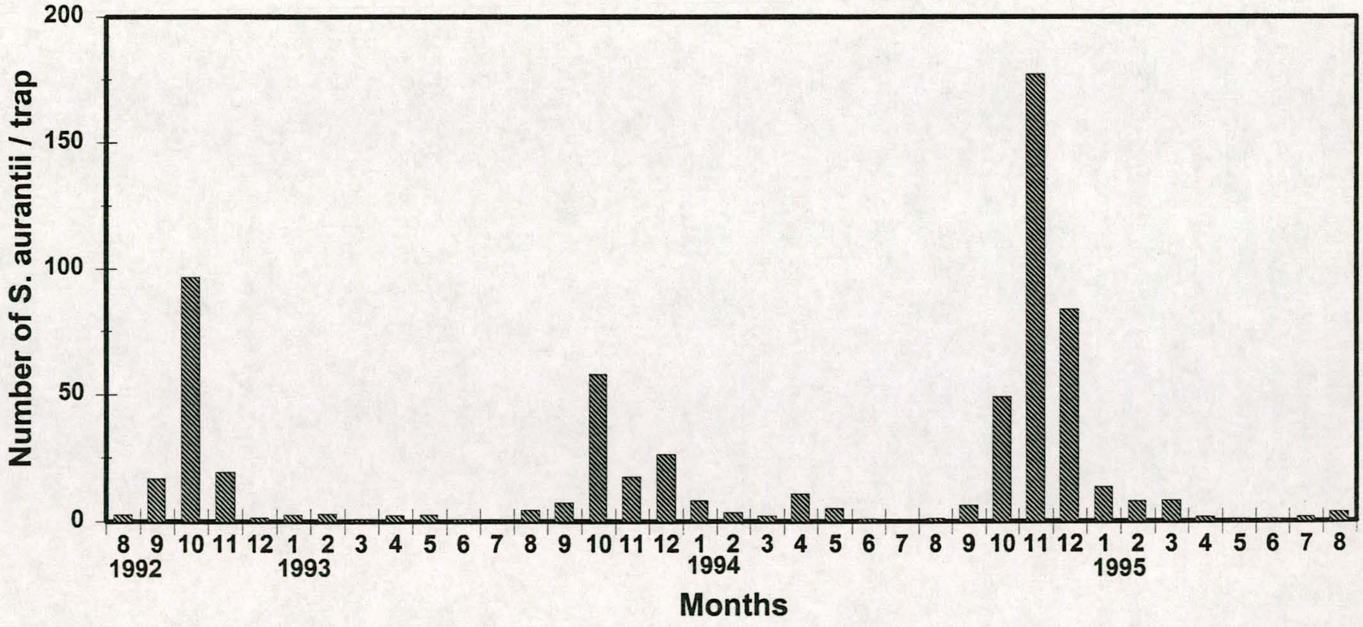

FIGURE 2 Mean number of adult *Scirtothrips aurantii* recorded on traps in a Sensation orchard (no. T4) at Friedenheim

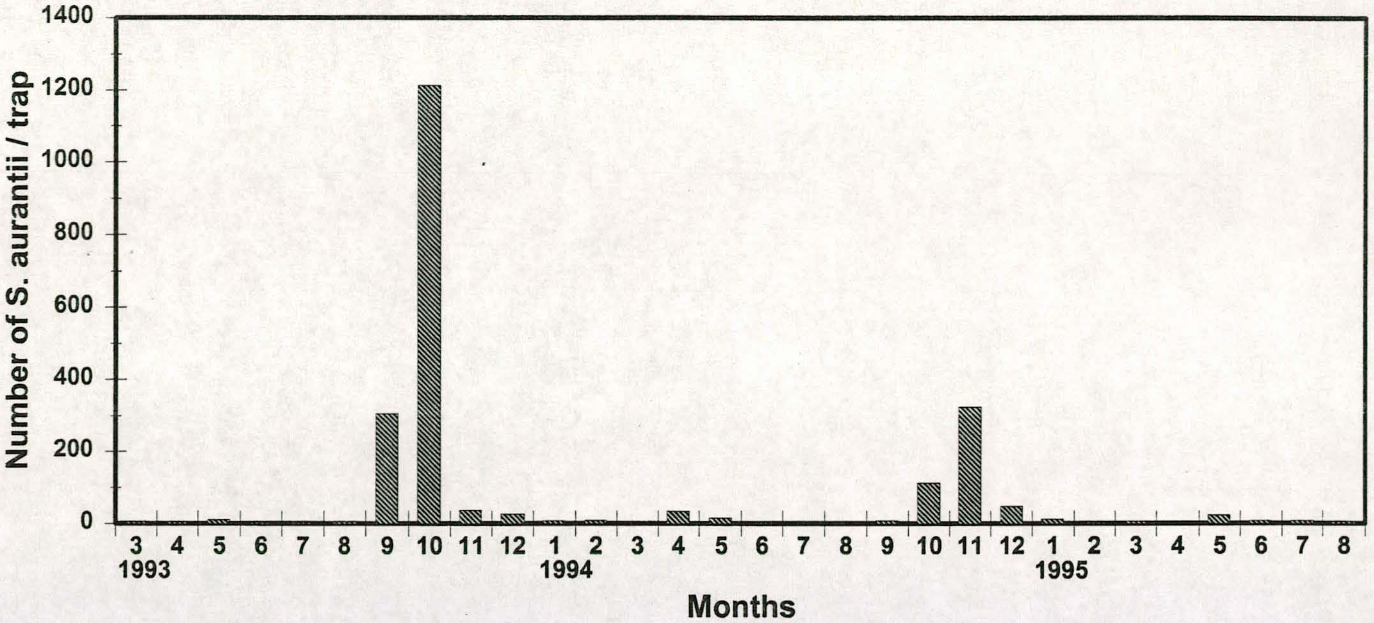

FIGURE 3 Mean number of adult *Scirtothrips aurantii* recorded on traps in a Sensation orchard (no. V6) at Friedenheim

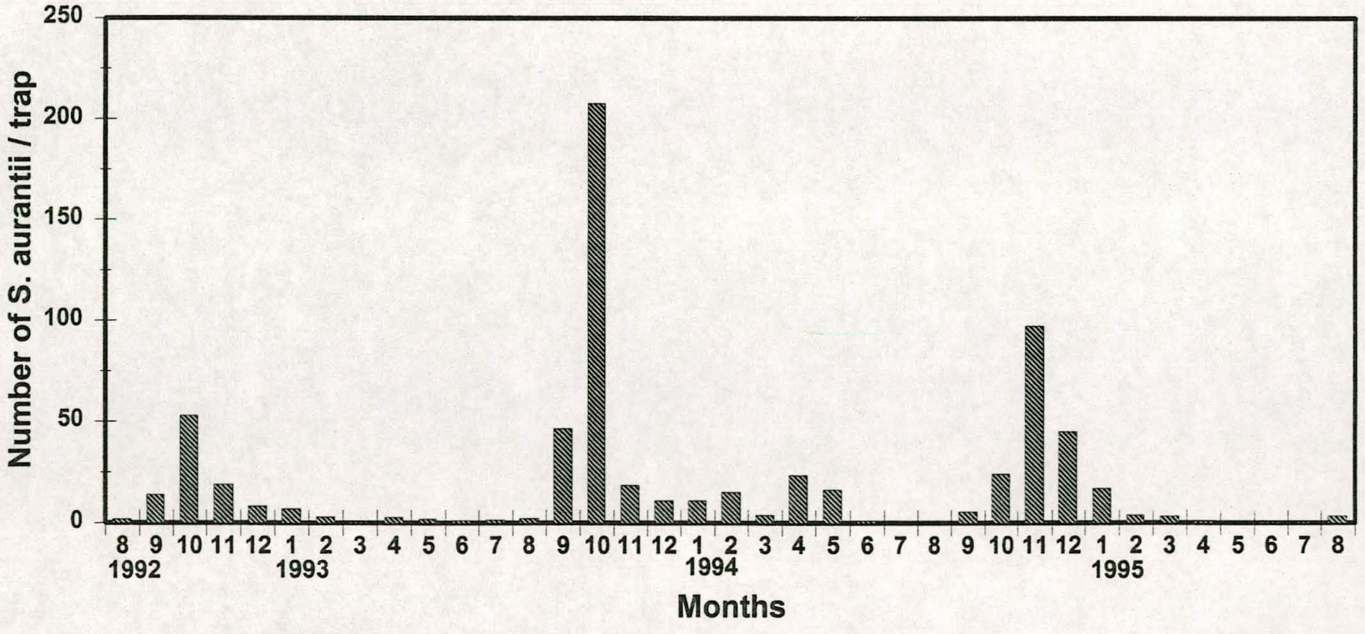

FIGURE 4 Mean number of adult *Scirtothrips aurantii* recorded on traps in a Zill orchard (no. V6) at Friedenheim

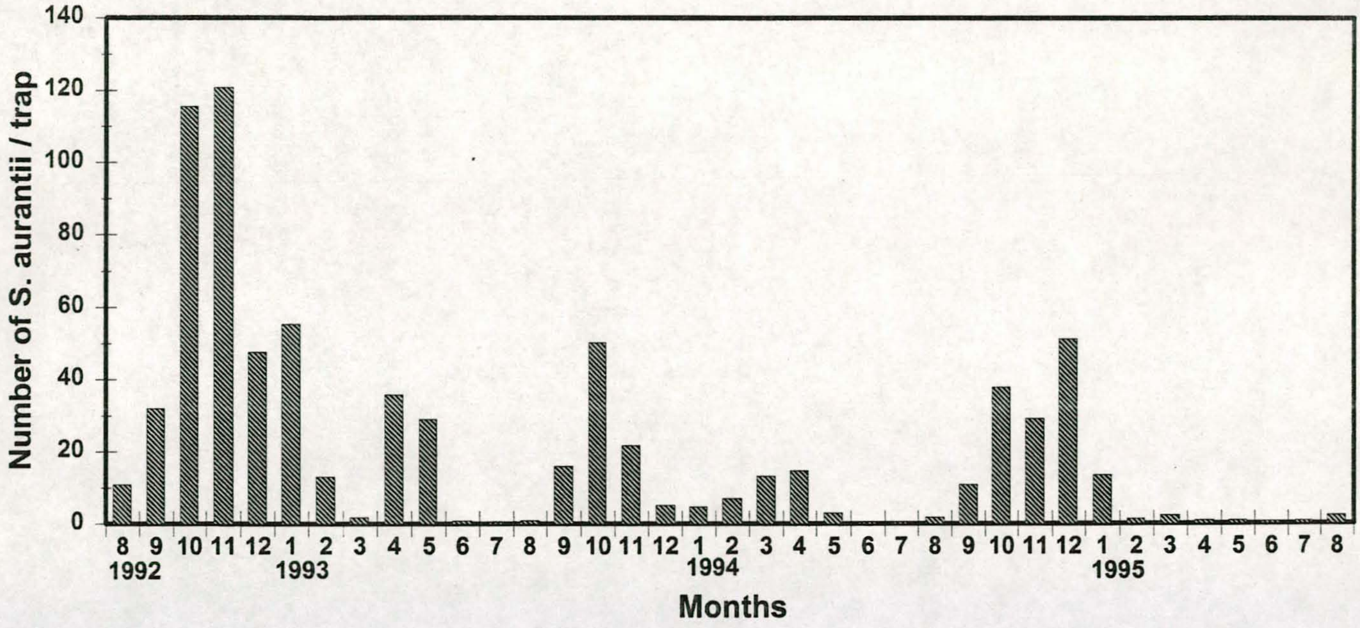

FIGURE 5 Mean number of adult *Scirtothrips aurantii* recorded on traps in a Sensation orchard (no. K8) at Nelspruit

CHAPTER 8

THE SEASONAL ABUNDANCE OF ALL STAGES OF THE CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) ON TWO MANGO CULTIVARS IN SOUTH AFRICA

ABSTRACT

Populations of the citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) were monitored using different methods. Adults were monitored using yellow sticky traps, dispersal/emergence traps, counts on fruit and counts after shaking flowers. Eggs and emergence holes on the new leaves were recorded. Numbers began to increase at the end of the flowering period (September) and maintained high levels until the fruiting period (November). Low numbers were present from May to August. Much higher population levels were present during 1995/1996 than during the 1996/1997 season. A higher infestation was present on the cultivar Sensation, than on Zill. *Scirtothrips aurantii* was present on the fruit for only a short period during the season and the population was maintained on flush that was present throughout the year.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) has been an important pest of citrus in southern Africa for more than 60 years (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978; Gilbert & Bedford, 1998). *Scirtothrips aurantii* also severely scars young fruit of the mango (*Mangifera indica* L.) (Annecke & Moran, 1982; Brink 1993). Mangoes with lesions are not suitable for the export market. It also causes leaf malformation and stunting of growth.

The biology and habits of *S. aurantii* in citrus orchards in Zimbabwe were described by Hall (1930) while the life cycle on citrus at Rustenburg was described by Bedford (1943). The eggs are laid separately in soft tissue of green fruit and tender leaves and shoots. The newly hatched first instar larva is colourless but becomes yellow before moulting. At maturity most second instar larvae drop to the ground and pupate beneath the trees. The prepupa possesses short wing pads and is a non-feeding developmental stage. The pupa has longer wing pads and is also a non-feeding stage.

The number of generations per year was estimated to be 9.4 in citrus orchards. Numbers were usually highest during the six months from September to February (Gilbert & Bedford, 1998). The population declined from the end of April to the beginning of August due to cooler weather and a diminishing food supply (Wentzel *et al.*, 1978). Although cooler weather lengthens development time, diapause of *S. aurantii* does not occur (Hall 1930, Bedford, 1943). Therefore larvae and adults may be found at any time of the year if suitable feeding areas are available. Populations in citrus trees were closely related to the flushing rhythm of the trees (Stassen & Catling, 1969). In the Mpumalanga Province, flushing of citrus trees and the setting of out of season fruit late in autumn following relatively high rainfall in March and April, allowed large numbers of *S. aurantii* to develop during winter (Gilbert, 1992). The infestation during the following spring was then particularly heavy. Numbers are therefore not always at their lowest in winter, although this is usually the case (Gilbert, 1992). On Reunion Island numbers on citrus increased during the end of the flowering period, maintained high levels until the end of the austral summer period and then began to decrease. No captures were registered from March until the beginning of September (Quilici *et al.*, 1988).

In contrast to citrus very little information is available on the seasonal occurrence of *S.*

aurantii in mango orchards. The aim of the study was therefore to monitor numbers of the different stages in the life cycle of *S. aurantii* in mango orchards throughout the year. Such data on the population fluctuations are essential in developing a better management strategy for *S. aurantii*.

MATERIALS AND METHODS

Site

For a period of one and a half years, *S. aurantii* was sampled using six different methods on the two cultivars, Sensation and Zill. The orchard in which the study was conducted was situated on the Institute for Tropical and Subtropical Crops Friedenheim Experimental Farm (25.27S,30.58E) in the Mpumalanga Province of South Africa. Half of the one hectare orchard consisted of Zill trees while the other half were Sensation trees. As this was a commercially productive orchard, fungicides were sprayed against powdery mildew, anthracnose and bacterial black spot while bait sprays were used against fruit flies (Tephritidae).

Yellow card traps

Yellow card traps were used for monitoring adult *S. aurantii* population levels from October 1995 until February 1997. The traps consisted of non-fluorescent yellow polyvinyl chloride (140mm X 76mm X 0.2mm). These traps and the monitoring system were developed for monitoring *S. aurantii* population levels in citrus orchards (Grout & Richards, 1990). Both sides of the traps were coated with a sticky adhesive, Fly-tac® and were placed 1.5m to 2m above the ground on the northern side of the tree. The card traps were placed on a diagonal across the orchard with one trap in the centre and the other two traps near the opposing corners. Every week traps were changed and wrapped in clear polyethylene plastic wrap. Counting was conducted by using a stereo microscope.

Dispersal /emergence traps

Mature larvae and emerging adults were sampled using dispersal/emergence (D/E) traps. D/E traps were used by Reed & Rich (1975) and Tanigoshi & Monero (1981) for monitoring *Scirtothrips citri* (Moulton). This method was also used by Gilbert (1992) for monitoring *S. aurantii* in citrus orchards. The trap captures mature *S. aurantii* larvae as they drop to the ground to pupate as well as newly emerging adults from the soil. Each trap consisted of a polyvinyl chloride irrigation pipe with a diameter of 130mm and a height of 100mm. The trapping surface was a square glass plate 250mm X 250mm X 3mm placed on top of the pipe. Both sides of the glass plates were covered with a sticky adhesive, Fly-tac®. Three traps per cultivar were placed 300mm from the trunk on the northern side and were changed and moved weekly. After covering the plates with clear polyethylene plastic wrap, counts were made in the laboratory using a stereo microscope.

Fruit counts

For each cultivar ten fruit on each of ten trees were visually inspected and the number of *S. aurantii* larvae and adults present on the fruit recorded. Trees and fruit were randomly chosen. The length of ten randomly chosen fruit was also measured using a calliper. Counting was conducted weekly, commencing during October (1995 and 1996) and continued until harvest.

Emerging larvae on fruit

Ten fruit were picked and brought to the laboratory where they were placed in jars. The number of larvae that emerged from the eggs after a week was counted.

Flower counts

The number of *S. aurantii* occurring in the flowers was determined by shaking ten flowers over a white tray and collecting the thrips with an aspirator. They were placed in a mixture of nine parts of 60% ethyl alcohol and one part acetic acid and later identified in the laboratory. This was conducted weekly from 22 July until 7 October 1996.

Eggs and emergence holes

The eggs and emergence holes on leaves were counted monthly using a stereo microscope. Three young, soft leaves per tree were sampled from 10 trees. Leaves were placed in N,N-dimethylformamide for 72 hours to dissolve the chlorophyll so that the eggs and emergence holes could easily be seen (Du Plessis, M.C., personal communication).

Flushing rhythm

The flushing rhythm of the Zill and Sensation trees was noted. At weekly intervals a square wooden frame (300mm X 300mm) was held against ten randomly chosen trees and the number of new flush points, touching the frame counted.

RESULTS

Yellow card traps

Adult *S. aurantii* were present in high numbers during October to December 1995 on both the cultivars (Fig. 1). The population remained low from May until August 1996 when numbers started to increase to reach a peak during the beginning of November 1996 on both cultivars. The infestation level was higher on Sensation than on Zill, and much higher during October to December in 1995 than during the same period of 1996.

D/E traps

A number of problems were experienced with the use of D/E traps. The top surface of the glass was often covered with fallen flowers and leaves. Weeds and grass in the orchard sometimes stuck to the plate, making if difficult to see the thrips. It was often difficult to see the larvae on the glass plate. In addition, it was not always possible to distinguish between larvae of *S. aurantii* and flower dwelling thrips, such as *Thrips tenellus* Trybom. Similar problems were experienced by Gilbert (1992). Adult *S. aurantii* could be readily distinguished from other species and therefore only the adults, on both sides of the traps, were counted.

As with the yellow card traps, the D/E traps also showed high numbers when monitoring started during 1995 (Fig. 1). In both cultivars high numbers were present during the beginning of October 1995 and January 1996 and thereafter numbers remained low. D/E traps in the Sensation orchard trapped higher numbers of *S. aurantii* than in the Zill orchard, and therefore numbers followed a similar pattern to those on the yellow card traps.

Fruit counts

The *S. aurantii* numbers on the fruit of both Zill and Sensation were much higher during October 1995 than during October 1996 (Fig. 2a). A similar pattern was observed with the yellow card traps and the D/E traps. No *S. aurantii* were recorded on the Zill and Sensation fruit after December for both years. When the peak number of *S. aurantii* was present on the Zill fruit, the average fruit length was 39.16mm and 46.54mm during 1995 and 1996 respectively. For Sensation the comparative figures were 21.81mm and 30.98mm during (Fig. 2c).

Emerging larvae on fruit

The number of larvae emerging from the fruit of both cultivars was much higher during 1996 than during 1997 (Fig. 2b). In the case of Zill fruit, larvae were found to emerge from October until the beginning of November in 1995 and during October in 1996. Larvae appeared from the Sensation fruit from October to November in 1995 and from October to the beginning of December in 1996.

Flower counts

No *S. aurantii* were collected from the flowers. *Thrips tenellus* Trybom and *Thrips acaciae* Trybom were the dominant species in the flowers.

Eggs and emergence holes

In the cultivar Zill, the highest number of eggs and emergence holes on the leaves was observed during November (Fig. 3). None were present during July and August. In Sensation, the highest numbers were found during October to November (Fig. 3). High numbers were also present between May and July. No eggs were present during August.

Flushing rhythm

New growth was present throughout the year in both cultivars (Fig. 4).

DISCUSSION

High numbers of *S. aurantii* were present during October to December and low numbers from May until August. With all trapping methods higher numbers of *S. aurantii* were present from September to December in 1995 compared to the same period in 1996. This was probably due to the higher daily temperatures for the above mentioned months in 1995 (Table 1). Bedford (1943) recorded less economic damage by *S. aurantii* during cooler and wetter seasons in citrus orchards.

The cultivar Sensation maintained higher numbers of *S. aurantii* than Zill. In the former, flowering between trees and among individual branches within a tree, is often conspicuously uneven. Consequently, the time of fruit set and the stage of fruit development at any point in time show pronounced variation (Oosthuyse, 1993). This may explain the higher *S. aurantii* numbers that persisted on Sensation because the insects were constantly provided with fruit that were within their preferred size range (fruit set until fruit were 40 mm in length) for feeding and breeding.

S. aurantii adults and larvae were only present on the young fruit from which larvae emerged during October and November. In controlling *S. aurantii* to prevent scarring of the fruit, the latter period is important and scouting on the fruit is therefore essential from fruit set until the end of November.

New flush was constantly present throughout the year in both cultivars and provided continuous breeding and feeding sites. During the spring *S. aurantii* was found to feed and breed on both the fruit and the flush. Although *S. aurantii* had been collected from the flowers on other occasions it was not found in the flowers during the observation period, possibly due to the low numbers. Numbers present in the mango orchards fluctuated widely between the two seasons and between the cultivars. It is therefore essential that any control programme for *S. aurantii* on mango be based on thorough inspections and monitoring.

ACKNOWLEDGEMENTS

The author thanks Mmes S. Dreyer and M.S. De Beer for assistance in the study. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association.

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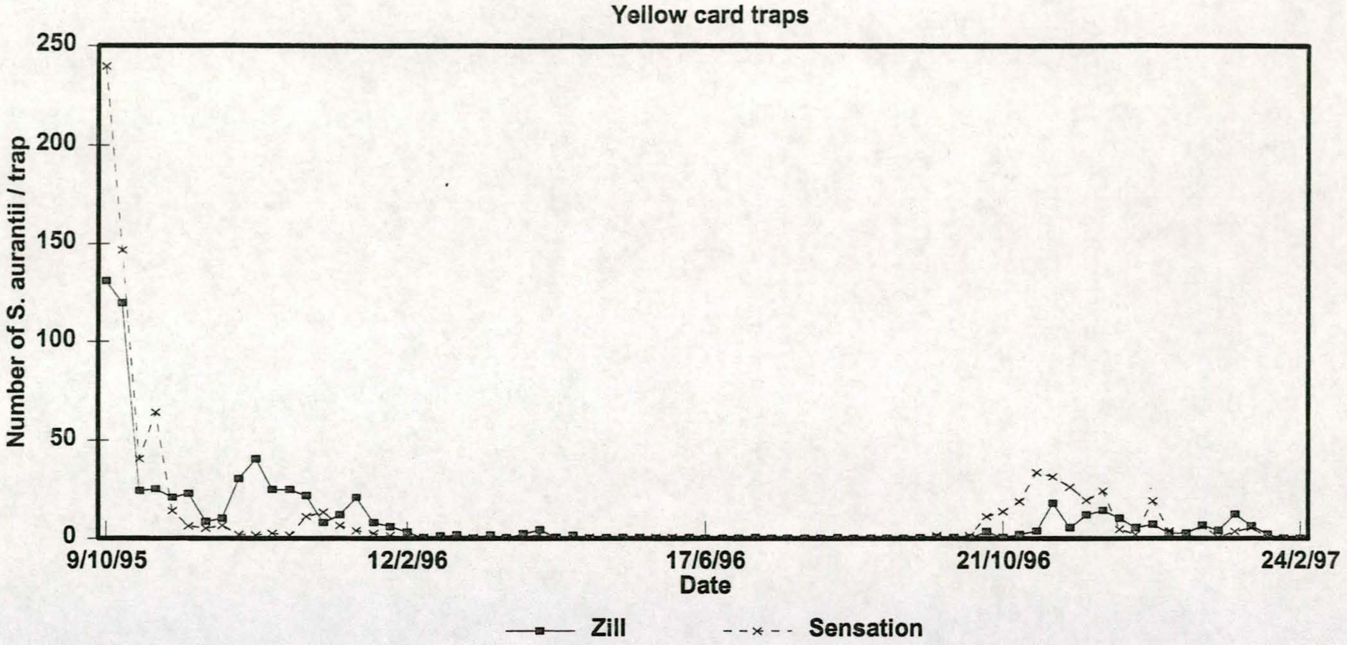
TABLE 1 The average relative humidity and temperatures for Friedenheim

Year	Month	Relative humidity (%)		Temperature (°C)	
		Minimum	Maximum	Minimum	Maximum
1995	July	29.9	89.9	6.1	24.8
	August	29.9	89.5	9.6	25.9
	September	27.9	86.9	12.0	29.0
	October	33.0	89.3	16.5	29.6
	November	47.0	92.9	17.0	27.2
	December	43.3	93.8	16.9	27.9
1996	July	31.9	91.8	6.3	21.5
	August	34.4	89.1	8.7	23.3
	September	28.8	87.4	12.4	28.7
	October	34.1	90.0	15.7	28.8
	November	43.6	95.1	16.8	28.7
	December	49.3	97.1	17.3	27.8



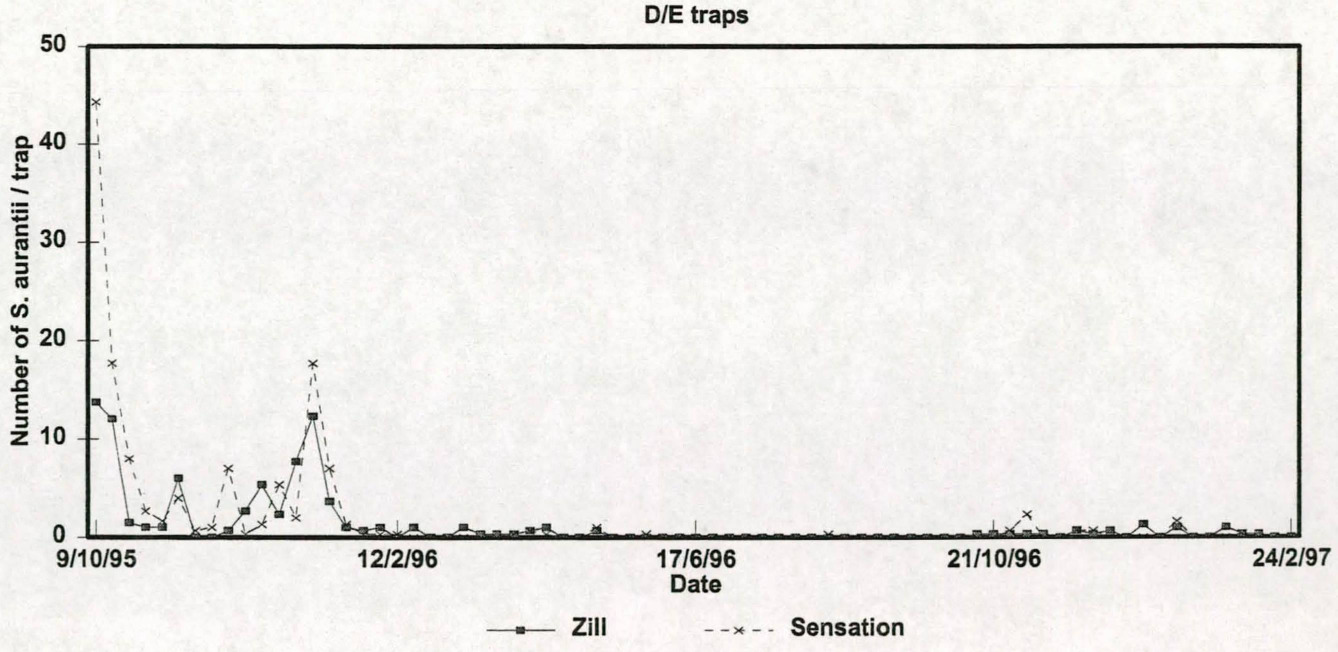


FIGURE 1 The number of adult *Scirtothrips aurantii* recorded on yellow card traps and D/E traps

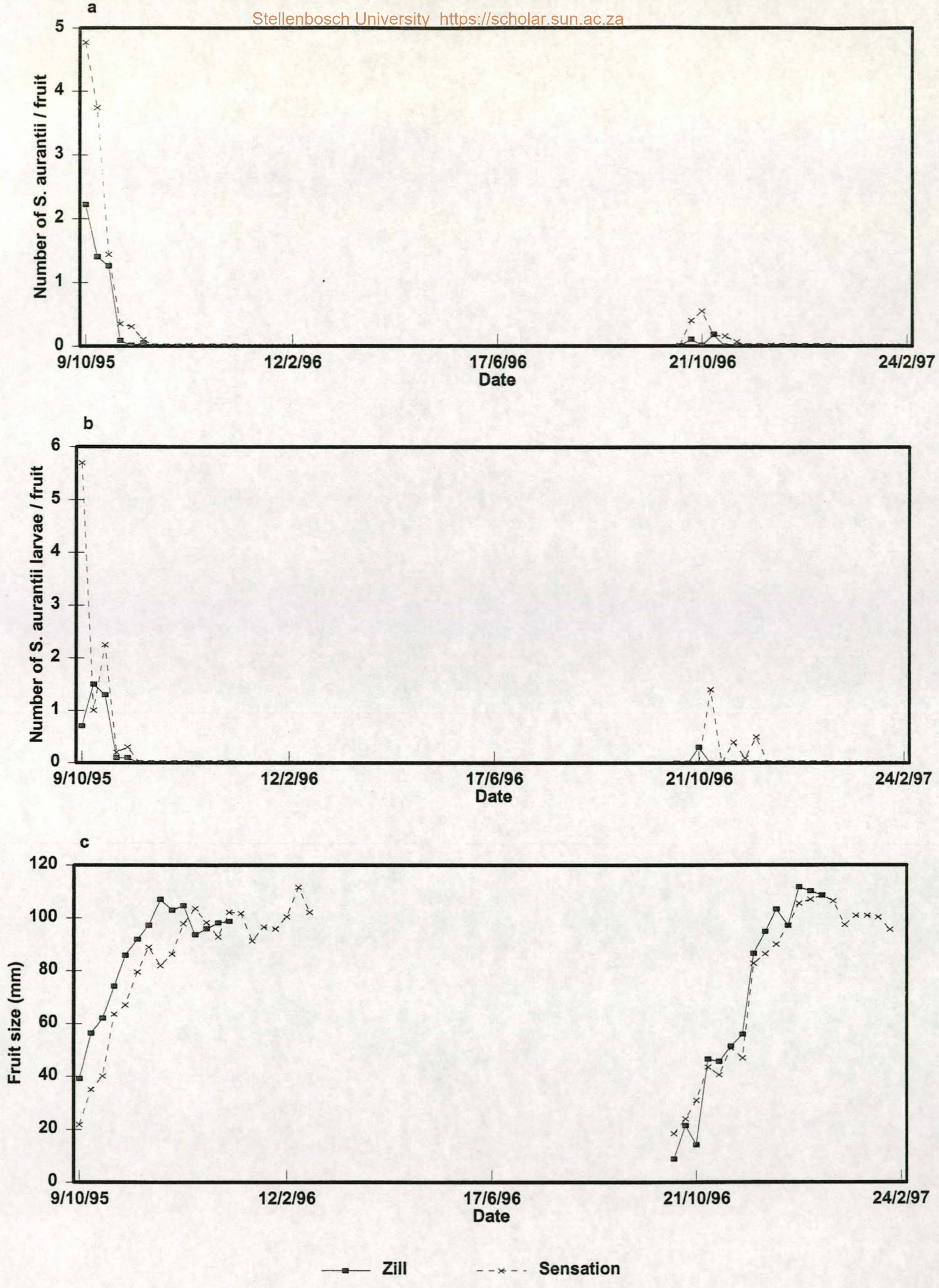
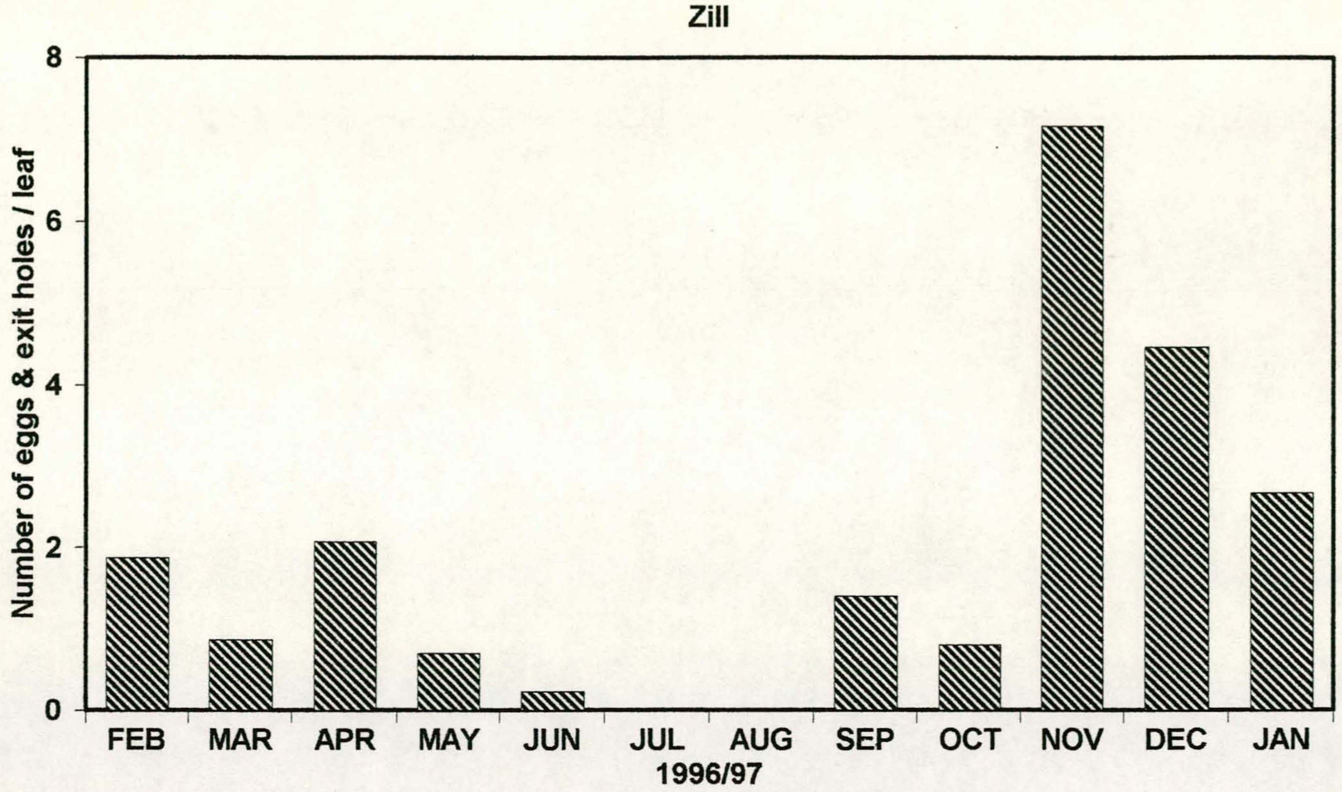


FIGURE 2 a) The number of *Scirtothrips aurantii* adults and larvae on the fruit b) The number of larvae emerging from the fruit c) Fruit size



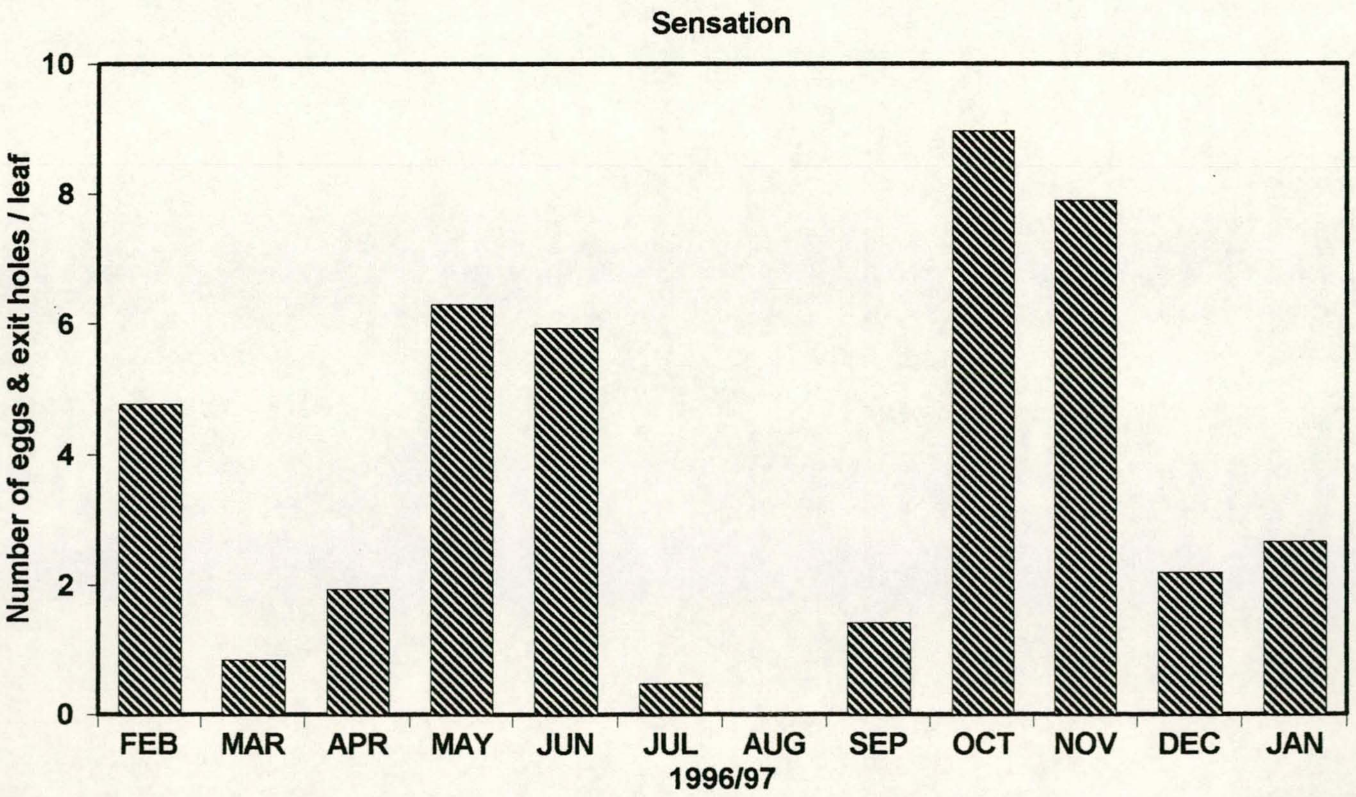


FIGURE 3 The number of *Scirtothrips aurantii* eggs and emergence holes present on the leaves of the cultivars Zill and Sensation

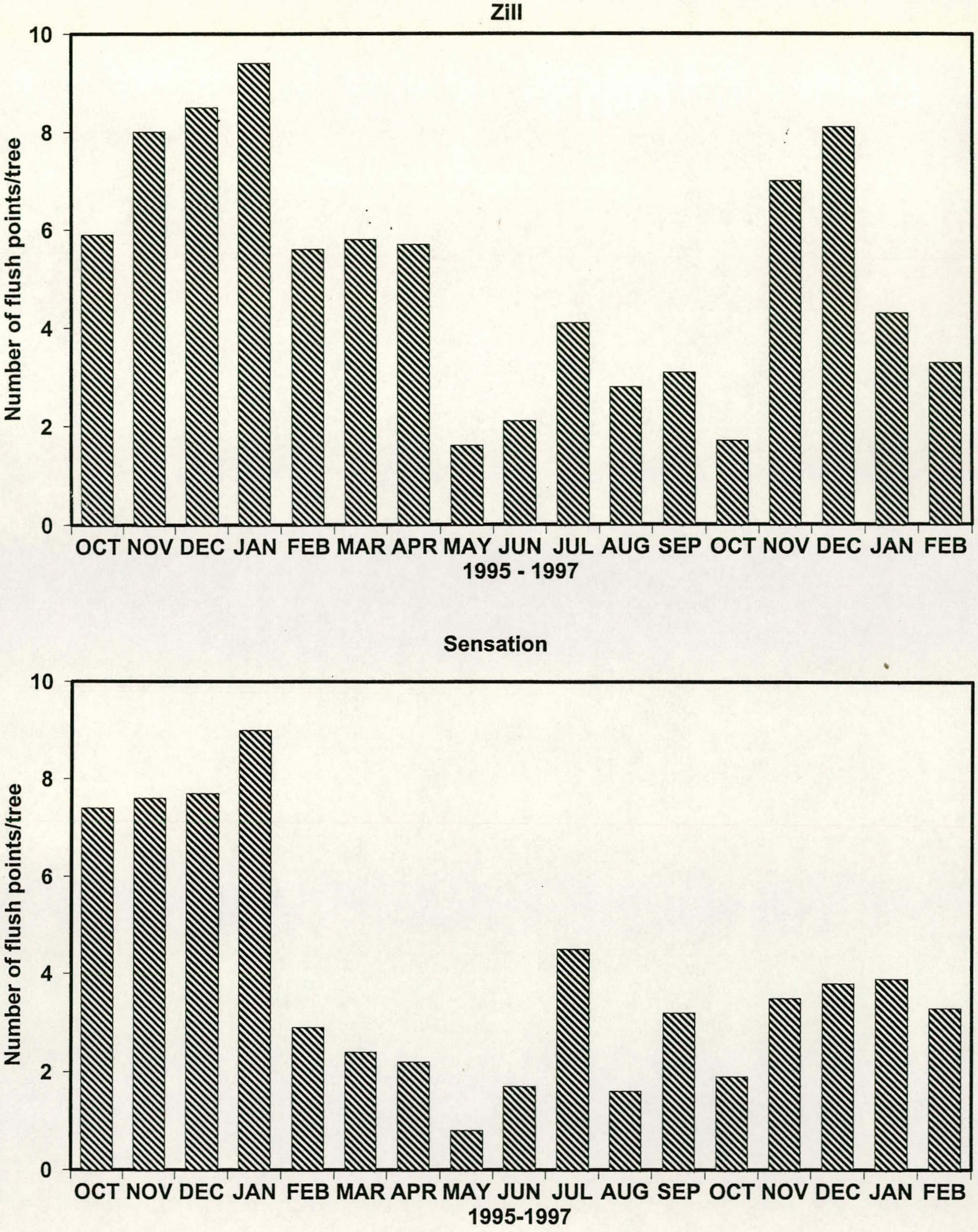


FIGURE 4 The number of flushing points on the cultivars Zill and Sensation

CHAPTER 9

FIELD EVALUATION OF INSECTICIDES FOR THE CONTROL OF CITRUS THRIPS *SCIRTOTHRIPS AURANTII* FAURE (THYSANOPTERA: THRIPIDAE) ON MANGO

ABSTRACT

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) is a pest of mango (*Mangifera indica* L.) causing lesions and rendering the fruit unsuitable for export. Several insecticides were evaluated in the field for the control of *S. aurantii* on mango fruit in the Mpumalanga Province of South Africa. The insecticides tested were formetanate, formetanate plus sugar, tartar emetic plus sugar, methamidophos, sulphur, phenthoate, cypermethrin, fipronil, fenthion, isophenfos and prothiofos and an extract of Syringa [*Melia azedarach* L. (Meliaceae)]. A non-toxic, garlic based insect repellent and feeding depressant was also evaluated. The best control was obtained with formetanate and fipronil. The garlic based substance showed potential, but not the Syringa extract.

INTRODUCTION

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae) is not only an important pest of citrus in southern Africa (Faure, 1929; Hall, 1930; Bedford, 1943; Wentzel *et al.*, 1978), but its status as a pest of mango (*Mangifera indica* L.) has increased over the past years (Brink, 1993). Annecke & Moran (1982) mentioned that *S. aurantii* severely scarred young fruit of the mango. This damage is cosmetic but fruit with lesions are not suitable for the export market. Other problems caused by *S. aurantii* are leaf malformation and stunting of young growth.

Presently, no environmentally safe methods such as biological control or resistant plants are available for the control of *S. aurantii* on mango and it appears that for the foreseeable future producers will have to rely on insecticides to manage thrips numbers. There were no thripicides registered on mango until 1995, when methamidophos 500g/ℓ AL was registered for the control of *S. aurantii* on this crop (Krause *et al.*, 1996). The product is recommended for the control of this insect and aphids on non-bearing and young mango trees up to three years of age. Methamidophos is a systemic pesticide and is applied as an undiluted stem treatment. The dosage rate is dependent on the trunk diameter. Methamidophos will control *S. aurantii* on young flush and limited efficacy is obtained on developing fruit. According to the prescriptions this thripicide must be applied at the first sign of an infestation or damaged young growth, and repeated after a 21 day interval if necessary. There are presently no registered thripicides for control on older bearing mango trees, while there are more than 18 registered insecticides for the control of *S. aurantii* on citrus in South Africa (Krause *et al.*, 1996). The objective of this study was therefore to evaluate different insecticides for the control of *S. aurantii* on mango trees. A non-toxic insect repellent and feeding depressant was also included, as insecticides applied for *S. aurantii* control often interfere with the biological control of other pests.

MATERIALS AND METHODS

Experiment 1

This trial was carried out in a Sensation mango orchard (planted in 1985) at the Institute for Tropical and Subtropical Crops (ITSC) Friedenheim Experimental Farm in the Mpumalanga Province of South Africa. Tree spacing was 10m X 10m. Five different treatments were used and each treatment was applied to five randomly chosen trees. The treatments were:

1. Untreated control.

2. Formetanate 500g/kg SP at 75g/100ℓ water applied, at 6ℓ spray mixture per tree.

3. Formetanate 500g/kg SP at 25g/100ℓ water plus sugar at 200g/100ℓ water, applied at 3ℓ spray mixture per tree.

4. Tartar emetic 995g/kg SP at 200g/100ℓ water plus sugar at 200g/100ℓ water, applied at 2.6ℓ spray mixture per tree.

5. Methamidophos 500g/ℓ AL applied undiluted to the stem - the dosage dependant on the circumference of the stem. The circumference of the stems was between 340 and 480mm and the amount of methamidophos applied between 10 and 17 mℓ. The dosages used were the same as those registered for control of *S. aurantii* on citrus.

All the above insecticides are registered for the control of *S. aurantii* on citrus in South Africa (Krause *et al.*, 1996). The insecticides were applied on 12 October 1993 and, except for methamidophos, reapplied on 19 October 1993 after rain. Methamidophos was not reapplied as this insecticide is absorbed within 72 hours (Buitendag & Naudé, 1992). The insecticides were applied when the average fruit length was 28mm. The water soluble powder (SP) formulations were applied with a knapsack sprayer. Methamidophos was applied by using a paint brush. The number of *S. aurantii* larvae and adults present on the fruit was noted every week from 26 October 1993 until 16 November 1993. Ten fruit per tree were inspected.

Experiment 2

This experiment was conducted in the same orchard as was used for Experiment 1. A randomized block design was used and each treatment was repeated on six single trees. Approximately 9ℓ spray mixture was used per tree. Insecticides were applied on 14 November 1994 using hand guns from a spray tank. The average fruit length at the time of application was 40mm. The treatments were:

1. Untreated control.
2. Formetanate 500g/kg SP at 75g/100ℓ water.
3. Sulphur 800g/kg WP at 300g/100ℓ water.
4. Phenthoate 500g/ℓ EC at 100mℓ/100ℓ water.
5. Cypermethrin 200g/ℓ EC at 15ℓ/100ℓ water.

Sulphur and cypermethrin are also registered for the control of *S. aurantii* on citrus (Krause *et al.*, 1996). Phenthoate is registered on mango for the control of mango scale *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) (Krause *et al.*, 1996). Pre-spray counts were made on 11 November 1994. After the application *S. aurantii* larvae and adults were counted weekly on 20 fruit per tree until 20 December 1994. The number of adult *A. tubercularis* females present on the fruit was also counted before harvest on 20 fruit per tree. This could give an indication of the effect of the insecticide on natural enemies of the scale or on the scale itself.

Experiment 3

This trial was carried out in a mango orchard consisting of different selections (planted in 1983-1987) at the ITSC Nelspruit Experimental Farm in the Mpumalanga Province. Tree spacing was 6m X 3m. A randomized block design was used and each treatment was replicated six times. Approximately 9ℓ spray mixture was used per tree. The average fruit length at the time of application was 5mm. Insecticides were applied on 22 September 1995 using hand guns from a spray tank. Each replicate consisted of five trees. The six treatments evaluated were:

1. Untreated control.
2. Formetanate 500g/kg SP at 75g/100ℓ water.

3. Fipronil 200g/ℓ SC at 7.5mℓ/100ℓ water.

4. Fenthion 960g/ℓ EC at 100mℓ/100ℓ water.

5. Isophenfos 500g/ℓ EC at 100mℓ/100ℓ water.

6. Phenthoate 500g/ℓ EC at 100mℓ/100ℓ water.

Fipronil is also registered for the control of *S. aurantii* on citrus (Krause *et al.*, 1996). Fenthion is registered on mango for the control of mango weevil *Sternochetus mangiferae* (F.) (Coleoptera: Curculionidae) (Krause *et al.*, 1996). The number of *S. aurantii* larvae and adults was determined weekly on the fruit until 9 November 1995. Twenty fruit from the centre of each replicate were inspected. The fruit were also evaluated for the presence of lesions before application and before harvest.

Experiment 4

This experiment was conducted in the same orchard as was used in Experiment 1. A randomized block design was used and each treatment was replicated on five single trees. Approximately 12ℓ spray mixture was used per tree. The insecticides were applied on 11 October 1995 using hand guns from a spray tank. The average fruit length at the time of application was 22mm. The five treatments used were:

1. Untreated control

2. Formetanate 500g/kg SP at 75g/100ℓ water.

3. Formetanate 500g/kg SP at 25g/100ℓ water plus sugar at 200g/100ℓ water.

4. Fipronil 200g/ℓ SC at 7.5mℓ/100ℓ water.

5. Prothiofos 500g/ℓ at 100mℓ/100ℓ water.

Prothiofos is registered for the control of *A. tubercularis* on mango (Krause *et al.*, 1996). Pre-spray counts were made on 10 October 1995. Counts of *S. aurantii* larvae and adults were made weekly on 20 fruit per tree. This continued until 8 November 1995. The number of adult *A. tubercularis* females present on the fruit was also counted before harvest. Ten fruit per tree were inspected.

Experiment 5

The objective of this pilot trial was to test a non-toxic garlic based insect repellent and feeding depressant, Guardian Spray, against *S. aurantii* on mango. The pilot trial was conducted in a 19 year old Fascell orchard on the ITSC Friedenheim Experimental Farm. A high infestation level of *S. aurantii* was present at the commencement of the trial on 28 November 1994. The average fruit length at the time of application was 39mm. A control treatment was compared with Guardian Spray of which one part was diluted with 10 parts of water. The spray mixture was applied using a knapsack sprayer. Ten randomly chosen branches were sprayed and compared with ten control branches. The number of *S. aurantii* present on the fruit was counted before spraying commenced and 7, 14 and 21 days after application.

Experiment 6

A pilot trial was conducted in the same orchard as was used for Experiment 3. Four treatments were used:

1. Untreated control.
2. Syringa [*Melia azedarach* L. (Meliaceae)] 10% extract (10g dried leaves per 100mℓ water).
3. Formetanate 500g/kg SP at 75g/100ℓ water.
4. Sulphur 800g/kg WP at 300g/100ℓ water.

Syringa extract was evaluated as this was thought to have potential for small scale farmers usage. The spray mixtures were applied using a knapsack sprayer. A high infestation level of *S. aurantii* was present at the commencement of the trial on 2 October 1995. The average fruit length was 22mm at application of insecticides. Ten randomly chosen branches were used for each treatment. The number of *S. aurantii* present on the fruit was counted before spraying and thereafter weekly until 17 October 1995.

Statistical analysis

Data for Experiments 1 to 4 and 6 were transformed using log(X + 1) and analysed using an analysis of variance. Mean differences were separated using Fisher's method (Fisher, 1951). The data from Experiment 5 were transformed using log(X+1) and evaluated using a t-test for two independent samples.

RESULTS

Experiment 1

Formetanate, followed by formetanate plus sugar, gave the best control of *S. aurantii* and was more effective than tartar emetic plus sugar, which is also a bait application (Table 1). Numbers of *S. aurantii* in the formetanate plus sugar treatment were less than in the control for two weeks after application while in the tartar emetic plus sugar numbers were less than in the control for only the first week after application. Methamidophos as a stem treatment did not control *S. aurantii* on the fruit. Four weeks after application there were no significant differences between treatments, but the number of *S. aurantii* was lowest in the formetanate treatment. Numbers in the control decreased during the experimental period.

Experiment 2

Numbers of *S. aurantii* did not differ significantly between blocks on 11 November before insecticides were applied (Table 2). All insecticides, except sulphur, gave effective control. Three weeks after application, the lowest number of *S. aurantii* was present in the phenthoate treatment and a week later there were no significant differences between the treatments, including the control. Numbers in the control showed a natural decline. The numbers of *A. tubercularis* in the formetanate and cypermethrin treatments did not increase significantly (Table 3). Thus one application of these compounds did not seem to affect the number of *A. tubercularis*. Phenthoate and sulphur seemed to control the scale as numbers were significantly lower than in the control and the other two treatments (Table 3).

Experiment 3

Before application the number of fruit with lesions did not differ significantly between the treatments, while formetanate and fipronil were the only two treatments which had significantly less fruit with lesions compared to the control prior to harvest (Table 4). The greatest reduction in numbers was also obtained with formetanate and fipronil (Table 5). Four weeks after application, *S. aurantii* numbers on the fruit were still suppressed by formetanate, fipronil and isophenfos (Table 5). Numbers in the fenthion treatment differed from the control until two weeks after application, while phenthoate only suppressed numbers for one week. The *S. aurantii* numbers in the isophenfos treatment differed from the control until four weeks after application.

Experiment 4

The number of *S. aurantii* on the fruit in the various treatments did not differ significantly in the prey-spray counts (Table 6). After spray application, the lowest numbers of *S. aurantii* were present where fipronil had been used, but all the insecticides reduced numbers for the first two weeks. Three and four weeks after application, there were no significant differences between the treatments. Numbers in the control decreased during the experiment. No build up of mango scale was observed in any of the treatments (Table 7).

Experiment 5

Before the application of Guardian Spray the number of *S. aurantii* on the fruit did not differ significantly between treatments (Table 8). The Guardian Spray application suppressed *S. aurantii* for three weeks. Numbers in the control decreased during the experiment.

Experiment 6

The pre-spray counts of *S. aurantii* on the fruit did not differ significantly in the various treatments (Table 9). The Syringa extract and sulphur did not control *S. aurantii* effectively, but formetanate gave good control. The numbers in the control decreased during the experiment and two weeks after application there were no significant differences between the treatments.

DISCUSSION

The experiments showed that several insecticides can provide effective control of *S. aurantii* on mango fruit. However, in selecting a particular insecticide consideration should be given to the possible effects the application could have on the biological control of *S. aurantii*, and the primary and potential secondary pests of mango. The primary pests are fruit flies (*Ceratitis* spp), the mango weevil {*Sternochetus mangiferae* (F.)} and *A. tubercularis*. An exotic parasitoid has recently been released by the ITSC for control of the latter.

One of the insecticides that gave very effective control of *S. aurantii* on mango was formetanate. This product has been shown to be detrimental to predacious mites of *S. aurantii* (Grout *et al.*, 1996a). The higher dosage gave better results than the bait spray with sugar. Tartar emetic plus sugar is currently the product registered against *S. aurantii* on citrus with the least detrimental effect on the natural enemies (Grout *et al.*, 1996b). It is well known that tartar emetic plus sugar cannot control high populations of *S. aurantii* on citrus and that it is also washed off by rain (Georgala, 1982). In the case of mango, a substantial number of *S. aurantii* can be tolerated before damage occurs and therefore control of this insect is by corrective, rather than preventative, treatments. *Scirtothrips aurantii* numbers on mango fruit are usually high by the time of application. For this reason, and the poor control obtained in Experiment 1, tartar emetic plus sugar can not be considered for control on mango. In addition, in Swaziland *S. aurantii* developed tolerance against tartar emetic bait (Grout *et al.*, 1996b).

Methamidophos applied to the stem did not give effective control of *S. aurantii* on the fruit (Table 1) and can therefore only be used for control on young trees as registered. A single application of sulphur was not effective against *S. aurantii* (Tables 2 and 9). Phenthoate, which is registered for the control of *A. tubercularis,* also suppressed *S. aurantii* (Tables 2 and 5). Cypermethrin caused a reduction in *S. aurantii* numbers but since it has a tendency to enhance infestations of mites, scales and mealybugs on citrus, this insecticide is not recommended for use in integrated pest management programmes (Bedford *et al.*, 1992). However, in Experiment 2, no build-up of *A. tubercularis* was observed for 3 months after application. Fipronil proved to be very effective (Tables 4, 5 and 6). This product had no effect on red scale parasitoids in bioassays although it is detrimental to predacious mites and may affect predatory beetles feeding on red scale or other insects (Netterville, 1994). Isophenfos caused a reduction in *S. aurantii* numbers (Table 5) but on citrus sometimes resulted in mite outbreaks (Bedford *et al.*, 1992). Fenthion and the scalicide, prothiofos, also caused a significant reduction in *S. aurantii* numbers for two weeks compared to the control (Tables 5 and 6).

Guardian Spray was found to reduce the number of *S. aurantii* present on the mango fruit for three weeks and therefore has potential in repelling this insect (Table 8). If Guardian Spray is used for total protection of the crop, more sprays would most probably be necessary. This product must be tested on a larger scale before a final conclusion can be drawn. Syringa (10% extract) was not effective in controlling *S. aurantii* (Table 9).

In all experiments, except Experiment 3, *S. aurantii* numbers in the control decreased during the experiments. *S. aurantii* numbers build up and reach a peak when average fruit length is between 2.94mm and 40.33mm and then tend to decrease as fruit size increases (Chapter 6). Lesions on the fruit can be caused from just after fruit set. In Experiment 3 applications were made just after flowering when the fruit length was only 5mm. In this experiment fipronil and formetanate were able to significantly reduce the number of fruit with lesions.

An insecticide should be applied against *S. aurantii* when numbers have reached unacceptable levels. This has been established as 2326 accumulative insect-days on the traps and 24 accumulative insect-days on the fruit for preventing more than 5% culled fruit (Chapter 4). The application should be done in the period after fruit set until fruit is 40mm. If insecticides are applied later in the fruiting period, the population of *S. aurantii* would already have started to decline and application would be superfluous. It seems that one application per season would be sufficient.

In conclusion, formetanate and fipronil were the most effective and useful insecticides for the control of *S. aurantii* on mango fruit. The decision to apply any of these chemicals should be based on regular monitoring which should start just after fruit set and last until the fruit is 40mm in length.

ACKNOWLEDGEMENTS

The author thanks Mmes M.S. De Beer, S. Dreyer and M. Maritz for assistance in the study. This project was funded by the Agricultural Research Council and the South African Mango Growers' Association. Messrs M.C. Welding and A. Toerien for help with the analyses of data.

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TABLE 1 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 1 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). Means followed by the same letter in the columns are not significantly different.

Treatment	**Mean number of *S. aurantii* per fruit**				
	93-10-26	**93-11-02**	**93-11-09**	**93-11-16**	**93-11-23**
Control	8.5600 (0.9438)**a**	1.7000 (0.4084)**a**	1.4400 (0.3799)**ab**	0.9200 (0.2730)**a**	0.0400 (0.0158)**a**
Formetanate	0.0400 (0.0158)**c**	0.0400 (0.0158)**c**	0.3400 (0.1053)**c**	0.2000 (0.0600)**a**	0.0800 (0.0324)**a**
Formetanate & Sugar	0.5000 (0.1602)**c**	0.6400 (0.1851)**bc**	0.7800 (0.2366)**bc**	0.9200 (0.2400)**a**	0.0400 (0.0158)**a**
Tartar emetic & Sugar	4.1400 (0.6804)**b**	1.3000 (0.3438)**ab**	1.9000 (0.4421)**a**	1.1800 (0.2690)**a**	0.2000 (0.0689)**a**
Methamidophos	6.2000 (0.8367)**ab**	2.0200 (0.4372)**a**	1.4000 (0.3593)**ab**	1.5400 (0.2960)**a**	0.2600 (0.0863)**a**
F-value DF	39.07 4; 20	6.38 4; 20	4.79 4; 20	0.94 4; 20	0.89 4; 20
P	0.0001	0.0018	0.0060	0.4624	0.4875

TABLE 2 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 2 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). The first column shows pre-spray counts. Means followed by the same letter in the columns are not significantly different.

Treatment	Mean number of *S. aurantii* per fruit					
	94-11-11	94-11-21	94-11-28	94-12-05	94-12-12	94-12-20
Control	9.2000 (0.8960)a	2.2200 (0.4598)a	0.3500 (0.1091)a	0.2700 (0.0982)a	0.1400 (0.0537)a	0.0400 (0.0175)a
Formetanate	15.3800 (1.1350)a	0.0800 (0.0336)**b**	0.0100 (0.0035)a	0.0300 (0.0106)**b**	0.0200 (0.0071)a	0.0300 (0.0101)a
Sulphur	12.7300 (1.1080)a	2.1700 (0.4882)a	0.1700 (0.0657)a	0.3400 (0.1221)a	0.1100 (0.0434)a	0.0300 (0.0106)a
Phenthoate	14.1300 (1.1110)a	0.1100 (0.0429)**b**	0.0500 (0.0205)a	0.0200 (0.0069)**b**	0.0600 (0.0244)a	0.0800 (0.0322)a
Cypermethrin	8.1300 (0.8730)a	0.1300 (0.0511)**b**	0.0100 (0.0035)a	0.0300 (0.0106)**b**	0.0100 (0.0035)a	0.0200 (0.0071)a
F-value DF	1.25 4; 25	25.71 4; 25	2.49 4; 25	8.60 4; 25	2.63 4; 25	0.82 4; 25
P	0.3139	0.0001	0.0692	0.0002	0.0581	0.5238

TABLE 3 The effect of the insecticides applied against *Aulacaspis tubercularis* on mango in experiment 2 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). Means followed by the same letter in the columns are not significantly different.

Treatment	**Number of *A. tubercularis* per fruit**
Control	0.9200 (0.2686)**a**
Formetanate	1.4300 (0.3569)**a**
Sulphur	0.3400 (0.1157)**b**
Phenthoate	0.0800 (0.0305)**b**
Cypermethrin	0.8200 (0.2574)**a**
F-value DF	9.04 4; 25
P	0.0001

TABLE 4 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 3 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). Means followed by the same letter in the columns are not significantly different.

Treatment	Number of fruit with lesions	
	Before application	Before harvest
Control	5.830 (0.736)a	31.670 (1.475)a
Formetanate	5.830 (0.822)a	2.500 (0.201)b
Fipronil	5.000 (0.607)a	3.330 (0.433)b
Fenthion	8.330 (0.834)a	27.500 (1.368)a
Isophenfos	5.000 (0.504)a	16.670 (1.165)a
Phenthoate	6.670 (0.653)a	17.500 (1.061)a
F-value DF	0.49 5; 30	8.96 5; 30
P	0.7789	0.0001

TABLE 5 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 3 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X + 1). Means followed by the same letter in the columns are not significantly different.

Treatment	**Mean number of *S. aurantii* per fruit**				
	95-9-29	**95-10-6**	**95-10-13**	**95-10-20**	**95-10-27**
Control	0.8100 (0.2109)**a**	2.1300 (0.4486)**a**	1.5000 (0.3391)**a**	0.9500 (0.2699)**ab**	0.1500 (0.0592)**a**
Formetanate	0.0000 (0.0000)**b**	0.0000 (0.0000)**c**	0.0300 (0.0106)**c**	0.0000 (0.0000)**d**	0.0000 (0.0000)**a**
Fipronil	0.0200 (0.0071)**b**	0.0400 (0.0175)**bc**	0.0500 (0.0207)**c**	0.0100 (0.0035)**d**	0.0200 (0.0069)**a**
Fenthion	0.0200 (0.0071)**b**	1.0800 (0.2074)**b**	1.0100 (0.2206)**ab**	1.2900 (0.3465)**a**	0.1500 (0.0565)**a**
Isophenfos	0.0200 (0.0071)**b**	0.1000 (0.0411)**bc**	0.1400 (0.0534)**bc**	0.3800 (0.1312)**c**	0.0800 (0.0329)**a**
Phenthoate	0.0100 (0.0035)**b**	0.4600 (0.1430)**a**	0.4500 (0.1480)**bc**	0.6800 (0.2123)**bc**	0.2300 (0.0828)**a**
F-value	5.25	6.34	4.03	12.38	2.33
DF	5; 30	5; 30	5; 30	5; 30	5; 30
P	0.0014	0.0004	0.0064	0.0001	0.0667

TABLE 6 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 4 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). The first column shows pre-spray counts. Means followed by the same letter in the columns are not significantly different.

Treatment	Mean number of *S. aurantii* per fruit				
	95-10-10	95-10-18	95-10-26	95-11-01	95-11-08
Control	8.3400 (0.9590)a	7.6700 (0.8790)a	1.3300 (0.3368)a	1.0800 (0.2762)a	0.3300 (0.1171)a
Formetanate	6.5600 (0.8120)a	0.1700 (0.0640)b	0.1100 (0.0444)b	0.3500 (0.1297)a	0.1100 (0.0445)a
Formetanate & Sugar	8.3600 (0.9000)a	1.3800 (0.2450)b	0.2100 (0.0744)b	0.4500 (0.1400)a	0.2700 (0.0909)a
Fipronil	6.4400 (0.8010)a	0.3900 (0.1250)b	0.0300 (0.0125)b	0.0800 (0.0326)a	0.0400 (0.0158)a
Prothiofos	9.6700 (0.9720)a	1.0000 (0.2890)b	0.3400 (0.1191)b	0.7400 (0.2023)a	0.2900 (0.1074)a
F-value DF	0.48 4; 20	12.34 4; 20	8.00 4; 20	1.88 4; 20	1.82 4; 20
P	0.7499	0.0001	0.0005	0.1536	0.1654

TABLE 7 The effect of the insecticides applied against *Aulacaspis tubercularis* on mango in experiment 4 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). Means followed by the same letter in the columns are not significantly different.

Treatment	**Number of *A. tubercularis* per fruit**
Control	4.100 (0.665)a
Formetanate	3.900 (0.641)a
Formetanate plus sugar	3.500 (0.599)a
Fipronil	4.660 (0.694)a
Prothiofos	2.020 (0.402)a
F-value DF	0.97 4; 20
P	0.4436

TABLE 8 Efficacy of Guardian Spray applied gainst *Scirtothrips aurantii* on mango in experiment 5 (DF = degrees of freedom, P = significance level). Figures in brackets are transformed to log(X + 1). The first column shows pre-spray counts. Means followed by the same letter in the columns are not significantly different.

Treatment	Mean number of *S. aurantii* per fruit			
	94-11-28	94-12-05	94-12-12	94-12-19
Control	3.8217 (0.6113)**a**	3.2951 (0.6068)**a**	1.2500 (0.2794)**a**	2.0418 (0.0836)**a**
Guardian Spray	3.7470 (0.6450)**a**	0.2733 (0.0924)**b**	0.0416 (0.0020)**b**	0.2222 (0.0132)**b**
DF	16	15	10	9
P	0.7420	0.0001	0.0067	0.0134

TABLE 9 Efficacy of the insecticides applied against *Scirtothrips aurantii* on mango in experiment 6 (DF = degrees of freedom for F-distribution, P = significance level for F-distribution). Figures in brackets are transformed to log(X+1). The first column shows pre-spray counts. Means followed by the same letter in the columns are not significantly different.

Treatment	Mean number of *S. aurantii* per fruit		
	95-10-02	95-10-09	95-10-17
Control	2.4983 (0.3690)**a**	1.5350 (0.2702)**a**	0.8333 (0.1999)**a**
Formetanate	2.2267 (0.4420)**a**	0.0000 (0.000)**b**	0.07143 (0.0252)**a**
Sulphur	2.8452 (0.4690)**a**	0.31667 (0.0972)**ab**	0.3125 (0.0874)**a**
Syringa extract	1.3900 (0.2850)**a**	0.6167 (0.1544)**ab**	0.3571 (0.1112)**a**
F-value DF	0.93 3; 27	3.25 3; 27	1.32 3; 19
P	0.4390	0.0373	0.2980

CONCLUSION

The overall objective of the study was to contribute towards the management of thrips in mango orchards. The research therefore focussed on the basic requirements for the development of a pest management programme, i.e. damage assessment, monitoring methods, the economic threshold, the biology of the pest organism and control methods. As a first step the Thysanoptera species found in association with the mango were identified. Of the 15 species identified, 11 belonged to the family Thripidae and the other four to the family Phlaeothripidae. The only two species found to cause lesions on the fruit were the citrus thrips, *Scirtothrips aurantii* Faure and the red banded thrips, *Selenothrips rubrocinctus* (Giard). *S. rubrocinctus* were usually found in low numbers and did not seem to be of economic importance. *Scirtothrips aurantii* was abundant on new growth, causing stunting of growth and leaf malformation and was the most economically important thrips species on the mango. The only two predatory thrips that were identified were *Aleurodothrips fasciapennis* (Franklin) and *Haplothrips bedfordi* Jacot-Guillarmod. The western flower thrips, *Frankliniella occidentalis* (Pergande) was collected for the first time on mango in South Africa. Although it was only found at Letsitele, it may expand its range as it is a recent introduction and it remains to be seen whether this species can cause the same kind of damage observed in Israel. *Thrips acaciae* Trybom, *Thrips tenellus* Trybom and *S. aurantii* were the most abundant in the flowers. The abundance of thrips species in the flowers varied from year to year.

The lesions on the fruit caused by *S. aurantii* tended to decrease in prominence as the fruit matured, however, badly marked fruit did not recover to the extent that it was acceptable for export.

It was found that *S. aurantii* could be monitored by using coloured sticky traps. Adults responded the best to yellow traps, followed by green traps while lower numbers were caught on red, blue and white traps. While searching for feeding or egg laying sites, flying insects receive various cues which stimulate or inhibit their behaviour. The colour of the substrate probably plays an important role in this regard. *Scirtothrips aurantii* must find succulent growth and small fruit where it can feed and lay eggs and the above results indicate that *S. aurantii* is attracted to the green-yellow region of the electromagnetic spectrum. The study confirmed that trap colour was important for effective monitoring and showed that yellow traps could be used effectively for assessing population activity of *S. aurantii* in mango orchards.

A positive relationship existed between the cumulative insect-days computed for *S. aurantii* on the traps and the percentage cull ($Y=0+0.002150X$). There was also a positive relationship between the cumulative insect-days computed on the fruit and the percentage cull ($Y = 0+0.209772X$). When mango fruit is packed for export, fruit with larger lesions is not accepted. To keep the percentage fruit with lesions at a 5% level, producers should introduce chemical control when the number of *S. aurantii* on the traps exceeds 2326 cumulative insect-days or when numbers on the fruit exceed 24 cumulative insect-days.

It is common practice to scout 100 mango fruit per orchard for *S. aurantii* but to achieve a sampling precision of D = 14%, which is an acceptable level, it was found that a sample of 5 fruit from 10 trees (50 fruit) was sufficient to establish the size of *S. aurantii* populations in mango orchards.

Hoerl's function ($Y = aX^{b}e^{cX}$) was used to describe the relationship between the number of *S. aurantii* on the fruit and fruit size, as well the number on the traps and fruit size. A noticeable feature in the population dynamics of *S. aurantii* is the rapid decline in numbers after the population peak had been reached. This occurred whether orchards were sprayed with fenthion or not, and whether peak numbers were high or low. The skin of the mango fruit also gets thicker as it expands and it may also be that the fruit becomes too tough for the mouthparts and the ovipositor to penetrate with the result that *S. aurantii* may move to the young leaves. The fruit size where the maximum number of *S. aurantii* was present on the fruit ranged from 20.22mm to 40.33mm, while at the maximum numbers on the traps it ranged from 2.94mm to 36.82mm. Therefore, it is essential to monitor thrips in mango orchards from fruit set until the fruit is at least 40 mm in length so that scarring of the fruit can be prevented by an emergency spray in time.

Generally, *S. aurantii* numbers started to build up during August or September, which is the end of the flowering period, and reached a peak during October or November when small fruit were present on the trees. Low numbers were present from June until August. Variation in *S. aurantii* numbers was observed in the same orchard from season to season. Numbers of *S. aurantii* are therefore highly unpredictable from year to year and therefore can be classified as a sporadic pest of the mango. Monitoring is thus essential for decisions on control measures. The highest *S. aurantii* numbers were observed on the cultivar Sensation.

Scirtothrips aurantii was present on the fruit for only a short period during the season and the population was maintained on flush that was present throughout the year. *Scirtothrips aurantii* adults and larvae were only present on the young fruit and larvae emerged from the fruit during October and November. In controlling *S. aurantii* to prevent scarring of the fruit, the latter period is important.

Various insecticides were tested for control of *S. aurantii* on mango fruit. The insecticides tested were formetanate, formetanate plus sugar, tartar emetic plus sugar, methamidophos, sulphur, phenthoate, cypermethrin, fipronil, fenthion, isophenfos and prothiofos and an extract of Syringa [*Melia azedarach* L. (Meliaceae)]. A non-toxic, garlic based insect repellent and feeding depressant was also evaluated. The experiments showed that several insecticides can provide effective control of *S. aurantii* on mango fruit. However in selecting a particular insecticide consideration should be given to the possible effects the application could have on beneficial organisms found on mangoes. Phenthoate and prothiofos which are registered for the control of mango scale, *Aulacaspis tubercularis* Newstead and fenthion which is registered for the control mango weevil, *Sternochetus magiferae* (F.) caused a significant reduction in *S. aurantii* numbers. Guardian Spray was found to reduce the number of *S. aurantii* present on the mango fruit for three weeks and therefore has potential in repelling this insect, while Syringa (10% extract) was not effective. If Guardian Spray is used for total protection of the crop, more than one spray would most probably be necessary during the season. This product must be tested on a larger scale before a final conclusion can be drawn. Overall, formetanate and fipronil were the most effective and useful insecticides for the control of *S. aurantii* on mango fruit. The decision to apply any of these chemicals should be based on regular monitoring which should start just after fruit set and last until the fruit is 40mm in length. It seems that one application per season would be sufficient.

In this study, the complex of thrips species was identified. The correlation between *S. aurantii* numbers and fruit damage was determined. A monitoring system was developed. The stage of fruit development susceptible to *S. aurantii* damage was assessed. The seasonal abundance of *S. aurantii* in mango orchards was determined. Different insecticides were tested for control of *S. aurantii* in mango orchards. This study contributed towards the knowledge of thrips in mango orchards and provides producers with new information to manage thrips in mango orchards. Therefore, the overall objective of this study was met. In future, more insecticides which can be used in integrated management should be tested. The biological control agents of *S. aurantii* on mango and their contribution towards controlling the pest should be investigated.