# Developing an attractant for monitoring fruit-feeding moths in citrus orchards

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# *Abstract*

Fruit-piercing moths are a sporadic pest of citrus, especially in the Eastern Cape Province of South Africa, where the adults can cause significant damage in outbreak years. Currently the only way in which to successfully control fruit-feeding moths within the orchards is the use of repellent lights. However, growers confuse fruit-piercing moths with fruit-sucking moths that don't cause primary damage, and there is no way of monitoring which moth species are attacking the fruit in the orchards during the night. In a previous study, banana was shown to be the most attractive bait for a variety of fruit-feeding moth species. Therefore the aim of this study was to determine the population dynamics of fruit-feeding moths develop a cost-effective alternative to the use of fresh banana as a bait for fruit-piercing moths. Fresh banana was compared to nine alternative synthetic attractants, frozen banana and a control under field conditions in several orchards in the Eastern Cape Province. Once again, banana was shown to be the most attractive bait. Some 23 species of fruit-feeding moth species were sampled in the traps, but there was only two fruit-piercing species, *Serrodes partita* (Fabricius) (Lepidoptera: Noctuidae) and *Eudocima* sp. Surprisingly *S. partita*, which was thought to be the main pest, comprised only 6.9% of trap catches. *Serrodes partita*, is a sporadic pest, only becoming problematic every five to 10 years after good rainfall in the Little Karoo region that causes flushes of their larval host, wild plum, *Pappea capensis* (Ecklon & Zeyher). During these outbreaks, damage to fruit can range from 70 to 90% and this is especially so for soft skinned citrus. A study on the morphology of the proboscis confirmed that only two species of fruit-piercing moths were present. Trap catches over three citrus growing seasons was linked to fruit damage found within several orchards. Once again fruit-piercing moth damage was relatively low in comparison to other types of damage such as mechanical and undefined damage. There was a very weak correlation between *S. partita* trap catches and damage, but generally damage was recorded two to three weeks after a peak in *S. partita* trap catches. Climatic conditions were also recorded and compared to weekly trap catches of *S. partita*, and while temperature and wind direction had no influence on moth populations, precipitation in the orchards was weakly correlated with trap catches. This study has shown that in non-outbreak seasons, the main fruit-piercing moth, *S. partita* comprises a small percentage of fruit-feeding moths in citrus orchards, but that growers are unable to determine the difference between fruit-piercing species and the harmless fruit-sucking species. Further fresh banana remains the best method for attracting fruit-piecing moths to traps, but this is not cost effective and thus a commercially viable protocol for monitoring these species remains elusive.

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# Chapter 1

# GENERAL INTRODUCTION

Fruit-feeding moths feed on a variety of tropical and deciduous fruit throughout the world. In South Africa, fruit-feeding moths are commonly recorded pests on citrus and this is especially so for soft skinned citrus such as Satsuma and other Mandarins (Johannsmeier 1998). There are two main groups of fruit-feeding moths: fruit-piercing moths which cause direct damage to the fruit and fruit-sucking moths, which can only feed on damaged fruit (Moore 2010; Zaspel 2008; Hattori 1969). Fruit-piercing moths cause significant damage to the fruit by inserting the proboscis into the skin to get to the juice within and the puncture allows access for micro-organisms, such as fungi, which cause internal fruit decay making the fruit unmarketable for farmers (Johannsmeier 1998). In this study, the population dynamics of fruit-feeding moths in citrus was determined and a baiting protocol for monitoring populations of these moths, or for an attract and kill control system was investigated.

## 1.1 Citrus in South Africa

### 1.1.1 Citrus production and export

Citrus trees were first introduced into South Africa in 1654, by the Dutch East India Company, at the Cape of Good Hope (Neumark 1938). Since then, the Southern African citrus industry has expanded, with about of 64,510 ha of citrus grown, scattered over seven of the nine provinces, Swaziland and Zimbabwe (CGA annual report 2015; CGA Key Industry Statistics 2015), with each region under the influence of different climatic and soil conditions. There are approximately 20 million citrus trees in the Republic of South Africa (Fig. 1.1) (CGA annual report 2015; CGA Key Industry Statistics 2015).

The major citrus producing areas in South Africa are located in Limpopo (26,960 ha), Mpumalanga (5,255 ha) and the Eastern Cape (16,752 ha) and Western Cape (10,214 ha). The remaining citrus producing areas comprise the Northern Cape (1,122 ha), Kwa-Zulu

Natal (2,119 ha), Swaziland (1,068 ha), Zimbabwe (784 ha) and North West (236 ha) (Fig. 1.1) (CGA annual report 2015; CGA Key Industry Statistics 2015).

Climatic conditions naturally vary considerably in the different citrus areas and even within each area. As a result, different cultivars are grown in each region, which become available at different times of the year. Furthermore, this accounts for the restricted distribution of some of the pests which are more sensitive to extremes of temperature and humidity. The Western and Eastern Cape provinces are located in cooler climatic zones where production is focused on Navel oranges, lemons and easy peeling Mandarin varieties, such as Clementines and Satsumas, whereas in Limpopo, Kwa-Zulu Natal and Mpumalanga provinces, climatic conditions are much warmer, favouring the production of grapefruit and Valencia oranges (Fig. 1.1) (CGA annual report 2014; CGA Key Industry Statistics 2014).

Exporters of citrus from South Africa, Mozambique, Swaziland and Zimbabwe produced an export revenue of ±R11.2 billion ($970 million) in 2014 (CGA annual report 2014; CGA Key Industry Statistics 2014). Although exports only represents 70% of production, they account for 85-90% of total industry income. The remaining fruit is sold to local markets (22%) or sent for processing (8%). There are 10 major export regions with the largest being Northern Europe (19%), followed by the Middle East (18%), Far East (15%), UK (14%), Russia (12%), Asia (7%), Canada (4%), Mediterranean (3%), USA (2%), Southern Europe (2%) and other (4%) (CGA annual report 2014; CGA Key Industry Statistics 2014).

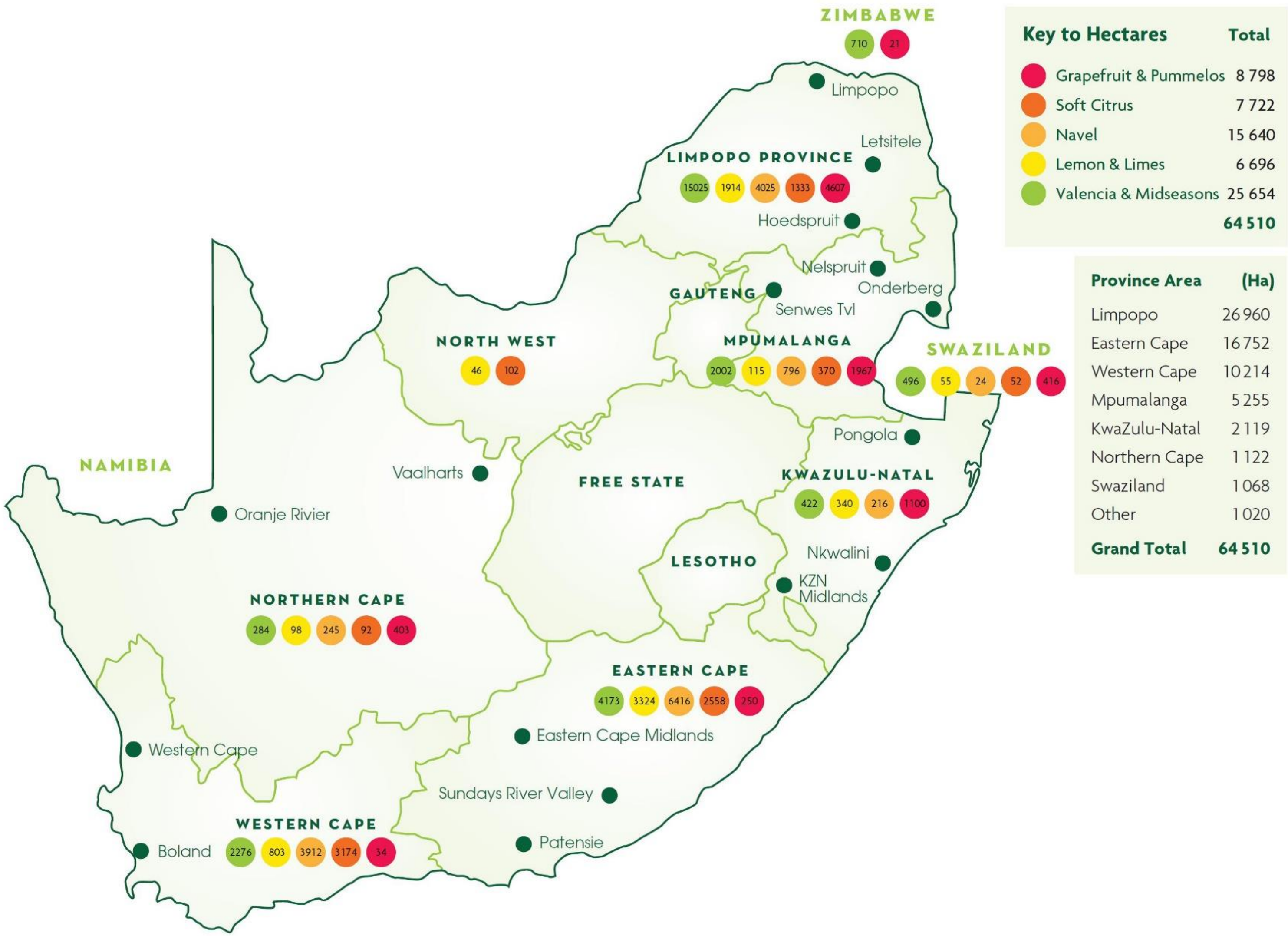


**Figure 1.1:** The citrus producing regions throughout South Africa, showing the number of hectares dedicated to the production of various citrus cultivars (Map: CGA annual report 2015).

### 1.1.2 Citrus pests: General overview

In 1895, C.P. Lounsbury was appointed the first Government Entomologist of the Colony of the Cape of Good Hope. Up until then there was no full time government employee to attend general insect matters. Therefore, he became the first applied entomologist in South Africa and the first economic entomologist to take an interest in biological control (Bedford 1998).

Since 1895, there have been approximately 100 different species of citrus pests identified (Table 1.1), and classified as either being a major or minor pest throughout South African citrus regions. Most of the pest species found throughout South Africa also occur in neighbouring countries such as Swaziland, Mozambique and Zimbabwe, while many also occur in Angola (Bedford 1998). In 1987, a key to the important citrus pest species was compiled and illustrated, providing growers with the means to identify these pests, according to the frequency of their attacks and the damage types caused on fruit and trees (Smith & Péna 2002).

Each separate growing region throughout South Africa has its own set of major and minor pests, differing in importance according to whether chemical insecticides are used, or whether an integrated spray programme is employed (Bedford 1998). However, the demarcation of pests in different areas and their varying importance is mainly a result of climatic differences, particularly temperature and humidity (Smith & Péna 2002). Citrus pests are generally more numerous and more difficult to control in the hotter low-lying regions such as the Lowveld of Limpopo Province and Mpumalanga, which includes Letaba, Letsitele, Malelane and Komatipoort, as well as in northern Kwa-Zulu Natal. Bedford (1998) also mentions that in other regions such as Citrusdal, Western Cape Province, there are a very few economical pests that justify regular control measures, due to the extremes of temperature from summer to winter.

**Table 1.1**: Insect pests of citrus in Southern Africa (Grout & Moore 2015).

| | | | |
|---|---|---|---|
| | | **CLASS INSECTA** | |
| **Family** | **Common name** | **Scientific Name** | **Feeds on** |
| | | ORDER ORTHOPTERA | |
| Pyrgomorphidae | Bush stick locust | *Phymateus leprosus* (Fabricius) | **L, Tw** |
| | Elegant grasshopper | *Zonocerus elegans* (Thunberg) | **L, Tw** |
| | | ORDER HEMIPTERA | |
| Coreidae | Large black tip wilter | *Anoplocnemis curvipes* Fabricius | **Tw** |
| Pentatomidae | Anestia bug | *Antestiopsis Thunbergii* (Gmelin) | **F, Fr** |
| | Green vegetable bug | *Nezara viridula* (Linnaeus) | **Fr** |
| Flatidae | | *Decipha* sp. | **Fr, L** |
| Cicadellidae | Green citrus leafhopper | *Empoasca distinguenda* Paoli | **Fr, L** |
| | | *Epignoma natalensis* Dworakowska | **Fr, L** |
| | Citrus Leafhopper | *Penthimiola bella* (Stål) | **Fr, L** |
| Triozidae | Citrus triozid | *Trioza erytreae* (Del Guercio) | **L, V** |
| Aleyrodidae | Spiny blackfly | *Aleurocanthus spiniferus* (Quaintance) | **L** |
| | | *Aleurocanthus zizyphi* Priesner & Hosny | **L** |
| | Citrus blackfly | *Aleurocanthus woglumi* Ashby | **L** |
| | Woolly whitefly | *Aleorothrixus floccosus* (Maskell) | **L** |
| Aphididae | Cotton aphid | *Aphis gossypii* Glover | **L, Tw, V** |
| | Spirea aphid | *Aphis spiraerola* Patch | **L, Tw** |
| | Brown citrus aphid | *Toxoptera aurantii* (Boyer de Fonscolombe) | **L, Tw** |
| | Black citrus aphid | *Toxoptera citricidus* (Kirkaldy) | **L, Tw, V** |
| Diaspididae | Red scale | *Aonidiella aurantii (Maskrell)* | **Br, Fr, L, Tw** |
| | Oleander scale | *Aspidiotus nerii* Bouche | **Br** |
| | Circular purple scale | *Chrysomphalus aonidum* (Linnaeus) | **Fr, L** |
| | Pinnule scale | *Chrysomphalus Pinnuler* (Maskell) | **L** |
| | Black thread scale | *Ischnaspis longirosrtis* (Signoret) | **L** |
| | Citrus mussel scale | *Lepidosaphes beckii* (Newman) | **Br, Fr, L, Tw** |
| | Long mussel scale | *Lepidosaphes gloverii* (Packard) | **Br, Fr, L, Tw** |
| Coccidae | White was scale | *Ceroplastes brevicauda* Hall | **L, Tw** |
| | Citrus wax scale | *Ceroplastes destructor* Newstead | **L, Tw** |
| | | *Coccus celatus* De Lotto | **L** |
| | Brown soft scale | *Coccus hesperidum* Linneaus | **Fr, L** |
| | Heart-shaped scale | *Protopulvinaria pyriformis* (Cockerell) | **L** |
| | White powdery scale | *Pseudocribrolecanium andersoni* (Newstead) | **L** |
| | Green soft scale | *Pulvinaria aethiopica* (De Lotto) | **L, Tw** |
| | Black scale | *Saissetia oleae* (Oliver) | **Fr, L, Tw** |
| Monophlebidae | Cottony cushion scale | *Icerya purchasi* Maskell | **L, Tw, Br** |

| CLASS INSECTA | | | |
|---|---|---|---|
| **Family** | **Common name** | **Scientific Name** | **Feeds on** |
| Pseudococcidae | | *Delottococcus aberiae* (De Lotto) | **Fr, L, Tw** |
| | Striped mealybug | *Ferrisia virgata* (Cockerell) | **Fr, L, Tw** |
| | Karoo thorn mealybug | *Nipaecoccus viridis* (Newstead) | **Fr, L, Tw** |
| | Oleander mealybug | *Paracoccus burnerea* (Brain) | **Fr, L, Tw** |
| | Citrus mealybug | *Planococcus citri* (Risso) | **Fr, L, Tw** |
| | Citrophilus mealybug | *Pseudococcus calceolariae* (Maskell) | **Fr, L, Tw** |
| | Long-tailed mealybug | *Pseudococcus longidpinud* (Targioni Tozzetti) | **Fr, L, Tw** |
| ORDER THYSANOPTERA | | | |
| Thripidae | Greenhouse thrips | *Heliothrips haemorrhoidalis* (Bouché) | **L, Fr** |
| | Citrus thrips | *Scirtothrips aurantii* Faure | **L, Fr** |
| ORDER COLEOPTERA | | | |
| Chrysomelidae | Blue-green citrus nibbler | *Colasposoma fulgidum* Lefévre | **L, F, Fr** |
| Curculionidae | Fuller's rose beetle | *Pantomorus cervina* (Boheman) | **L, R, Fr** |
| ORDER DIPTERA | | | |
| Tephritidae | Asian fruit fly | *Bactrocera dorsalis* Drew, Tsuruta & White | **Fr** |
| | Mediterranean fruit fly | *Ceratitis capitata* (Wiedemann) | **Fr** |
| | Natal fruit fly | *Ceratitis rosa* Karsch | **Fr** |
| ORDER LEPIDOPTERA | | | |
| Tortricidae | Citrus leaf roller | *Christoneura occidentalis* (Walsingham) | **Fr, L** |
| | False codling moth | *Thaumatotibia leucotreta* (Meyrick) | **Fr** |
| | Apple leaf roller | *Lozotaenia capensana* (Walker) | **Fr, L** |
| Gracillariidae | Citrus leaf miner | *Phyllocnisitis citrella* Stainton | **L, Tw** |
| Praydidae | Citrus flower moth | *Prays citri* (Milliére) | **F, Fr** |
| Pyralidae | Carob moth | *Ectomyelois ceratoniae* (Zellar) | **Fr** |
| Geometridae | Citrus looper | *Ascotis reciprocaria* (Walker) | **F, Fr** |
| Noctuidae | Fruit-sucking moth | *Achaea lienardi* (de Boisduval) | **Fr** |
| | African bollworm | *Helicoverpa armigera* (Hübner) | **F, Fr, L** |
| | Fruit-piercing moth | *Serrodes partita* (Fabricius) | **Fr** |
| Papilionidae | Citrus swallowtail | *Papilio demodocus* Esper | **L** |
| | Green-banded swallowtail | *Papilio nireus lyaeus* Doubeday | **L** |
| | Mocker swallowtail | *Pailio dardanus cenea* Stoll | **L** |
| ORDER HYMENOPTERA | | | |
| Formicidae | Pugnacious ant | *Anoplolepis custodiens* (Smith) | |
| | Brown house ant | *Pheidole megacephala* (Fabricius) | |

**Br** = branches; **F** = Flowers; **Fr** = Fruit; **L** = Leaves; **R** = Roots; **Tw** = Twigs; **V** = Disease vector

### 1.1.3 Control of citrus pests

The control of citrus pests can be done in a variety of ways. Considerable progress has been achieved during recent decades towards understanding the biology of the various pest species, so control can be achieved more successfully by targeting the pest at the most appropriate times (Bedford 1998). Prior to 1948, control focused mainly on the use of chemical pesticides such as DDT and HCN (Wilson & Goldsmid 1962; Smit 1937). The majority of chemicals used were harmful as they persisted in the field and were detrimental to humans, vertebrates and, importantly, beneficial insects (Wilson & Goldsmid 1962). However, these chemicals were replaced with organophosphates (OPs), which later were also discovered to be detrimental to the environment (Bedford 1968, 1998). Although the pest pressure usually decreases considerably when more potent insecticides were used, continued use often lead to the development of resistance by the pest and secondary pest repercussions (Bedford 1968, 1998). As a result, farmers and citrus technologists were forced to look for alternative strategies to control citrus pests. Integrated pest management (IPM) therefore became an important philosophy in pest control and its implementation is important to ensure the survival of beneficial natural enemies for biological control of pests (Bedford 1968, 1998).

IPM can essentially be described as the use of a variety of control techniques which can be considered safe for beneficial invertebrates or other pests which are under biological control, but detrimental to the pest population (Bedford 1998). The end goal of IPM is not to eliminate the pest population, but to bring it below a predetermined economic threshold. Below this threshold, damage caused by the pest is no longer of economic importance (Smith & Péna 2002; Bedford 1998).

For all methods of controlling a pest, monitoring is regarded as one of the most essential components. Monitoring allows for the determination of pest levels and enables economic thresholds to be established (Johannsmeier 1998). It allows farmers to time applications to coincide with the life cycles of pest species. This results in better control and reduces the unnecessary use and overuse of control techniques (Smith & Péna 2002). There are currently no monitoring protocols for fruit-feeding moths, the topic of this thesis.

## 1.2 Fruit-feeding moths

### 1.2.1 Categories of fruit-feeding moths

In South Africa, there are approximately 30 species of noctuid moths which have been recorded as feeding on a variety of tropical and deciduous fruit as adults (Bedford 1998; Johannsmeier 1998). With better understanding of fruit-feeding moth morphology, with emphasis on the proboscis, it was discovered in 1922 that there were two main groups of these moths, namely fruit-piercing moths and fruit-sucking moths (Johannsmeier 1998; Jack 1922). These are the only groups of moths where the adults, rather than larvae, cause the damage to the fruit (Robinson *et al.* 2012; Moore 2010; Zaspel 2008; Johannsmeier 1998; Hattori 1969).

Fruit-piercing moths have specially adapted proboscises which allow the moths to cause direct damage to the fruit. They have the ability to perforate the rind and pulp in order to access the juice, as a result of homologous proboscis modifications (Robinson *et al.* 2012; Moore 2010; Zaspel 2008; Johannsmeier 1998). Fruit-sucking moths can only feed on fruit that is already damaged, lacking the stronger and more barbed proboscis of the fruit-piercing moths and thus unable to pierce the rind (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; see Chapter 3). Therefore, fruit-sucking moths are only able to access the juice if the rind has already been pierced by a fruit-piercing moth or damaged by other means (Moore 2010; Zaspel 2008; Hattori 1969).

The punctures caused by fruit-piercing moths also create access for micro-organisms, especially fungi, which start internal fruit decay before outward signs appear (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). Johannsmeier (1976) showed a correlation between proboscis structure and ability to pierce intact fruit, testing fruit feeding moths' ability to penetrate the rind or flesh of fruit with varying hardiness and studied the morphology of their proboscises. A relatively small portion of the fruit-feeding moths are known to be fruit-piecing moths while the majority are fruit-sucking moths.

Unlike other lepidopteran pest species, where the larvae cause the damage to the fruit, fruit-feeding moth adults cause the damage to the fruit, and the larvae feed on alternative, usually native hosts (Moore 2010; Johannsmeier 1998). The larvae of the fruit-piercing moth

*Serrodes partita* (Fabricius) (Family: Noctuidae) feed on a diverse range of plants, mainly on the wild plum, *Pappea capensis* (Ecklon & Zeyher) in the Little Karoo (Moore 2010; Johannsmeier 1998; Pinhey 1975), where the adults migrate to the orchards to feed on fruit (Moore 2010; Johannsmeier 1998).

Migratory fruit-piercing and fruit-sucking moths have an acute sense of smell, being able to detect ripening fruit over a distance of 10 km, especially downwind from orchards, temporarily invading orchards along the way and damaging fruit, only to disappear again after a few days (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). In peach orchards in the Western Cape, *S. partita*, were observed feeding on the leeward side of the orchards, where they did significant damage to the fruit on the trees, with the centre trees seldom being affected (Johannsmeier 1976; 1998).

Fruit-feeding moths have been observed to hide in vegetation near to the orchards during the day, where it was shown that less than 5% of marked *S. partita* returned to the same orchard on subsequent nights (Moore 2010; Johannsmeier 1998; Whitehead & Rust 1971). Three *Achaea* spp. and *Sphingomorpha chlorea* (Cramer) fruit-sucking moths, showed a similar relationship to *S. partita* as only 7.6% returned to the same orchards the next night (Johannsmeier 1998).

### 1.2.2 Fruit-piercing moths

There are only 10 species of fruit-piercing moth reported in Southern Africa and in the genera *Eudocima* (=*Othreis*), *Oraesia* (formerly *Calpe*), *Serrodes*, *Egybolis* and *Pericyma* (Moore 2010; Johannsmeier 1998). *Serrodes partita* is regarded as the main fruit piercer in the Eastern and Western Cape, feeding on a variety of tropical and deciduous fruit (Johannsmeier 1998; Pinhey 1975).

Fruit-piercing moths are present in small numbers in orchards, mostly causing negligible damage to citrus and other fruits. Outbreaks of economic importance rarely occur and are almost impossible to predict (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). Weather conditions which favour growth of larval host plants (e.g. *Pappea capensis*, *Acacia* sp., *Jasminum* sp. (Pinhey 1975)), such as good rainfall in bush-veld regions, are associated with large-scale invasion of moths into orchards (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; Whitehead & Rust 1971).

Although mass movements of fruit-piercing moths have been observed on occasion in different countries and long distance migration has been assumed, no definitive research relating to migration of fruit-piercing moths has been undertaken (Moore 2010; Johannsmeier 1998). However, studies of noctuid moths, viz. *Spodoptera* and *Pseudaletia* spp. (army worms) and *Agrotis* spp. (cutworms), some of which were marked, show that they migrate well beyond 1000 km within a few nights under favourable weather, especially windy conditions (Johannsmeier 1998). The ability of fruit-piercing moths to migrate large distances in a single night, allows them to find food. Fruit-piercing moths have to regularly feed, as Johannsmeier (1976) observed that frequent feeding with intervals of not more than three days is essential for survival.

### 1.2.3 Fruit-sucking moths

The many other secondary fruit-piercing species are known as fruit-sucking moths, which are unable to penetrate the intact skin of even soft, ripe peaches (Johannsmeier 1998). They do, however, utilize holes previously punctured through the skin of fruit by piercing moth species (Moore 2010), thereby increasing the unseen damage beneath the skin, or feed on soft, ripe fruit that has been damaged by birds, hail or mechanical damage (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). The better known fruit-sucking moths include the following genera: *Achaea*, *Anomis*, *Cyligramma*, *Grammodes*, *Helicoverpa*, *Ophiusa*, *Parallelia*, *Sphingomorpha* and *Ulotichopus*. *Achaea lienardi* (Biosduval) in Southern Africa, is regarded as the most common fruit-sucking moth on citrus as it has been recorded in thousands in orchards during outbreak years (Grout & Moore 2015; Moore 2010; Johannsmeier 1998; Pinhey 1975).

### 1.2.4 Economic importance

Damage due to fruit feeding moths was reported at 15-70% in the Eastern Cape, South Africa in 1925 but as much as 75% of the annual citrus crop on the Gold Coast in West Africa during the same year (Johannsmeier 1998; Box 1942; Gunn 1929). In 1962, there was considerable damage to the citrus crop and more particularly to Navel oranges in Limpopo, with *Oraesia (= Eudocima) provocans* (Walker) being the main pest (Johannsmeier 1998). In one particular orchard in the vicinity of Tzaneen the damage was so serious, that the grower was advised not to pick the crop, to avoid picking and transport costs (Bedford 1998; Johannsmeier 1998).

As fruit-piercing moth outbreaks are not recorded every year, records are scarce, but during 1987 in the Sundays River Valley growing region, *S. partita* activity on Satsumas was described as "sporadic" (Johannsmeier 1998); more than 100 fruit were recorded to have dropped per tree per week due to the feeding activities of the moths in some cases (Johannsmeier 1998). Historically, *S. partita* has caused substantial damage to crops in the Eastern Cape Province (Robinson *et al.* 2012; Johannsmeier 1998). Outbreaks of *S. partita* occur every five to 10 years with the most recent being in 2009 (Robinson *et al.* 2012; Moore 2010). These outbreaks cause major yield losses, especially to soft skin citrus like the Satsuma Mandarins as the fruit ripens early, coinciding with the outbreak period (Robinson *et al.* 2012; Moore 2010). In more recent years, pre-harvest losses to Satsuma Mandarins have been recorded at 20% in Sundays River Valley, 50% near Uitenhage and 50% at Knysna (Robinson *et al*. 2012; Moore 2010).

### 1.2.5 Control of fruit-feeding moths

In most cases fruit-feeding moths were controlled with baits of poisoned fruit, a method used widely in South Africa and tropical regions of West Africa in the past (Gunn 1929). These baits, however, killed few fruit-piercing moths (Johannsmeier 1998). Research entered a new phase during the 1960s when work was done on peach crops in the South-Western Cape, where migratory *S. partita* ravaged the fruit (Johannsmeier 1998; Kriegler 1957). Lead researchers investigated the life cycle, behaviour, damage patterns and control of fruit-piercing moths, and were able to successfully apply light barriers around peach orchards as a control method, a procedure which had first been advocated in Japan (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; Johannsmeier 1998; Kriegler 1957).

# 1.3 *Serrodes partita*

## 1.3.1 Nomenclature

*Serrodes partita* (Fabricius), commonly known as the Catapult Moth, is the most important fruit-piercing moth in this genus (Fig. 1.2) (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; Pinhey 1975). This moth is migratory, robust and a strong flying. It is a citrus piercer, where it has been recorded in different regions of Africa and India as a pest. Furthermore, in the Eastern Cape of South Africa this moth has been recorded as a serious pest of different kinds of citrus, especially soft skinned citrus (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). *Serrodes partita* has been known by a few other names: *Noctua inara* Cramer, 1779 (India); *Serrodes campona* Guenée, 1852; *Serrodes nigha* Guenée, 1852; *Ophiusa basisgnum* Walker, 1858; *Phoberia korana* Felder and Rogenhofer, 1874 (Pinhey 1975).

## 1.3.2 Biology

The forewing of this moth is pale brown or grey-brown with three black spots forming a thin broken V or triangular shape near the base of the forewing (Moore 2010; Johannsmeier 1998; Pinhey 1975). It has a straight postmedial line on the forewing and the hindwing is a pale yellowish-brown. The tooth on the outer margin of the forewing is often not very noticeable (Pinhey 1975). The forewing length is 25-28 mm long. The '*Serrodes'* seems to originate from Serra, meaning a saw. There are close relatives in central and tropical Africa (Pinhey 1975).

**Figure 1.2**: A *Serrodes partita* adult sampled during the 2013 sampling season.

The larva of the moth is a humped semi-looper, nocturnal, grey to brown or greyish-green to dirty brown, dotted with black and has a pre-anal dorsal tubercle (Fig. 1.3 A and B) (Taylor 1951). The larvae grow to a length of 30-55 mm and build a pupal case under the soil surface, closely woven with sediment. The pupa is a dull black (Fig. 1.3 C and D).

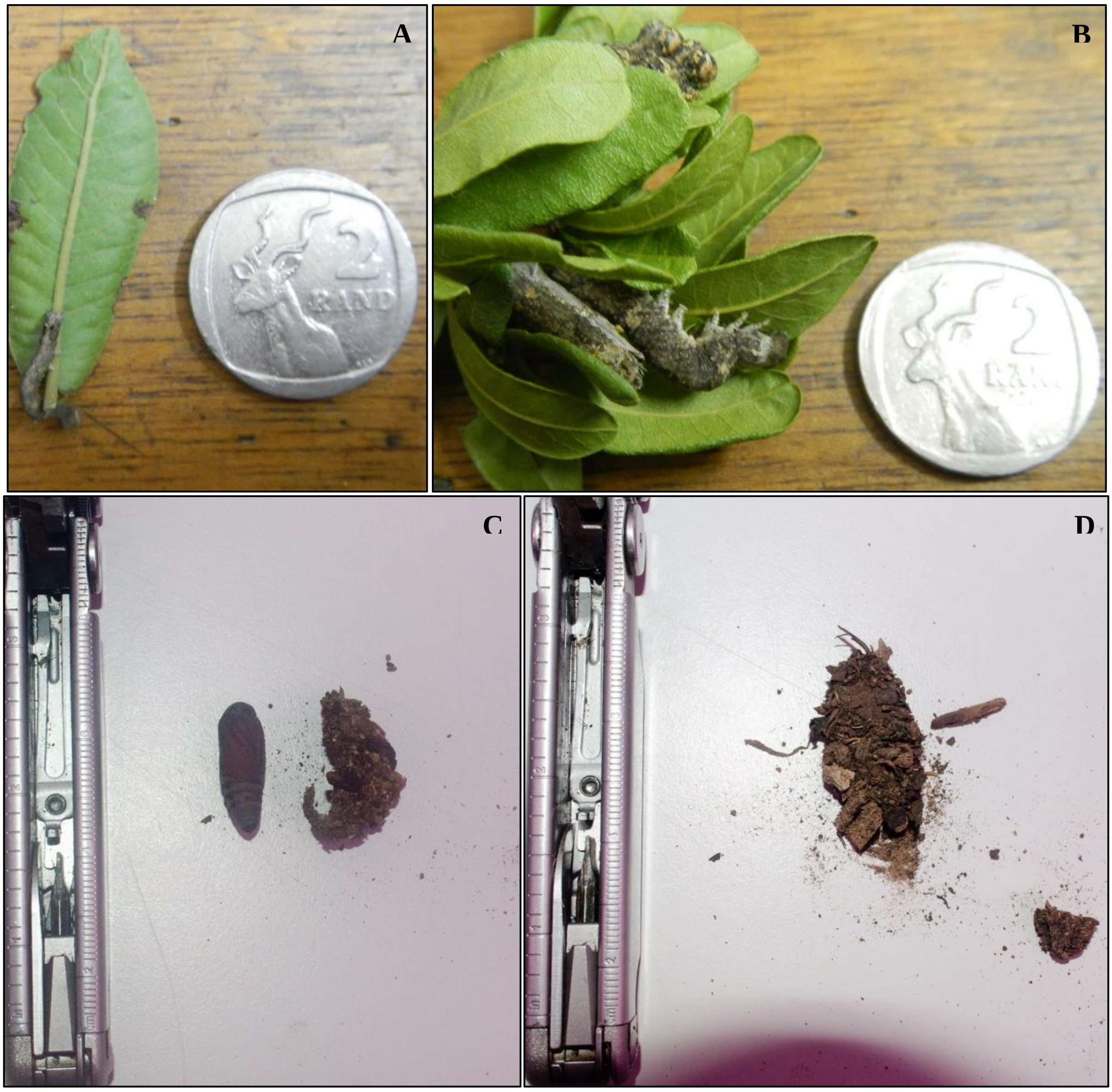


**Figure 1.3**: The larvae (A and B) and pupae (C and D) of *Serrodes partita* from the laboratory culture started during the 2015 sampling season.

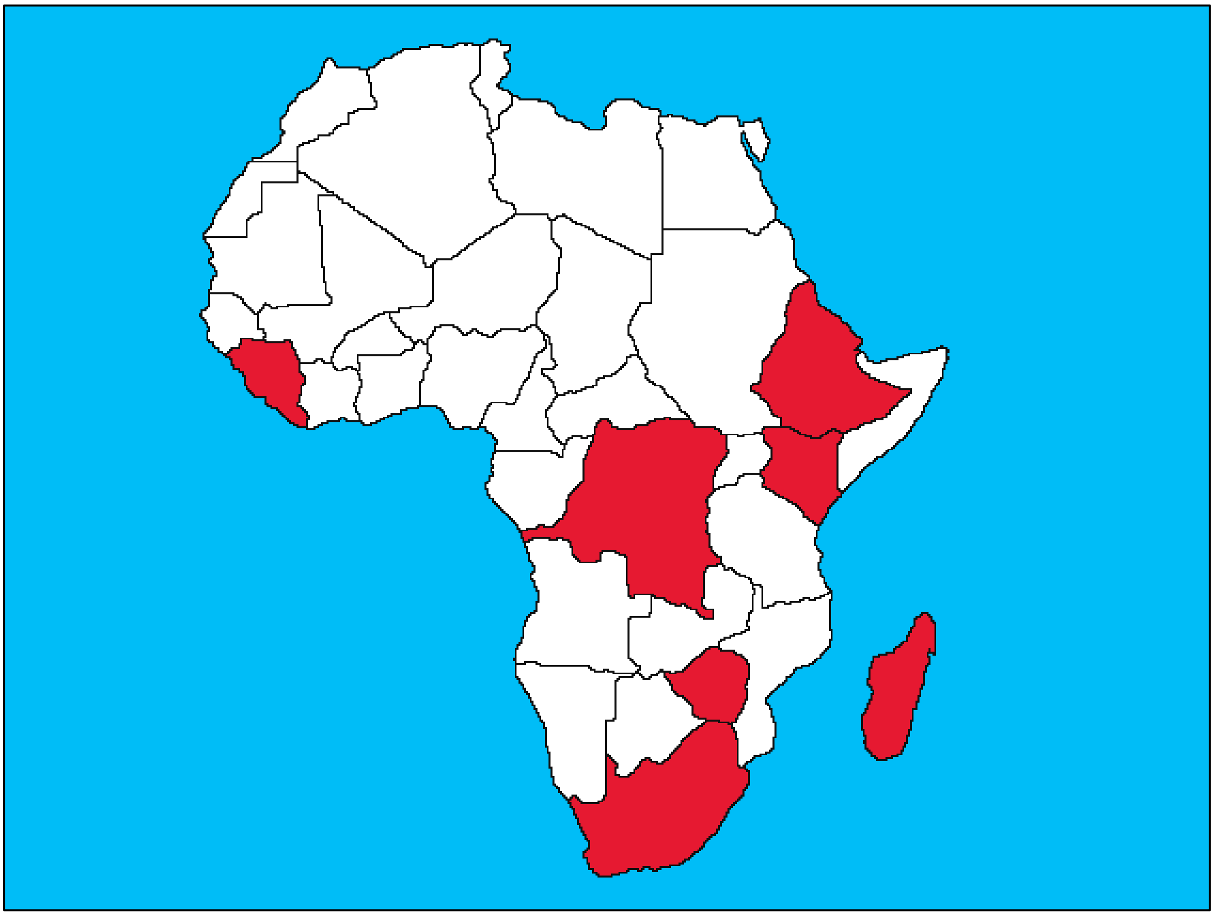

**Figure 1.4**: The geographical distribution of *Serrodes partita* in Africa. Red filled countries indicate the presence of *Serrodes partita* (http://www.africanmoths.com/index.html).

### 1.3.3 Distribution and host range

*Serrodes partita* occurs throughout the greater part of Southern Africa, where its main host, 'wild plum', *Pappea capensis* (Ecklon & Zeyher) occurs in the Little Karroo. The adult moths migrate into the orchards during the night and feed on the fruit. The moth also occurs across most of the Ethiopian region (Fig. 1.4) and has been recorded throughout Asia and into Australia (Pinhey, 1975). The larvae have also been recorded feeding on, *Deinbollia oblongifolia* (E.May & Ex Arn.) Radlkofera), *Acacia sp.*, *Deinbollia pinnata* (Poiret) Schumacher & Thonning), *Eucalyptus globulus* (Labillardiére), *Grewia occidentalis* (Linnaeus), *Jasminum sp.*, *Leptospermum laevigatum* (Gaertner) Mueller) (Johannsemier 1998; Rust & Myburgh 1986; Pinhey 1975).

### 1.3.4 Life history

*Serrodes partita* takes a total of 83-91 days under natural conditions to go from egg to adult (Neubecker 1962; Tayler 1951). The adult moths lay eggs singly on the foliage of the host plant. The eggs take two to three days to hatch. The larvae are nocturnal and feed almost exclusively on the foliage of *P. capensis,* taking 51-58 days from hatching through 7 instars. The larvae pupate in the soil, where they make a pupal case from sand and dead leaves (Fig. 1.3). The adult ecloses after an average of 20-33 days. The adult life span is an average of 56 days (Neubecker 1962; Kriegler 1957; Tayler 1951).

### 1.3.5 Economic importance and threshold

Large summer outbreaks of *S. partita* in the Little Karoo and South-Western Cape occur every 5-10 years after an effective rainfall of 50-70 mm, which induces the larval host plant to produce a flush of young foliage (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). Two months later, millions of moths migrate up to 500 km to damage fruit orchards of the South-Western Cape (Rust & Myburgh 1986). A trap catch of 1000 *S. partita* moths per data trees represent an outbreak or heavy infestation, whereas a medium to light infestation would yield 50-100 moths per 40 data trees (Robinson *et al.* 2012; Johannsmeier 1998).

In other regions of South Africa and in other countries where fruit-piercing moths are a problem, several different species are present at any one time, with the non-piercing moths dominating (Johannsmeier 1998). Determining the economic threshold and population densities of piercing moths under such conditions and with other kinds of fruit, is difficult. The usual method of counting moths at night with a torch can nevertheless be employed, particularly if the survey is restricted to piercing moths (Robinson *et al.* 2012; Johannsmeier 1998).

For citrus fruit it is suggested that, besides evening surveys of moths, ripe fruit should be sampled in the orchard to determine the extent of injury before control measures are considered. Injury to fruit by piercing moths may be detected by visual inspection or by squeezing the fruit to force the juice out of the punctures, or watching for bubbles coming out of the fruit that has been placed in hot water (Robinson *et al.* 2012; Rust & Myburgh, 1986; Johannsmeier 1998).

### 1.3.6 Control measures

#### 1.3.6.1 Chemical control

Gunn traps were the classic method for controlling fruit-feeding moths within orchards. These traps were paraffin tins that were baited with either treacle or brown sugar syrup, and mixed with a poison, either lead arsenate or sodium arsenite (Gunn 1929). The traps were then cut open on two sides and hung in trees. The bait was shown to be more attractive if ripe, fermenting fruit was mixed with the syrup (Johannsmeier 1998; Gunn 1929). Although used successfully in the Eastern Cape, mainly against the fruit-sucking moth *A. lienardi*, the same method or modification of the traps was employed elsewhere, where there was little or no success in controlling fruit-piercing moths (Johannsmeier 1998).

Fruit-feeding moths were shown to be repelled by DDT and OPs on peaches and by Bordeaux mixture (a mixture of copper (II) sulphate ($CuSO_4$) and slaked lime ($Ca(OH)_2$) used as a fungicide) on grapes (Johannsmeier 1998; Kriegler 1957). In laboratory conditions *O. provocans* fed on peaches sprayed with systemic insecticides, where they died only if they fed on poisoned fruit for three days. Farmers were warned not to spray ripe fruit with insecticides to kill fruit-piercing moths, as it takes less than a minute for the moths to pierce the fruit. Furthermore, no insecticide would kill the moths within this short period while they fed, and each night a new wave of moths fed in orchards (Johannsmeier 1998; Whitehead & Rust 1971).

#### 1.3.6.2 Traps and barriers

Noctuid moths have been shown to be strongly attracted to ultra-violet lights, whereas they are less attracted to and repelled by incandescent lights which are in the green-yellow spectrum. The use of repellent light against fruit-piercing moths in South Africa was first used in the 1960s (Johannsmeier 1998; Whitehead & Rust 1967, 1971, 1972). Incandescent light, falls in the 500-600 nm wavelength range; this wavelength range is assumed to induce daylight resting conditions and inactivates most noctuid moths at night. There are three types of lights, mercury vapour lamps, yellow incandescent lamps and paraffin pressure lamps. All the lights reduced *S. partita* moth activity by 50-90% (Whitehead & Rust 1967). This depended on whether one or two sides of the orchard were illuminated or how heavy the infestation was. The moths are not easily disturbed once feeding, therefore it is important to keep the lights on from before dark until midnight (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; Rust & Myburgh 1986).

#### 1.3.6.3 Biological control

Natural enemies of the larvae include, bacterial and viral diseases, or parasitoid wasps and a tachinid fly (Swart *et al.* 1975*;* Myburgh *et al.* 1973). Parasitism by the tachinid fly in outbreak years has been recorded to be as high as 80%. However, parasitism by the tachinid fly only reaches this level when the host, *S. partita*, reach high densities. Under conditions of low *S. partita* larval densities, parasitism has been shown to be less than 1% (Johannsmeier 1998; Myburgh *et al.* 1973).

Bats have been recorded catching fruit-piercing moths at night (Johannsmeier 1976). Furthermore, bats flying past trees abundant with fruit feeding moths, have caused the moths to scatter out of trees simultaneously in an obvious alarm reaction, as the tympanic organ of noctuid moths is sensitive to ultrasonic pulses emitted by insectivorous bats (Johannsmeier 1998).

#### 1.3.6.4 Cultural control

Fruit-piercing moths have a strong attraction to the scent of ripe and decaying fruit over long distances. Regular orchard sanitation is regarded as an essential part of keeping fruit-piercing moths at low numbers within the orchards. When citrus fruit can be picked earlier, it should be practised, because the greener the fruit the less attractive it is to the moth (Robinson *et al.* 2012; Johannsmeier 1998).

## 1.4 *Achaea lienardi*

### 1.4.1 Nomenclature

*Achaea lienardi* (Biosduval), commonly known as Lienard's Achaea, belongs to a large genus within the noctuid moths. The forewings are broad and triangular. Most of the species in the genus *Achaea* are attracted to light and to overripe fruit. *Achaea lienardi* has been known scientifically by a few other names: *Achaea chamaeleon* (*G*uenée, 1852); *Ophiusa cerbera* (Guenée, 1852); *Achaea spectatura* (Walker, 1858); *Achaea ophismoides* (Walker, 1873); *Achaea partita* (Walker, 1873) and *Achaea hilaris* (Plötz, 1880) (Pinhey 1975).

### 1.4.2 Biology

*Achaea lienardi* can be identified by their immense variation of colour and distinguishing patterns of the forewings (Fig. 1.5). The wings are a greyish-brown colour. The forewings have an oblique but almost straight inner line and the hindwing a brown colour with a trace of white in the centre and white marginal spots (Pinhey 1975). The length of the forewing is 25-30 mm.

**Figure 1.5**: An *Achaea lienardi* adult sampled during the 2013 sampling season.

### 1.4.3 Distribution and host range

*Achaea lienardi* was first recorded in Madagascar, but is found throughout sub-Saharan Africa (Fig. 1.6) (Pinhey 1975). The larva is a semi-looper and has been recorded feeding on *Acacia* spp., citrus leaves, *Maerua*, *Pappea*, *Ptaeroxylum*, *Rhus*, *Schotia*, and *Sideroxylon* (Pinhey 1975).

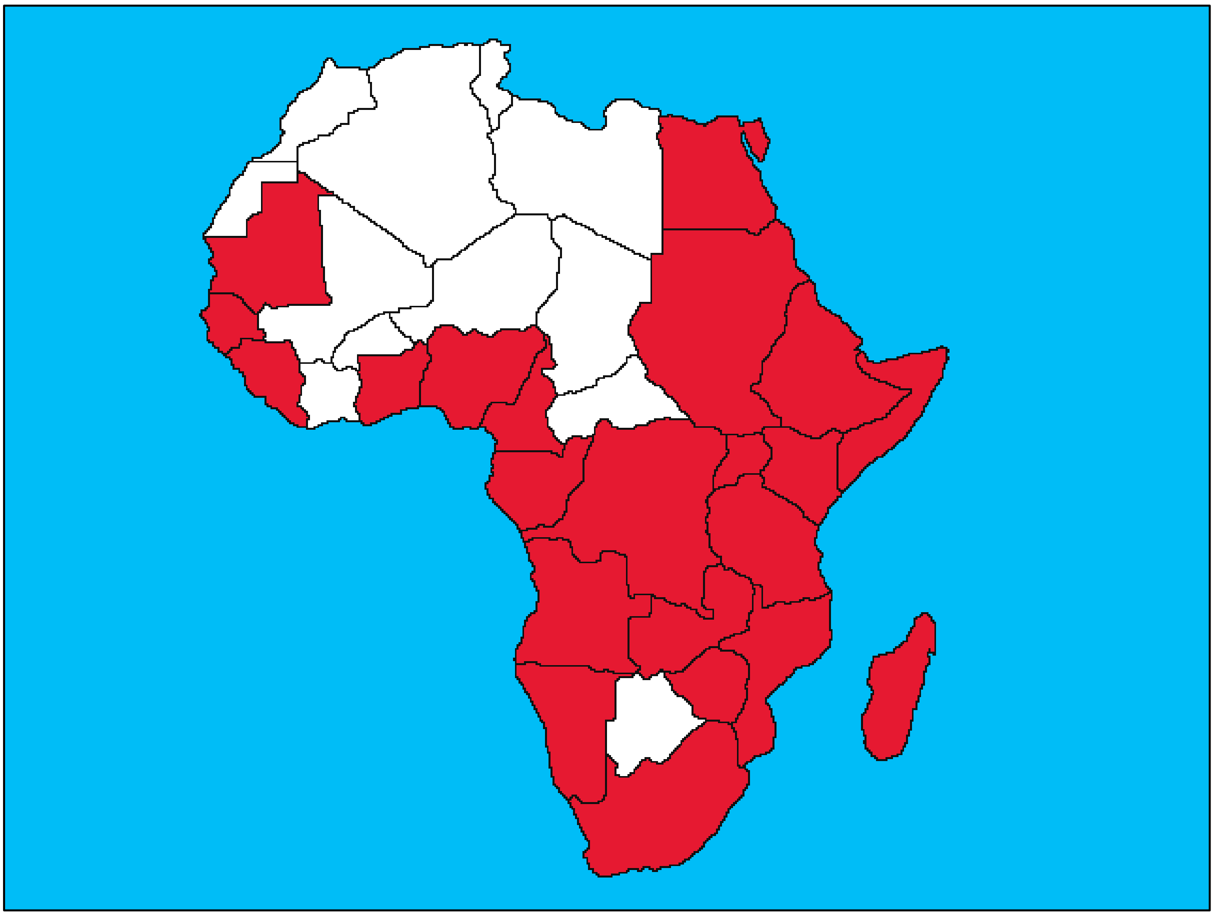

**Figure 1.6**: The geographical distribution of *Achaea lienardi* in Africa. Red filled countries indicate the presence of *Achaea lienardi* (http://www.africanmoths.com/index.html).

### 1.4.4 Control

*Achaea lienardi* has been controlled with the same methods that have been shown to control *S. partita* (see section 1.3.5). However, there is no true need to control these moths within citrus orchards as they are fruit-sucking moths and can only feed on already damaged fruit.

## 1.5 Research aims

Robinson *et al.* (2012) used a variety of attractants, Magnet® (Ag Biotech Australia), Texas Volatile™ (Insect Science), molasses, banana and citrus to attract and monitor fruit-feeding moths. Robinson *et al.* (2012) showed that crushed banana was the most effective bait for monitoring fruit-feeding moths in citrus orchards, as it caught the most fruit-piercing and fruit-sucking moths compared to the other baits. This is consistent with other literature showing the attractiveness of banana to fruit-feeding moths (Reddy & Muniappan 2007; Johannsmeier 1998). The commercial baits used were not effective and the bait patented for attracting fruit-piercing moths in Australia by Fay & Halfpapp (2006) has not become commercialized since its registration in 2003, indicating that it might not be a viable product.

Given the knowledge gaps in our understanding of the fruit-feeding moth complex in South Africa, the aims of this study were (1) to identify all possible species of fruit-feeding moths in orchards of the Eastern Cape and Tshipise growing regions (Chapter 2); (2) to examine the morphology of the proboscis of fruit-feeding moths recorded to determine which feeding group it falls in (Chapter 3); (3) to quantify the attractiveness of banana as a trap bait to fruit-piercing and fruit-sucking moths in comparison to synthetic attractants (Chapter 4); (4) to determine the level of damage caused to fruit in citrus orchards (particularly Satsuma Mandarins) during the course of three seasons (Chapter 5); (5) and to establish a relationship between weather conditions and the level of presence of *S. partita* in citrus orchards (Chapter 5).

# Chapter 2

# FRUIT-FEEDING MOTH SPECIES FOUND IN CITRUS ORCHARDS OF TSHIPISE AND THE EASTERN CAPE

## 2.1 Introduction

In South Africa there are a number of fruit-piercing moth genera, which have been recorded on citrus (Moore 2010; Johannsmeier 1998). These are *Eudocima, Oraesia, Serrodes, Egybolis*, *Pericyma* and *Plusiodonta* (Johannsmeier 2001; Swart 1969), in the Noctuidae, or at least the Noctuoidea, which means that they are night-flyers (Moore 2010). The most common species of fruit-piercing moth recorded on citrus orchards in the Eastern and Western Cape is *S. partita* (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998; Swart 1969). Furthermore, there are a number of genera of fruit-sucking moths on citrus (Moore 2010; Johannsmeier 1998) which include the genera *Achaea*, *Cyligramma, Grammodes, Helicoverpa*, *Ophiusa*, *Paralleia*, *Shingomorpha* and *Ulotrichopus* (Johannsmeier 2001). The most common fruit-sucking moth is *Achaea lienardi*, also in the Noctuidae (Johannsmeier 1998). However as these moths are frequently misidentified by growers, the frequency of occurrence and therefore damage caused by the main fruit-piercing moth, *S. partita* may thus have been over-emphasised. Therefore the aim of this chapter was to determine the species composition and abundance of fruit-feeding moths in the two main citrus growing areas of the Eastern Cape Province (Kate River Valley and Sundays River Valley), and in one of the most northerly growing regions of South Africa, Tshipise (Limpopo Province), where there have been reports of outbreaks of fruit-piercing moths.

# 2.2 Materials & Methods

## 2.2.1 Collecting protocol

The study was first conducted in the 2013 growing season, where two growing regions were chosen, both in the Eastern Cape. The first region was the Kat River Valley and the second region was the Grahamstown growing region. Within the Kat River Valley growing region, there were two farms, Blinkwater (32°39’34”S, 26°32’35”E) and Riverside (32°45’44”S, 26°36’50”E). Within the Grahamstown growing region, there was only a single farm, Mosslands (33°23’55”S, 26°25’38”E), which is situated 20 km outside of Grahamstown. With the continuation of the study in 2014 the project expanded and the Sundays River Valley growing region was added. Within the Sundays River Valley growing region, four new sites were chosen, Dunbrody Estates - Enterprise (33°29’03”S, 25°34’30”E) and Riverside (A - 33°28’02”S, 25°33’29”E and B - 33°28’52”S, 25°34’26”E), Hitgeheim (33°30’15”S, 25°36’27”E) and Halaron Farm (33°29’26”S, 25°40’25”E) and in 2015 Hitgeheim was replaced by a third orchard at Dunbrody Estates – Riverside C (33°27’32”S, 25°33’16”E), as the orchard at Hitgeheim was replanted with another variety. In the Kat River Valley growing region, there was the addition of two new sites used in 2015, Bath Farm (32°49’40”S, 26°40’17”E), Glinkwater Farm (32°40’33”S, 26°33’46”E). All the sites chosen grew Satsuma Mandarin as this is the earliest ripening cultivar and has historically been affected by fruit-piercing moths. In 2014 and 2015 there were reports of grapefruit being damaged by fruit-piercing moths at Alicedale Farm (22°37’52”S, 30°08’29”E) in the Tshipise growing region. Therefore, Alicedale Farm was added as additional sampling site.

The traps used were yellow bucket funnel traps which are available from Insect Science™ (Tzaneen, South Africa), and were placed in the orchards at the end of January for 2013 and 2014, and only at the end of February for 2015. The traps were monitored weekly until harvest. Each trap had a dichlorovos block (Vapona) placed inside the bucket, as this was used to kill any attracted insects without damaging them, so that they could be pinned and identified.

Traps were placed on the north-eastern side of each orchard, as these are the trees that are generally most affected by fruit-feeding moths as the moths usually enter from this side of the orchards (upwind side). The traps were placed in the third row from the northern edge and four trees in, so they would all have an equal chance of attracting moths. The traps were placed singly on the southern side of the tree and secured to the Satsuma Mandarin trees at approximately 2 m high. Fresh bananas were bought weekly from a local produce shop and then squashed into a lumpy palp using a work, this palp was placed into the plastic cages that are placed into the lid of each trap. Freshly squashed banana was used to attract fruit-feeding moths within the orchards, as it was shown by Robinson *et al.* (2012), to be the most successful bait in attracting fruit-feeding moths.

During the 2013 season, a total of 30 traps were placed in the Kat River Valley and Grahamstown growing regions. Eighteen traps were placed in the Kat River Valley growing region with 6 traps placed in each orchard, Riverside (A and B) and Blinkwater. Twelve traps were placed in the Grahamstown growing region at Mossland (A and B). Twelve traps were setup up in the 2014 and 2015 growing season. Seven traps were placed in the Kat River Valley growing region, where a single trap was placed in each orchard, Blinkwater and at Riverside (A and B), Bath Farm (A and B) and Glinkwater Farm (A and B). Similarly, five traps were set up in the Sundays River Valley growing region, where a single trap was set up at Dunbrody Estates - Enterprise, Dunbrody Estates - Riverside (A and B), Halaron Farm and Hitgeheim, which was changed to Dunbrody Estates - Riverside (C) in 2015.

During the 2014 and 2015 growing season, 10 traps baited with frozen banana, were placed singly in grapefruit orchards (B2, B3, E2, E5, E11, F1, F2, F8, M2, M7, M9 and M14) at Alicedale Farm in the Tshipise growing region, Limpopo. Traps were placed towards the end of January and monitored weekly for 7 weeks.

### 2.2.2 Identification of fruit-feeding moths sampled in traps in the orchards

Moths sampled weekly during the three growing seasons, in each of the growing regions, Kat River Valley, Sundays River Valley, Grahamstown and Tshipise, were identified to species and if this was not possible, they were identified to the lowest scientific name possible. Pinhey (1975) and Johannsmeier (1998) were used to identify the moths. Once the moths were identified, each species description was given, including any host records (Appendix I).

All specimens were lodged in the Rhodes University collection and assigned an AcRh number.

### 2.2.3 Statistical analysis

A Shannon-Weiner diversity index was conducted in Microsoft Excel (2013) and used to compare the diversity of species within each growing region.

The data collected was analysed using Statistica 12 (2014) and was not normally distributed and thus failed to meet the assumptions to allow parametric statistics. The mean trap catches of *S. partita*, *Achaea* spp. and all fruit-feeding moths were compared between the three growing seasons and each growing region, by a Kruskal-Wallis test. A further Kruskal-Wallis test was conducted to compare the mean trap catches of *S. partita*, *Achaea* spp. and all fruit-feeding moths between orchards in each growing region and growing season to determine if there was a difference in activity within each season and growing region. Further, a Kruskal-Wallis test was used to compare the moth catches of *S. partita*, *Achaea* spp. and all fruit-feeding moths sampled between the orchards at Alicedale Farm for each growing season. The mean was determined for the trap catches by taking the total of each week sampled and dividing it by the number of weeks sampled.

## 2.3 Results

### 2.3.1 Identification of fruit-feeding moths

During the three seasons, a total of 17,069 moths were sampled: 12,256 were sampled in Kat River Valley, 4,214 in Sundays River Valley, 476 were sampled in Grahamstown and 123 in Tshipise (Table 2.1). The highest abundance of moths was sampled during 2014. There were three species of *Achaea* collected, they were *A. lienardi*, *A. echo* and *A. indeterminata*, the three species were categorised as *Achaea* spp. as these three species are regarded as fruit-sucking moths (see Chapter 3). From the total trap catches over the three years, 1,178 of the moths sampled were *S. partita* and 4,406 were *Achaea* spp.

The Kat River Valley (Table 2.1) had the highest abundance and diversity of moth species sampled in the orchards (H = 2.1930; E = 0.7203) with 442 (3.61 %) *S. partita* sampled, whereas 3,387 (27.65 %) *Achaea* spp. were sampled. The Sundays River Valley had the second highest abundance and diversity of moth species sampled within the orchards (H = 1.1550; E = 0.6606), where only 712 (16.90%) *S. partita* were sampled and 688 (16.33 %) *Achaea* spp. were sampled (Table 2.1). There was a higher abundance of *S. partita* collected in Sundays River Valley than in any other region. Tshipise (Table 2.1) had a similar diversity of moths sampled to that in Sundays River Valley (H = 1.7733; E = 0.8528).There were no *S. partita* collected in Tshipise, however there was another fruit-piercing moth collected, *Eudocima* sp. but it comprised only 2.44% of the total catch during 2014 and 2015. There was also a low abundance of *Achaea* spp. found within the Tshipise orchards, where only eight (6.50 %) were sampled. The most abundant species collected in this growing region was *S. chlorea* where 38 (30.89 %) were collected within the orchards. Grahamstown (Table 2.1) recorded the lowest diversity of moths sampled (H = 1.1919; E = 0.5176) and had a low abundance of *S. partita*, making only 5.04% (24 moths) of total trap catches, whereas *Achaea* spp. had the highest abundance of 67.86% (323 moths) of the total trap catches.

There were several specimens that could not be identified (Table 2.1) due to them being too damaged from the traps being filled with rain water or by mice partially eating the moths from the traps; these were grouped as “undetermined”. The descriptions of each species can be found in Appendix I.

**Table 2.1:** Species of moths from the trap catches over 2013, 2014 and 2015 within Kat River Valley, Grahamstown, Sundays River Valley and Tshipise.

| | | The species abundance in each growing region (percent and total sampled ) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kat River Valley | | Grahamstown | | Sundays River Valley | | Tshipise | |
| **Family** | **Scientific Name** | **Total Sampled** | **Percent Sampled (%)** | **Total sampled** | **Percent sampled (%)** | **Total sampled** | **Percent sampled (%)** | **Total sampled** | **Percent sampled (%)** |
| Noctuidae | *Achaea spp.* | 3387 | 27.65 | 323 | 67.86 | 688 | 16.33 | 8 | 6.50 |
| | *Ericeia inangulata* | 1992 | 16.25 | 61 | 12.82 | 243 | 5.77 | 11 | 8.94 |
| | *Shingomorpha chlorea* | 905 | 7.38 | 5 | 1.05 | 32 | 0.76 | 38 | 30.90 |
| | *Anomis flava* | 709 | 5.78 | 24 | 5.04 | 778 | 18.46 | 10 | 8.13 |
| | *Hypanua xylina* | 555 | 4.53 | 12 | 2.52 | 1 | 0.02 | -- | -- |
| | *Hypanua roseitincta* | 548 | 4.47 | -- | -- | -- | -- | -- | -- |
| | *Serrodes partita* | 442 | 3.61 | 24 | 5.04 | 712 | 16.90 | -- | -- |
| | *Nagia sacerdotis* | 492 | 4.01 | 8 | 1.68 | 20 | 0.47 | -- | -- |
| | *Parallelia algira* | 184 | 1.50 | 15 | 3.15 | 13 | 0.31 | 3 | 2.44 |
| | *Ophiusa tirhaca* | 195 | 1.59 | -- | -- | 5 | 0.12 | -- | -- |
| | *Ulotrichopus catocala* | 134 | 1.09 | 2 | 0.42 | -- | -- | -- | -- |
| | *Hydrillodes uliginosalis* | 123 | 1.00 | -- | -- | 764 | 18.13 | -- | -- |
| | *Cuneisigna obstans* | 35 | 0.29 | -- | -- | -- | -- | -- | -- |
| | *Prodotis stolida* | 30 | 0.24 | -- | -- | 4 | 0.09 | -- | -- |
| | *Anua dianiris* | 21 | 0.17 | -- | -- | 6 | 0.14 | -- | -- |
| | *Rhodogastria bauri* | 23 | 0.19 | -- | -- | -- | -- | -- | -- |
| | *Aganais speciosa* | 9 | 0.07 | -- | -- | 7 | 0.17 | -- | -- |
| | *Digama culta* | 5 | 0.04 | -- | -- | 21 | 0.50 | -- | -- |
| | *Cyligramma latona* | 2 | 0.02 | -- | -- | -- | -- | -- | -- |
| | *Grammodes congenita* | -- | -- | -- | -- | 1 | 0.02 | -- | -- |
| | *Spodoptera capicola* | -- | -- | -- | -- | -- | -- | 32 | 26.02 |
| | *Eudocima sp.* | -- | -- | -- | -- | -- | -- | 3 | 2.44 |
| Tortricidae | | 149 | 1.22 | -- | -- | 9 | 0.21 | -- | -- |
| Undetermined | | 2316 | 18.90 | 2 | 0.42 | 910 | 21.60 | 18 | 14.63 |
| **Shannon-Wiener diversity index (H)** | | 2.1930 | | 1.1919 | | 1.8717 | | 1.7733 | |
| **Species Evenness (E)** | | 0.7203 | | 0.5176 | | 0.6606 | | 0.8528 | |

-- Was not collected in the growing region

## 2.3.2 Abundance and diversity of fruit-feeding moths, within growing regions during three growing seasons

### 2.3.2.1 Kat River Valley and Grahamstown

In the following section all statistical differences are shown by letters on the graphs, where the letters differ shows significant difference and where they are the same shows no significance. Tables of statistical values are presented in Appendix II.

During 2013 in Grahamstown (Fig. 2.1) (Table II.1) there was no difference between the mean number of *S. partita*, sampled at Mosslands A (Fig. 2.1 A) and Mosslands B (Fig. 2.1 B). Similarly there was no significant difference in trap catches of *Achaea* spp. between the orchards. This was the same for the mean number of fruit-feeding moths sampled weekly at each orchard, even though Mosslands A had a larger number of fruit-feeding moths sampled weekly. However there were significantly more *Achaea* spp. sampled in Mosslands A than there were *S. partita* at Mosslands B ($p = 0.0121$) (Table II.1).

The Kat River Valley (Fig. 2.1) (Table II.1), showed similar results to that of Grahamstown as there was no significant difference in the mean number of *S. partita* sampled weekly at Blinkwater (Fig. 2.1 E), Riverside A (Fig. 2.1 C) or Riverside B (Fig. 2.1 D). There was also no difference between *Achaea* spp. sampled between the orchards. However there were significantly more fruit-feeding moths sampled weekly at Blinkwater than at Riverside B ($p = 0.0332$) (Table II.1), but no difference between weekly trap catches at Riverside A and Riverside B. Furthermore there was no difference between Blinkwater and Riverside A. There were significantly more *Achaea* spp. sampled weekly at Blinkwater (Table II.1) than there were *S. partita* at Blinkwater ($p = 0.0053$), Riverside A ($p = 0.0001$) and Riverside B ($p = 0.0001$). There was no difference between weekly trap catches of *Achaea* spp. sampled at Riverside A and Riverside B than *S. partita* sampled at Blinkwater. However there were significantly more *Achaea* spp. sampled weekly at both Riverside A ($p = 0.0023$) (Table II.1) and Riverside B ($p = 0.0001$) (Table II.1) than *S. partita* in the same orchards.

When comparing the weekly trap catches of *S. partita* between orchards in Grahamstown and Kat River Valley, there was no significant difference (Table II.1). However there were significantly more *Achaea* spp. sampled weekly at Blinkwater (Table II.1) than there were at Mosslands A ($p = 0.0350$) and Mosslands B ($p = 0.0052$), but there was no difference between weekly trap catches at Riverside A, Riverside B, Mosslands A and Mosslands B (Table II.1). There were significantly more fruit-feeding moths sampled weekly at Blinkwater, Riverside A, than there were at Mosslands A (Blinkwater, $p = 0.0001$; Riverside A, $p = 0.0045$) (Table II.1) and Mosslands B (Blinkwater, $p = 0.0001$; Riverside A, $p = 0.0001$) (Table II.1). Blinkwater, Riverside A and Riverside B sampled significantly more *Achaea* spp. weekly than *S. partita* at Mosslands A (Blinkwater, $p = 0.0001$; Riverside A, $p = 0.0023$; Riverside B, $p = 0.0004$) (Table II.1) and Mosslands B (Blinkwater, $p = 0.0001$; Riverside A, $p = 0.0001$; Riverside B, $p = 0.0001$) (Table II.1).

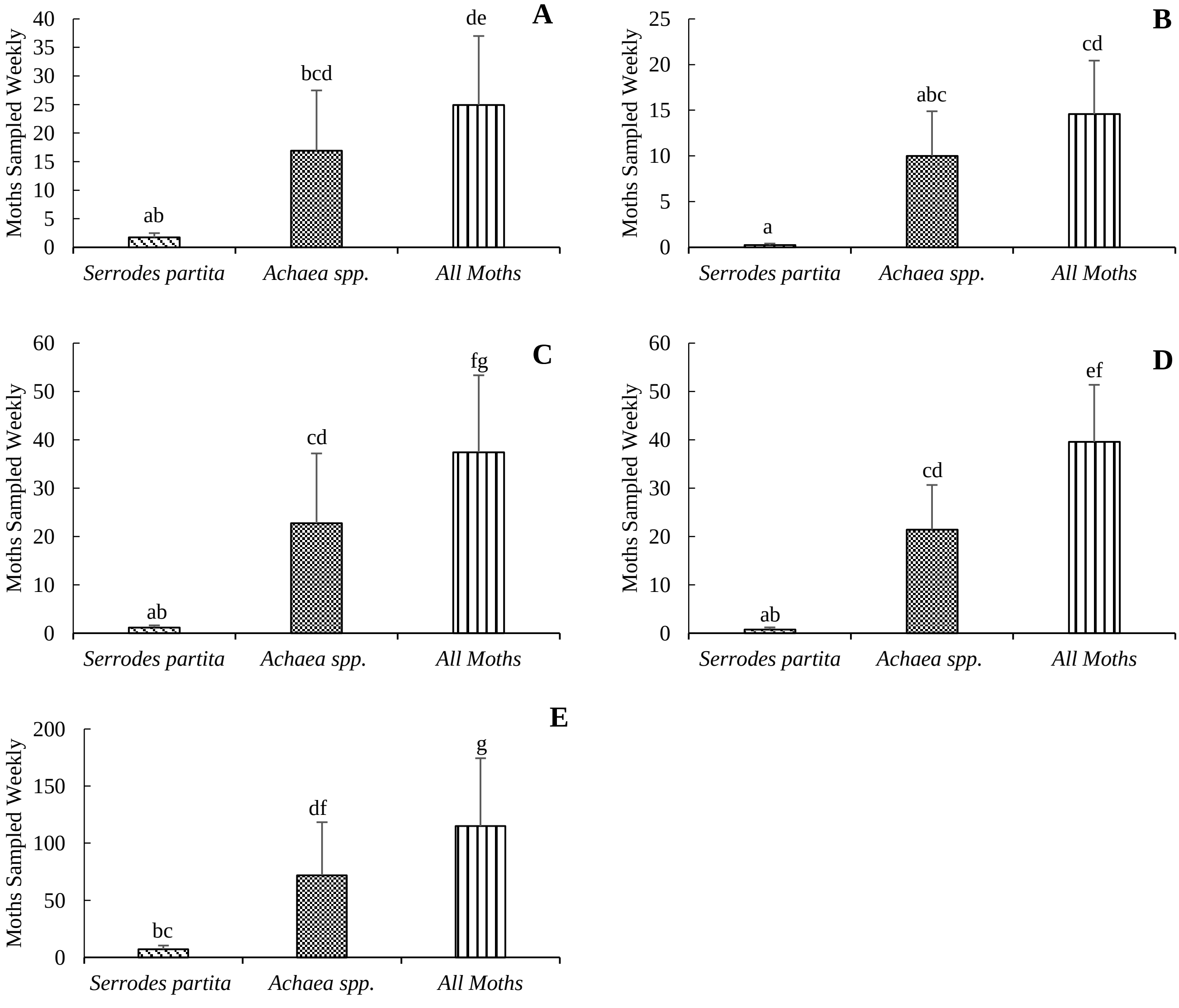


**Figure 2.1:** Mean number of moths, sampled weekly over a 12 week sampling period, in six traps at each orchard during 2013 in Grahamstown and Kat River Valley. **A** - Mosslands A; **B** - Mosslands B; **C** - Riverside A; **D** - Riverside B; **E** - Blinkwater.

During 2014 in Kat River Valley (Table II.2) there was no significant difference between *S. partita*, sampled weekly at Blinkwater (Fig. 2.2 G), Bath Farm A (Fig. 2.2 A), Bath Farm B (Fig. 2.2 B), Riverside A (Fig. 2.2 C), Riverside B (Fig. 2.2 D), Glinkwater Farm A (Fig. 2.2 E) and Glinkwater Farm B (Fig. 2.2 F). There was also no significant difference in the weekly trap catches for *Achaea* spp. and this was also so when comparing the weekly trap catches of all fruit-feeding moths sampled between each orchard. When comparing the weekly trap catches of *S. partita* to that of *Achaea* spp. there was no difference between the orchards either.

During 2015 in Kat River Valley (Table II.3) the results were similar to that of 2014 as there was no significant difference between *S. partita*, sampled at Blinkwater (Fig. 2.3 G), Bath Farm A (Fig. 2.3 A), Bath Farm B (Fig. 2.3 B), Riverside A (Fig. 2.3 C), Riverside B (Fig. 2.3 D), Glinkwater Farm A (Fig. 2.3 E) and Glinkwater Farm B (Fig. 2.3 F). Furthermore there was also no significant difference in the weekly trap catches for *Achaea* spp. and all fruit-feeding moths sampled between each orchard. When comparing the trap catches of *S. partita* to that of *Achaea* spp. there was no difference between the orchards either.

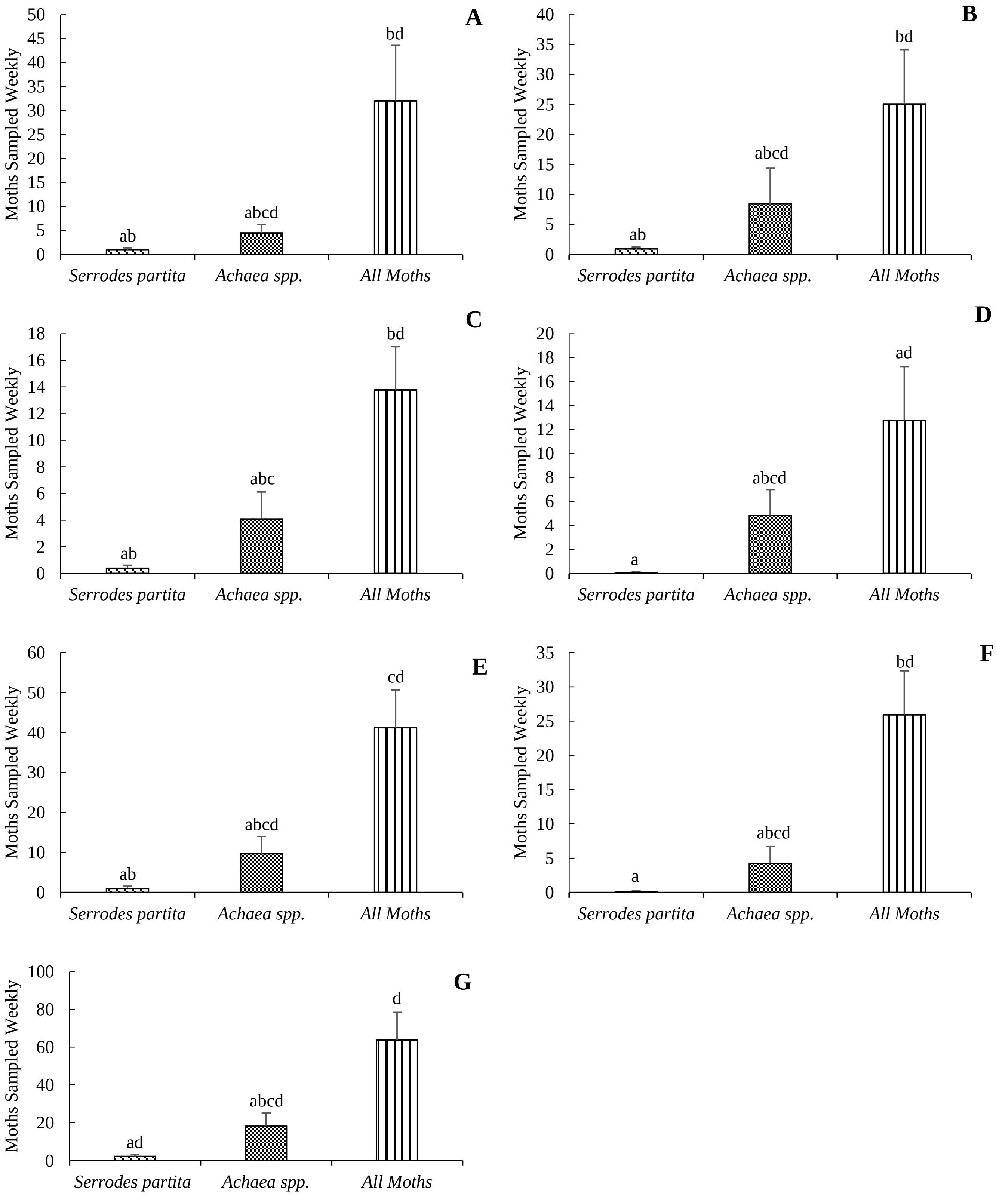


**Figure 2.2:** Mean number of moths, sampled weekly over a 12 week sampling period, in single traps in each orchard during 2014 in Kat River Valley. **A** – Bath Farm A; **B** – Bath Farm B; **C** - Riverside A; **D** - Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B; **G** – Blinkwater.

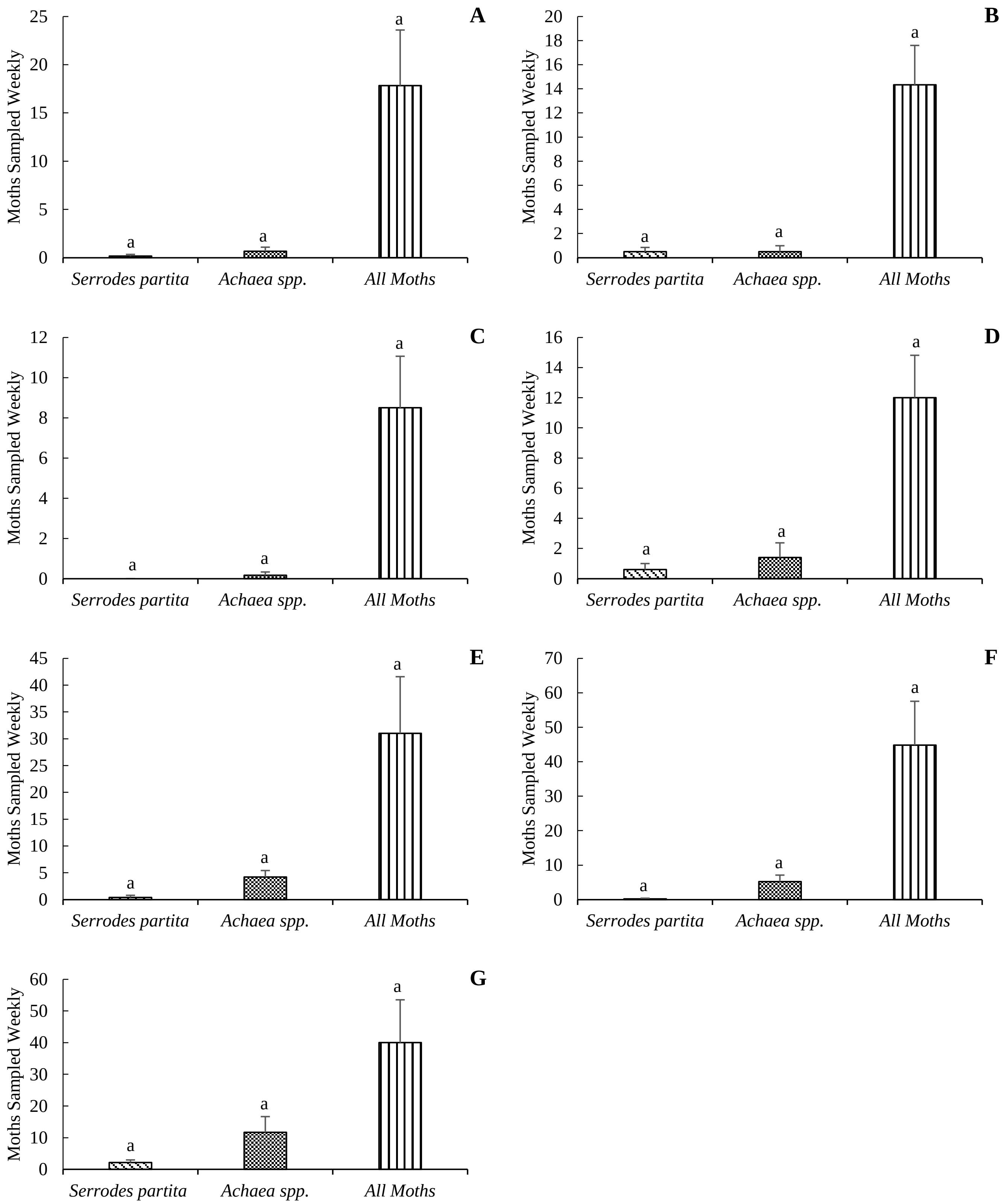


**Figure 2.3:** Mean number of moths, sampled weekly over a 5 week sampling period, in single traps during 2015 in Kat River Valley. **A** – Bath Farm A; **B** – Bath Farm B; **C** - Riverside A; **D** - Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B; **G** – Blinkwater.

#### 2.3.2.2 Sundays River Valley

The results for Sundays River Valley (Table II.4) are similar to those obtained in Kat River Valley as there were no significant difference between *S. partita*, sampled weekly at Halaron Farm (Fig. 2.4 B), Hitgeheim (Fig. 2.4 A), Dunbrody Estates - Riverside A (Fig. 2.4 C), Dunbrody Estates - Riverside B (Fig. 2.4 D) and Dunbrody Estates – Enterprise (Fig. 2.4 E) for 2014. There was also no significant difference in weekly trap catches for *Achaea* spp. and fruit-feeding moths sampled between each orchard. When comparing the trap catches of *S. partita* to those of *Achaea* spp. there was no difference between the orchards either.

During 2015 (Table II.5) there was no significant difference between *S. partita*, sampled weekly at Halaron Farm (Fig. 2.5 A), Dunbrody Estates - Riverside A (Fig. 2.5 B), Dunbrody Estates - Riverside B (Fig 2.5. C), Dunbrody Estates - Riverside C (Fig. 2.5 D) and Dunbrody Estates – Enterprise (Fig 2.5. E). There was also no difference in weekly trap catches for *Achaea* spp. and fruit-feeding moths sampled weekly between each orchard. Furthermore when comparing the weekly trap catches of *S. partita* to that of *Achaea* spp. between the orchards, there was no significant difference.

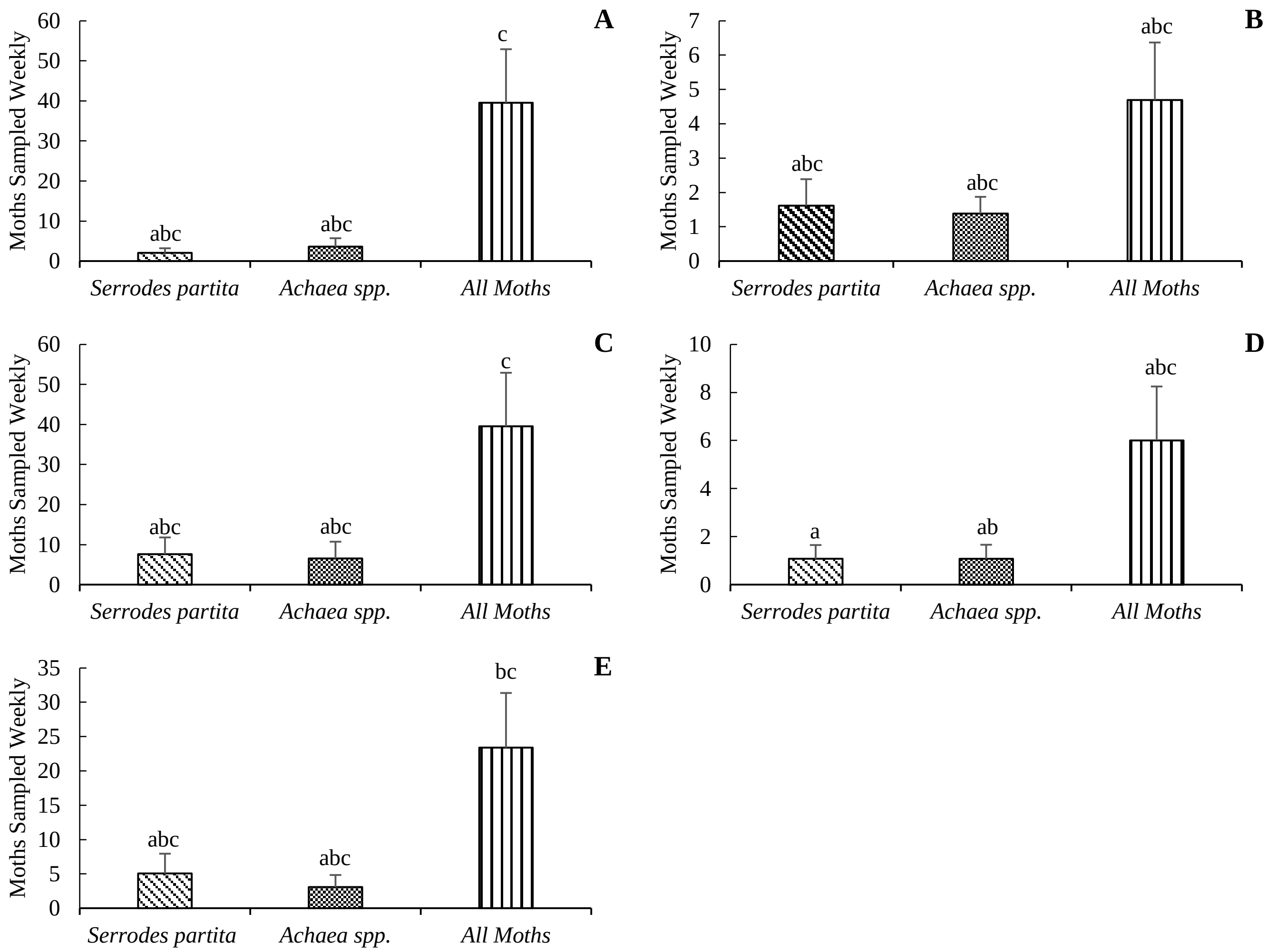


**Figure 2.4**: Mean number of moths, sampled weekly over a 12 week sampling period for 2014 in Sundays River Valley. **A** – Hitgeheim, **B** – Halaron Farm, **C** – Dunbrody Estates - Riverside A, **D** – Dunbrody Estates - Riverside B, **E** – Dunbrody Estates – Enterprise.

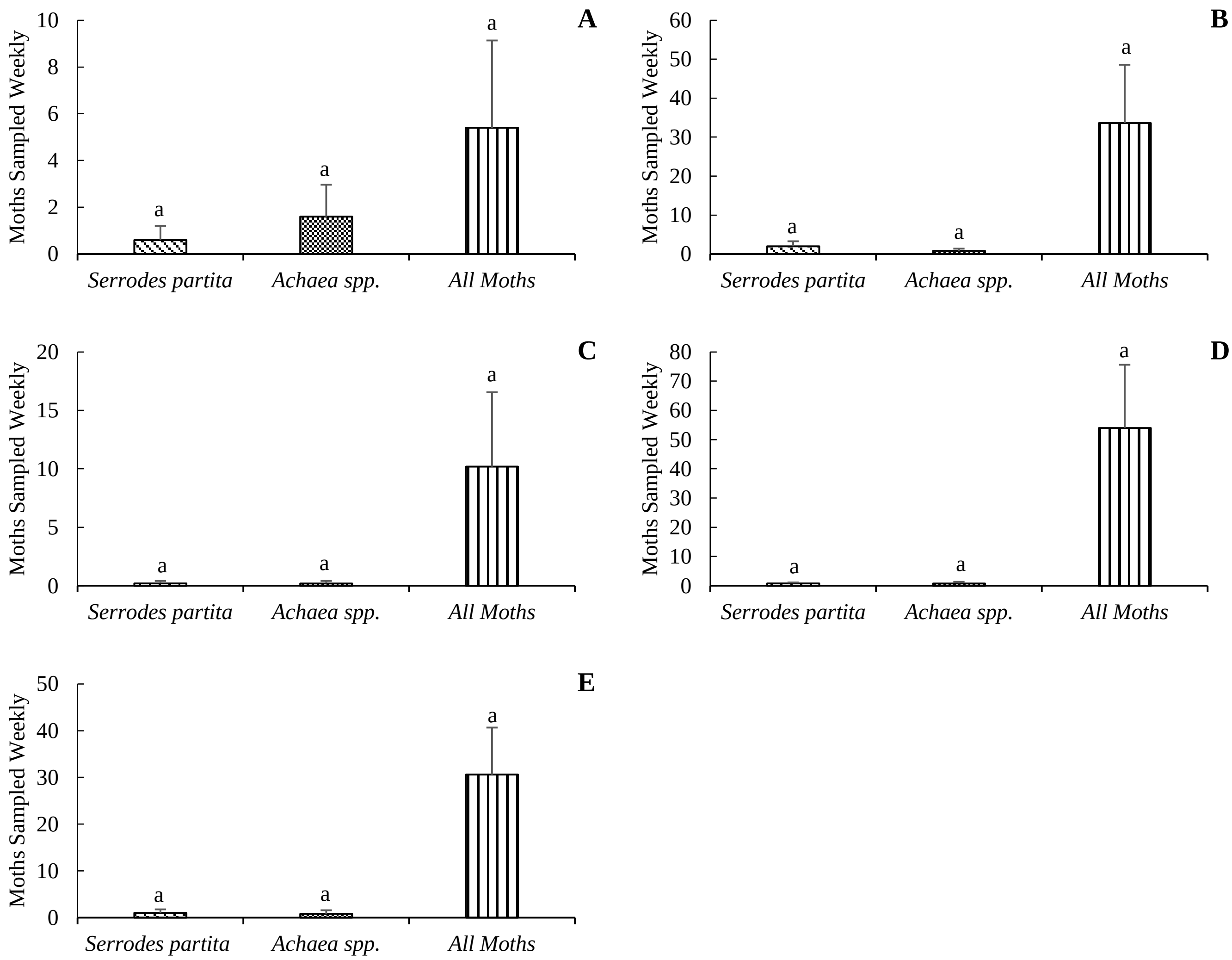


**Figure 2.5**: Mean number of moths, sampled weekly over a 12 week sampling period for 2015 in Sundays River Valley. **A** – Halaron Farm; **B** – Dunbrody Estates - Riverside A; **C** – Dunbrody Estates - Riverside B; **D** – Dunbrody Estates - Riverside C; **E** – Dunbrody Estates – Enterprise.

#### 2.3.2.3 Kat River Valley, Grahamstown and Sundays River Valley

During 2014 in Sundays River Valley (Table II.6) there were significantly more *S. partita* collected weekly than there were in during 2013 at both Grahamstown (p = 0.0008) and Kat River Valley (p = 0.0203). However, there was no significant difference between trap catches of *S. partita* in the other regions and years. There were significantly more *Achaea* spp. collected weekly during 2013 in Grahamstown (Table II.6) than 2014 (p = 0.0012) in Kat River Valley. There was no significant difference between the other regions and years in the trap catches of *Achaea* spp. In the Grahamstown during 2013 (Table II.6), there were significantly less fruit-feeding moths collected weekly than 2013 Kat River Valley (p = 0.0001), 2014 Kat River Valley (p = 0.0001) and Sundays River Valley (p = 0.0001) 2015 in Kat River Valley (p = 0.0001). Furthermore there were more fruit-feeding moths sampled in 2014 than 2013 (p = 0.0001) (Table II.6) in Kat River Valley.

There were significantly more *Achaea* spp. than *S. partita* collected weekly during 2013 (Table II.6) in both Grahamstown (p = 0.0065) and Kat River Valley (p = 0.0001) and also for 2014 in Kat River Valley (p = 0.0001). Furthermore, there were significantly more *Achaea* spp. collected in both 2014 (p = 0.0077) and 2015 (p = 0.0240) than *S. partita* during 2013 in Kat River Valley (Table II.6). There were significantly more *Achaea* spp. than *S. partita* during 2014 in Kat River Valley (Table II.6) than during for both 2014 (p = 0.0001) and 2015 (p = 0.0007) in Kat River Valley. For the other regions and years, there was no significant difference observed. Whereas, there were significantly more *S. partita* sampled weekly during 2014 in Sundays River Valley (Table II.6) than there were *Achaea* spp., collected weekly in 2013 in both Grahamstown (p = 0.0003) and Kat River Valley (p = 0.0078).

There was no significant difference between trap catches of *S. partita* sampled in any of the orchards during 2013, 2014 and 2015 (Table II.7). This was also recorded for the trap catches of *Achaea* spp., as there was no significant difference between orchards for the three years. However Blinkwater (p = 0.0195) (Table II.7) and Glinkwater Farm A (p = 0.0117) (Table II.7), sampled significantly more fruit-feeding moths during 2014, than during 2013 at Mosslands B. Mosslands A (p = 0.0093) (Table II.7) and Mosslands B (p = 0.0001) (Table II.7) during 2013 sampled significantly more fruit-feeding moths weekly than at Riverside A during 2014. There was no significant difference between any of the other orchards during the three years for the trap catches of fruit-feeding moths. There were significantly more *S. partita* sampled weekly at Blinkwater during 2013 than *Achaea* spp. during 2014 at Riverside B (p = 0.0240) (Table II.7).

#### 2.3.2.4 Tshipise

There were no *S. partita* sampled at Alicedale farm during 2014 (Table II.8) and 2015 (Table II.9), where the only fruit-piercing moth species sampled was a *Eudocima* sp. (Johannsmeier 1998) and it was sampled at low numbers in the orchards (Fig 2.6, 2.7). There was no significant difference between trap catches of *Eudocima* sp. for either 2014 and 2015. *Achaea* spp. were also observed at low numbers and there was no significant difference between trap catches for each year. Furthermore there were was no significant difference between orchards in trap catches of fruit-feeding moths during 2014 and 2015.

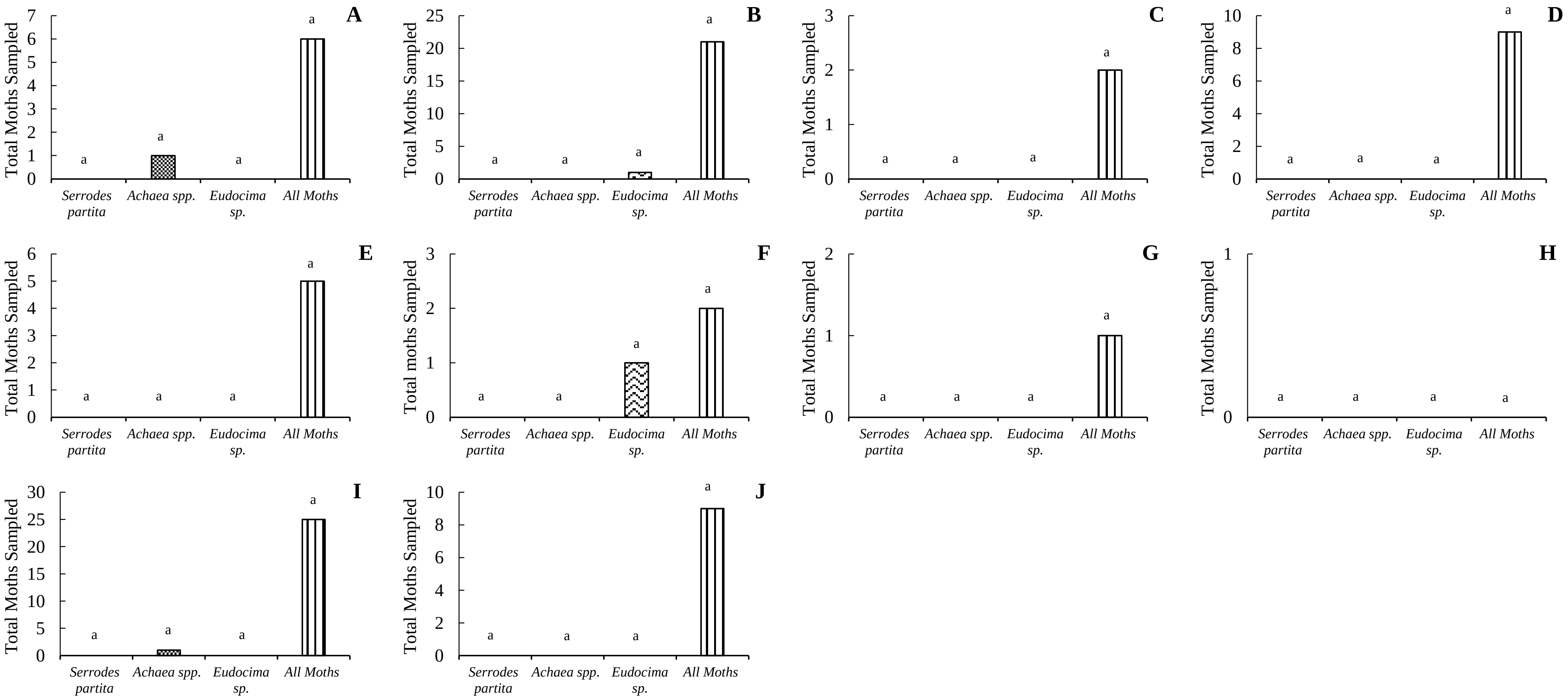


**Figure 2.6:** Total number of moths, sampled weekly over a 7 week sampling period, in single traps in grapefruit orchards at Alicedale Farm, Tshipise, during 2014. **A** – B2; **B** – B3; **C** - E5; **D** - E11; **E** -F2; **F** - F8; **G** - M2; **H** - M7; **I** - M9; **J** - M14.

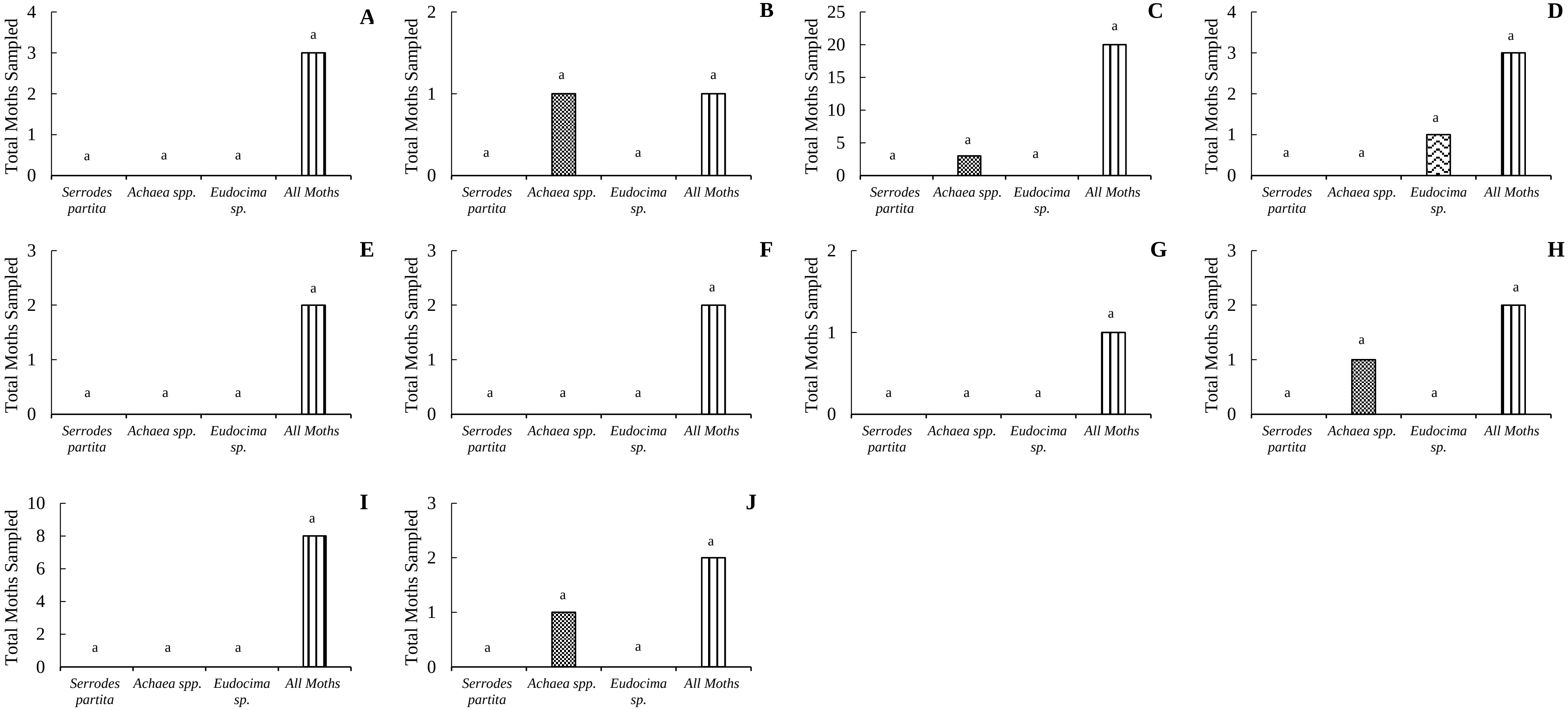


**Figure 2.7:** Total number of moths, sampled weekly over a 7 week sampling period in grapefruit orchards on Alicedale Farm, Tshipise, during 2015. **A -** E2; **B** - E5; **C** - E11; **D** - F1; **E** - F2; **F** - F8; **G** - M2; **H** - M7; **I** - M9; **J** - M14.

## 2.4 Discussion

In the areas surveyed, for the periods 2013 to 2015 there was a high diversity of fruit-feeding moths associated with citrus, where 23 species were trapped within the orchards throughout the three growing regions. Interestingly, *S. partita* comprised only 6.9% of the total trap catches, an average of seven to 28 *S. partita* being trapped on a weekly basis, throughout the growing regions in the Eastern Cape. These numbers of *S. partita* are similar to those observed by Robinson *et al.* (2012) in the Sundays River Valley growing region, where an average of 12 *S. partita* were trapped per week. *Serrodes partita* was collected at low numbers in all the orchards during the three growing seasons. During the 2013 growing season there was an average of 12 *S. partita* sampled weekly, the majority of which were sampled in the Kat River Valley growing region and the minority being sampled in the Grahamstown growing region. The 2014 growing season had the highest abundance of *S. partita* sampled weekly. The lowest trap catches occurred during the 2015 growing season as an average of seven *S. partita* were sampled weekly, while both the Kat River Valley and Sundays River Valley growing regions sampled an average of 4 *S. partita* weekly. The activity of *S. partita* within the orchards in the growing regions can be considered a low level of presence as 1000 *S. partita* was described to be a heavy level of presence by Johannsmeier (1998).

*Achaea* spp. were far more abundant in the orchards than *S. partita*, with 156 *Achaea* spp. sampled weekly during the 2013 growing season, where the majority were sampled in the Kat River Valley growing region (an average of 122 per week) and the minority of *Achaea* spp. sampled weekly in the Grahamstown growing region (an average of 27 per week). During the 2014 growing season an average of 113 *Achaea* spp. were sampled weekly, the majority being sampled in the Kat River Valley (an average of 82 per week) and less in the Sundays River Valley growing region (an average of 20 per week). The lowest trap catches occurred during the 2015 growing season, as an average of 24 *Achaea* spp. were sampled weekly, with an average of 24 *Achaea* spp. sampled weekly in the Kat River Valley growing region and an average of four *Achaea* spp. sampled weekly in the Sundays River Valley growing region. This pattern has been observed in outbreak years where both *S. partita* and *Achaea* spp. have been recorded feeding in the orchards on fruit at the same time (Moore 2010; Johannsmeier 1998).

There was a total of 23 species observed within orchards throughout the growing regions. *Serrodes partita* has been shown to be recorded at low numbers, only making 6.9% of the total trap catches, where *Achaea* spp. made up 25.8% of the total trap catches. Furthermore the remaining 67.3% of the total trap catches could lead to uncertainty in identifying which moth species is/are causing the damage to the fruit, in the absence of actually observing the moths feeding on the fruit. Growers have confused *Achaea* spp. as the primary cause of damage of fruit in the past, as *Achaea* spp. have been observed feeding on the fruit during the day (Robinson *et al.* 2012; Johannsmeier 2001, 1998) and it is likely that the importance of *S. partita* has been exaggerated. Therefore it is important to determine the relationship between the numbers of *S. partita* within the orchards and the damage they inflict on the fruit to better determine the yield loss these moths can cause in citrus orchards (Chapter 5). Banana was shown to attract a wide diversity of fruit-feeding moths within the orchards and a more selective method for attracting *S. partita* would be ideal for monitoring populations of this moth within the orchards and may thus reduce confusion for farmers, assuming (based on recent and historical observation) that *S. partita* is the main culprit (Chapter 4).

# Chapter 3

# MORPHOLOGY OF THE PROBOSCIDES OF FRUIT-FEEDING MOTHS COLLECTED IN CITRUS ORCHARDS IN SOUTH AFRICA

## 3.1 Introduction

The lepidopteran proboscis structure and function has been studied across multiple families in order to determine how each function (Bänziger 1971, 1973; Büttiker *et al*. 1996; Krenn 1990, 1997; Speidel *et al.* 1996; Zaspel 2008). Earlier work done on the structure of the proboscis used light microscopy to better understand each structure and therefore the function (Hattori 1962; Bänziger 1970, 1973, 1980). Light microscopy was later replaced by scanning electron microscopy (SEM) which allowed for better understanding of the structures and function (Cochereau 1977; Büttiker *et al.* 1996; Speidel *et al.* 1996). Previous research has shown that there are uniquely specialized proboscis structures such as cutting ridges, erectile barbs and tearing hooks moved by haemolymph blood-pressure, that occur on the proboscis of moths and this is especially so for the piercing moths in the family Noctuidae and in the subfamily Calpinae (Bänziger 1970, 1973, 1980; Zaspel 2008).

The subfamily Calpinae is defined by the tearing structures of the proboscis (Zaspel 2008; Fibiger & Lafontaine 2005; Holloway *et al*. 2001; Holloway 2005). The tearing hooks are unique to a tribe within the Calpinae of fruit-piercing moths, with the well-known genera being *Eudocima*. *Eudocima* sp. are well-known pests of fruit ranging from hard-skinned, thick-skinned citrus, to soft-skinned or ripening fruit such as peaches, but nothing is known about the proboscis structure of *S. partita*, which also belongs to the subfamily, Calpinae.

As farmers in the past have confused fruit-sucking moths with fruit-piercing moths, this study aimed to confirm which species sampled in traps (Chapter 2) are in fact fruit-sucking moths and which are fruit-piercing moths. Thus the aim of this chapter was to link morphology of the proboscis to fruit-feeding behaviour of the moths sampled in chapter 2.

## 3.2 Materials & Methods

All moths selected were within the Noctuidae, the species chosen being *Achaea lienardi*, *A. indeterminata*, *A. echo*, *Anua dianiris*, *Ericeia inangulata*, *Ophiusa tirhaca*, *Serrodes partita*, *Eudocima* sp. and *Shingomorpha chlorea.* The fruit-feeding moths selected were either recorded due to their relatively high abundance within the orchards or as it was deemed necessary to confirm (or otherwise) their categorisation as fruit-piercing moths (see Chapter 2, Table 2.1). The sex of each species was determined by dissecting the genitalia of each specimen and viewing it under a light microscope. This was done in order to select three males and three females from each species, to determine any differences in proboscides between sexes and species.

A total of 48 proboscide micrographs were taken from nine species of moths (three males and three females of each species) in order to determine any differences in proboscides between sexes and species. This was accomplished by dissecting the proboscis from each specimen. Once dissected the proboscides were prepared for Scanning Electron Microscopy (SEM) by leaving each proboscis overnight in 80% ethanol, to remove any liquid from the proboscis. The next step was placing each proboscis in a DG-1 supersonic cleaner (MRC Ltd.) for two minutes. The DG-1 supersonic cleaner gently vibrates the proboscis, which does not damage it, but loosens any scales or dirt that may have become attached to the proboscis. After this step, each proboscis was left to dry for two hours on fibreless filter paper. Each proboscis, once dry, was cautiously inserted onto individual metal stubs using black double-sided tape. These studs were coated with a thin layer of gold, by inserting each stud into a Quorum Q150RS gold splutterer with a current of 20 Ma. The final step was to place each stub inside the vacuum chamber of a TESCAN Vega TS 5136LM SEM from which detailed micrographs were taken.

Each micrograph was then used to observe the detailed morphology of each specimen's proboscis, with a focus on the distal end (Fig. 3.1). This was done to determine what species were fruit-piercing moths and which were fruit-sucking moths.

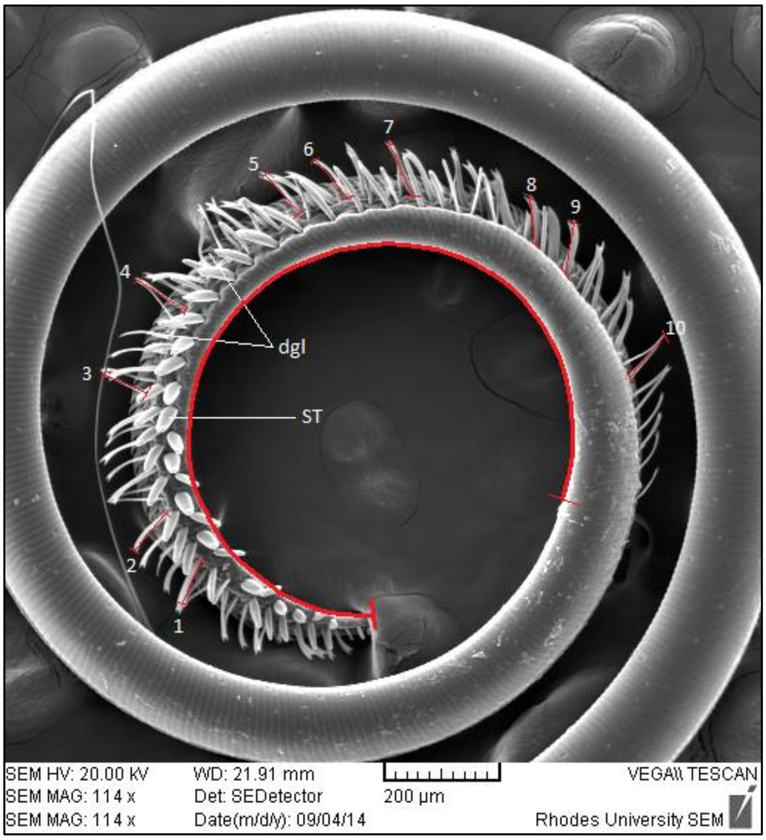


**Figure 3.1:** Example showing where the measurements were taken for each proboscis, as 10 dorsal galeal linkages (dgl) were measured from each specimen. The distal length of the proboscis was also measured, which is shown by the tip of the proboscis to the start point of Sensilla Styloconica (ST) on the proboscis.

### 3.2.1 Statistical analysis

The mean length of dorsal galeal linkages and distal length between sexes were measured and analysed using a Kruskal-Wallis test, to determine if there was any difference between sexes. A further Kruskal-Wallis test was done to compare the differences of 10 dgl, which were measured from each proboscis and a single length of the distal end of the proboscis, and this was done to determine if there was any difference between sexes. All Statistical analyses were conducted using Statistica 12 (2014). The structure of each species proboscis (Table 3.1) was examined on the same photos, which was done to determine what species were fruit-piercing moths and which were fruit-sucking moths. A Kruskal-Wallis test was done to compare the differences between species.

**Table 3.1:** A description of the structural and sensory adaptations and their proposed function visible on the proboscides of noctuid moths.

| Structure (Abbreviation): | Description |
|---|---|
| Tearing hooks (th): | A cuticular structure used to pierce through the skin of fruit or mammal tissue. It is attached to the socket by elastic endocuticula, where it is moveable by blood pressure. Possible mechanoreception. |
| Sensilla Styloconica (ST): | Used as a contact chemo-mechanoreceptor. Flattened, feather-like structure lacking a distal cone |
| Erectile barbs subtype 1 (eb): | A modified sensilla styloconica, used for mechanoreception and possibly contact chemoreception. |
| Furcate Erectile barbs (feb): | A cuticular structure which may be used to perceive mechanical distortions that are generally asymmetrical hair or finger like projections. |
| Serrate ridge (sr): | Serrated cuticular ridge on ventral side of proboscis, used for piercing hard-skinned fruit (e.g. grapefruit, litchi). |
| Dorsal Galeal Linkage (dgl): | Glossae and paraglossae forming a zipper-like structure which hold the two tubes of the proboscis together. |

Modified from Zaspel *et al.* (2011)

## 3.3 Results

In the following section all statistical differences are shown by letters on the graphs, where the letters differ shows significant difference and where they are the same shows no significant difference. Tables of statistical values are presented in Appendix III. Only females of species *Eudocima* sp. and *O. tirhaca* were sampled in the orchards, whereas, for all other species mentioned above both male and females were sampled in the orchards.

There was no significant difference in the lengths of dgl (Fig. 3.2) between males and females (Table III.1) of the same species, *A. echo*, *A. indeterminata*, *A. lienardi*, *A. dianiris*, *E. inangulata*, *S. partita*, and *S. chlorea*.

*Eudocima* sp. had the longest dgl (Fig. 3.2) (Table III.2), compared to the other species, but it was only significantly longer than *A. indeterminata* ($p = 0.0001$), *A. lienardi* ($p = 0.0272$), *A. dianiris* ($p = 0.0003$), *E. inangulata* ($p = 0.0001$), *O. tirhaca* ($p = 0.0356$) and *S. chlorea* ($p = 0.0001$), but not significant to *A. echo* and *S. partita*. The shortest dorsal galeal linkages belonged to *E. inangulata* (Fig. 3.2) (Table III.2), which was significantly smaller than *A. echo* ($p = 0.0001$), A. *lienardi* ($p = 0.0001$), *A. dianiris* ($p = 0.0001$), *O. tirhaca* ($p = 0.0001$), *S. partita* ($p = 0.0001$), *S. chlorea* ($p = 0.0062$) and *Eudocima* sp. ($p = 0.0001$).

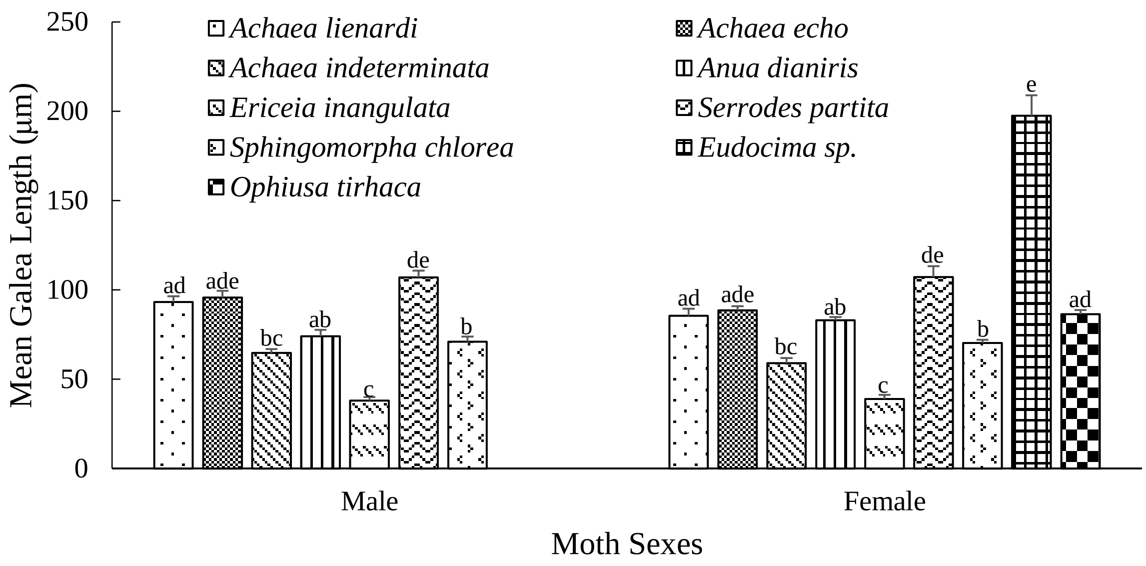


**Figure 3.2:** Mean (± SE) dorsal galeal linkages of proboscides of female species of *Eudocima* sp., *Ophiusa tirhaca* and male and female species of *Achaea echo, Achaea indeterminata*, *Achaea lienardi*, *Achaea dianiris*, *Ericeia inangulata*, *Serrodes partita* and *Sphingomorpha chlorea*.

The difference in length between males and females of the distal length of the proboscides was not significant (Fig. 3.3) (Table III.3), *A. echo*, *A. indeterminata*, *A. lienardi*, *A. dianiris, E. inangulata*, *S. partita* and *S. chlorea*. *Eudocima* sp. had the longest distal length of proboscis (Fig. 3.3) (Table III.4), and this was significantly longer than *A. lienardi* (p = 0.0011)*, A. echo* (p = 0.0093)*, A. indeterminata* (p = 0.0001) and *E. inangulata* (p = 0.0001), but not significantly different to the other species sampled. The shortest distal length was found in *E. inangulata* and *A. indeterminata* (Fig. 3.3) (Table III.4) which was significantly shorter than *A. dianiris* (*E. inangulata,* p = 0.0046; *A. indeterminata,* p = 0.0018), *Eudocima* sp. (*E. inangulata,* p = 0.0001; *A. indeterminata*, p = 0.0001)*, O. tirhaca* (*E. inangulata,* p = 0.0002; *A. indeterminata*, p = 0.0001)*, S. partita* (*E. inangulata,* p = 0.0001; *A. indeterminata,* p = 0.0001) and *S. chlorea* (*E. inangulata,* p = 0.0025; *A. indeterminata,* p = 0.0004).

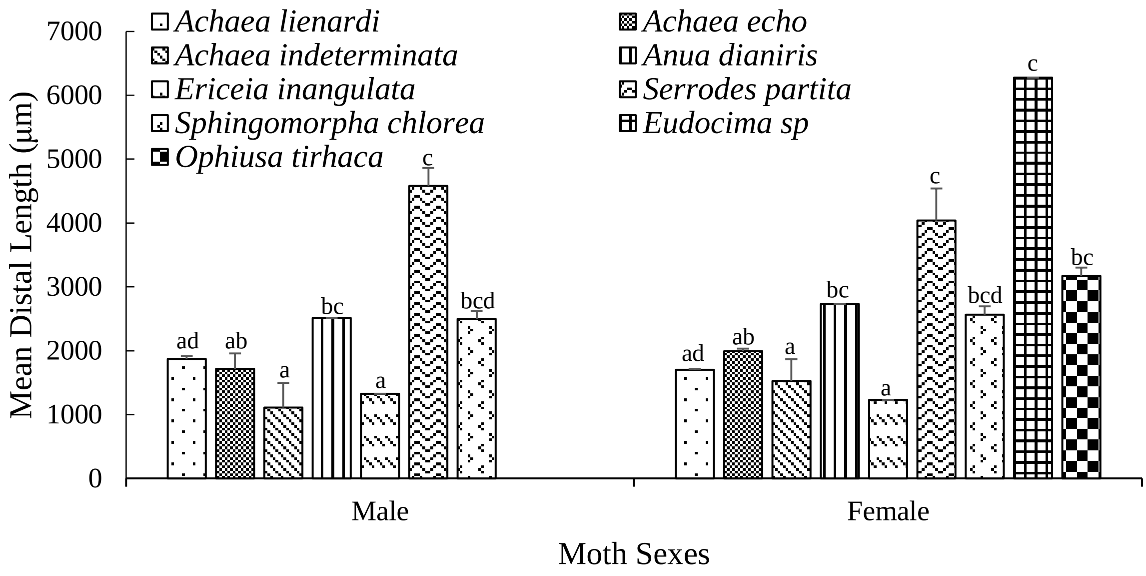


**Figure 3.3:** Mean (± SE) distal length of the proboscides in µm of female species of *Eudocima* sp., *Ophiusa tirhaca* and male and female species of *Achaea echo, Achaea indeterminata*, *Achaea lienardi*, *Achaea dianiris*, *Ericeia inangulata*, *Serrodes partita*, and *Sphingomorpha chlorea*.

Both the male and female of *S. partita* (Table 3.2, Fig. 3.4 A and B) showed the presence of erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb) and dorsal galeal linkages (dgl), whereas *Eudocima* sp. (Table 3.2, Fig. 3.4 C) showed the presence of erectile barbs (eb) and tearing hooks (th), serrate ridge (sr) and dorsal galeal linkages (dgl) on their proboscis, all necessary morphological adaptations to pierce through the skin of fruit.

**Table 3.2:** Morphological structures measured on the proboscis and linking *Achaea lienardi*, *Achaea indeterminata*, *Achaea echo*, *Anua dianiris*, *Ericeia inangulata*, *Ophiusa tirhaca*, *Serrodes partita, Eudocima* sp. and *Shingomorpha chlorea* into a feeding group.

| | | Proboscis structures | | | | | |
|---|---|---|---|---|---|---|---|
| **Moth Species** | **Sex** | **feb** | **th** | **ST** | **sr** | **eb** | **Feeding group** |
| *Achaea lienardi* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |
| *Achaea echo* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |
| *Achaea indeterminata* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |
| *Anua dianiris* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |
| *Ericeia inangulata* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |
| *Eudocima sp* | Female | - | + | - | + | + | **FPM** |
| *Ophiusa tirhaca* | Female | - | - | + | - | - | **FSM** |
| *Serrodes partita* | Male | + | + | - | - | + | **FPM** |
| | Female | + | + | - | - | + | **FPM** |
| *Sphingomorpha chlorea* | Male | - | - | + | - | - | **FSM** |
| | Female | - | - | + | - | - | **FSM** |

+ present on proboscis; - not present
feb - Furcate Erectile Barbs; th - Tearing Hooks; ST - Sensilla styloconica; sr - Serrate Ridge; eb - Erectile Barbs
FSM - fruit-sucking moth; FPM - fruit-piercing moth

Both male and female species of *A. lienardi* (Table 3.2, Fig. 3.5 A and B), *A. indeterminata* (Table 3.2, Fig. 3.6 A and B), *A. echo* (Table 3.2, Fig. 3.5 C and D), *S. chlorea* (Table 3.2, Fig. 3.7 C and D), *A. dianiris* (Table 3.2, Fig. 3.6 C and D), *E. inangulata* (Table 3.2, Fig. 3.7 A and B) and female of *O. tirhaca* (Table. 3.2, Fig 3.4 D) lack the necessary structures in order to pierce the skin of fruit such as, erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb), serrate ridge (sr) but they all do have sensilla styloconica (ST), and dorsal galeal linkages (dgl), which are regarded to be morphological adaptations for fruit-sucking moths.

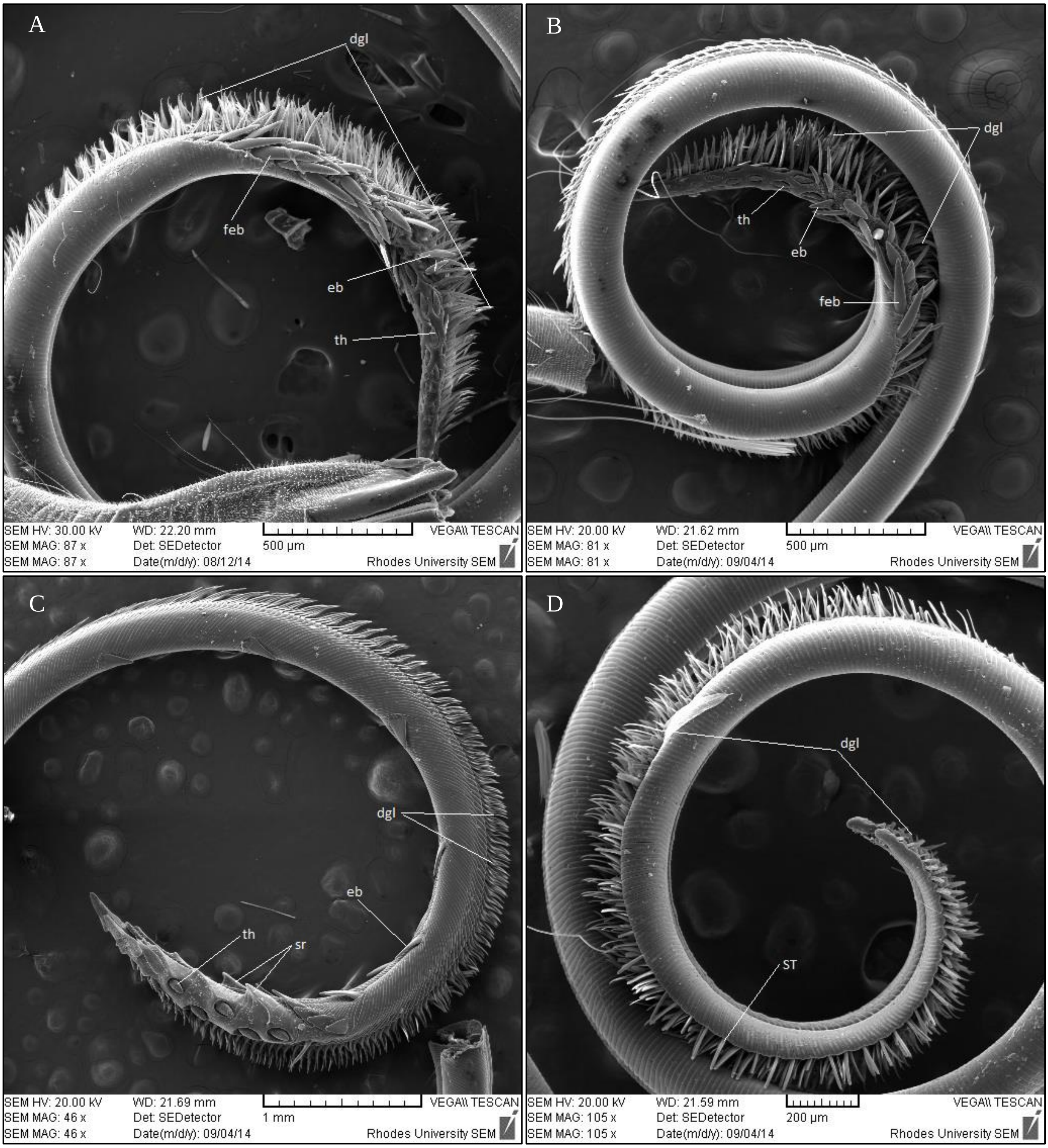


**Figure 3.4**: Scanning electron micrographs images of proboscides of *Serrodes partita* male (A), female (B), *Eudocima sp.* (C) and *Ophiusa tirhaca* (D). Erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb), sensilla styloconica (ST), serrate ridge (sr) and dorsal galeal linkages (dgl).

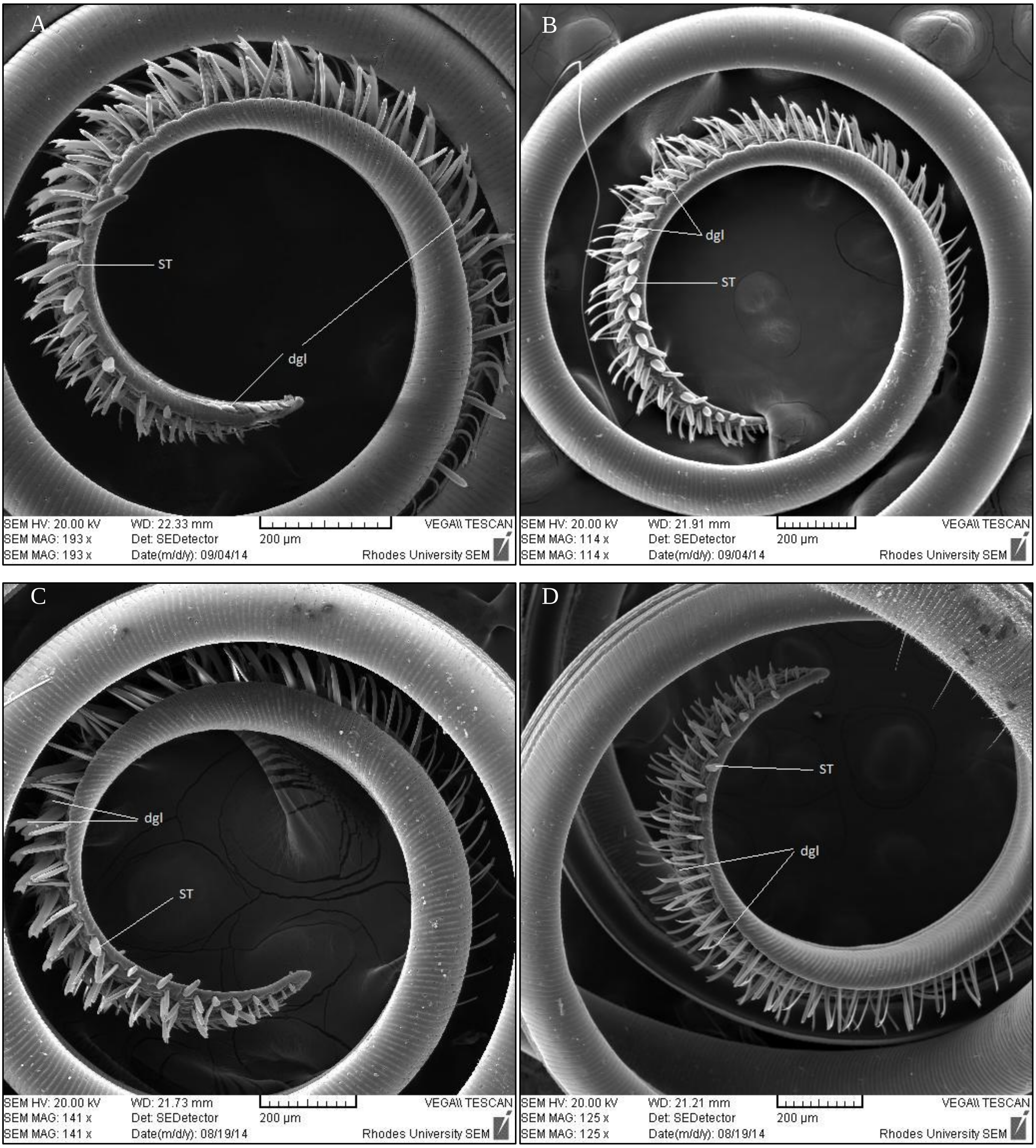


**Figure 3.5**: Scanning electron micrographs images of proboscides of *Achaea lienardi* female (A), male (B) and *Achaea echo* female (C), male (D). Erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb), sensilla styloconica (ST), serrate ridge (sr) and dorsal galeal linkages (dgl).

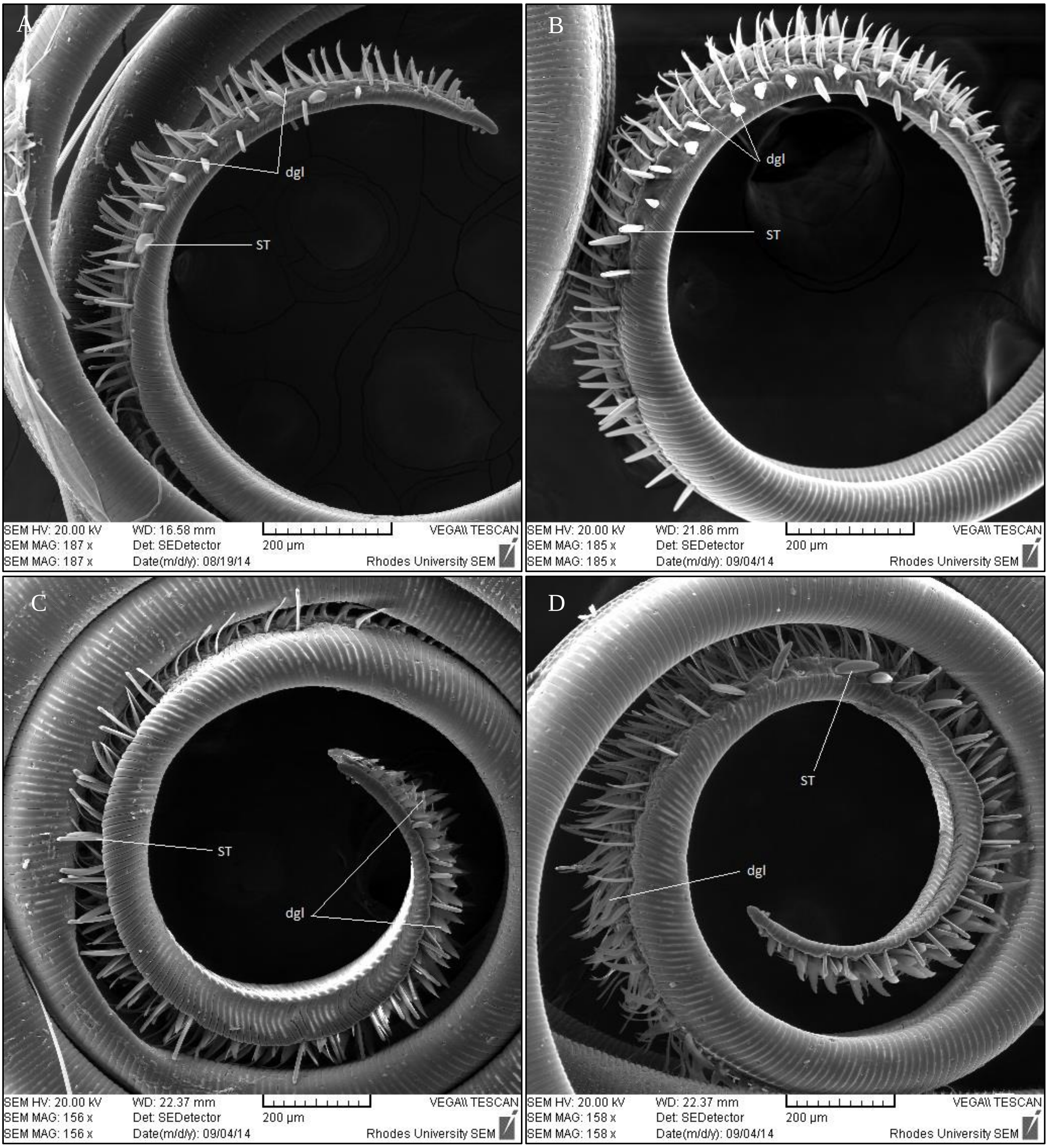


**Figure 3.6**: Scanning electron micrographs images of proboscides of *Achaea indeterminata* female (A), male (B) and *Anua dianiris* female (C), male (D). Erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb), sensilla styloconica (ST), serrate ridge (sr) and dorsal galeal linkages (dgl).

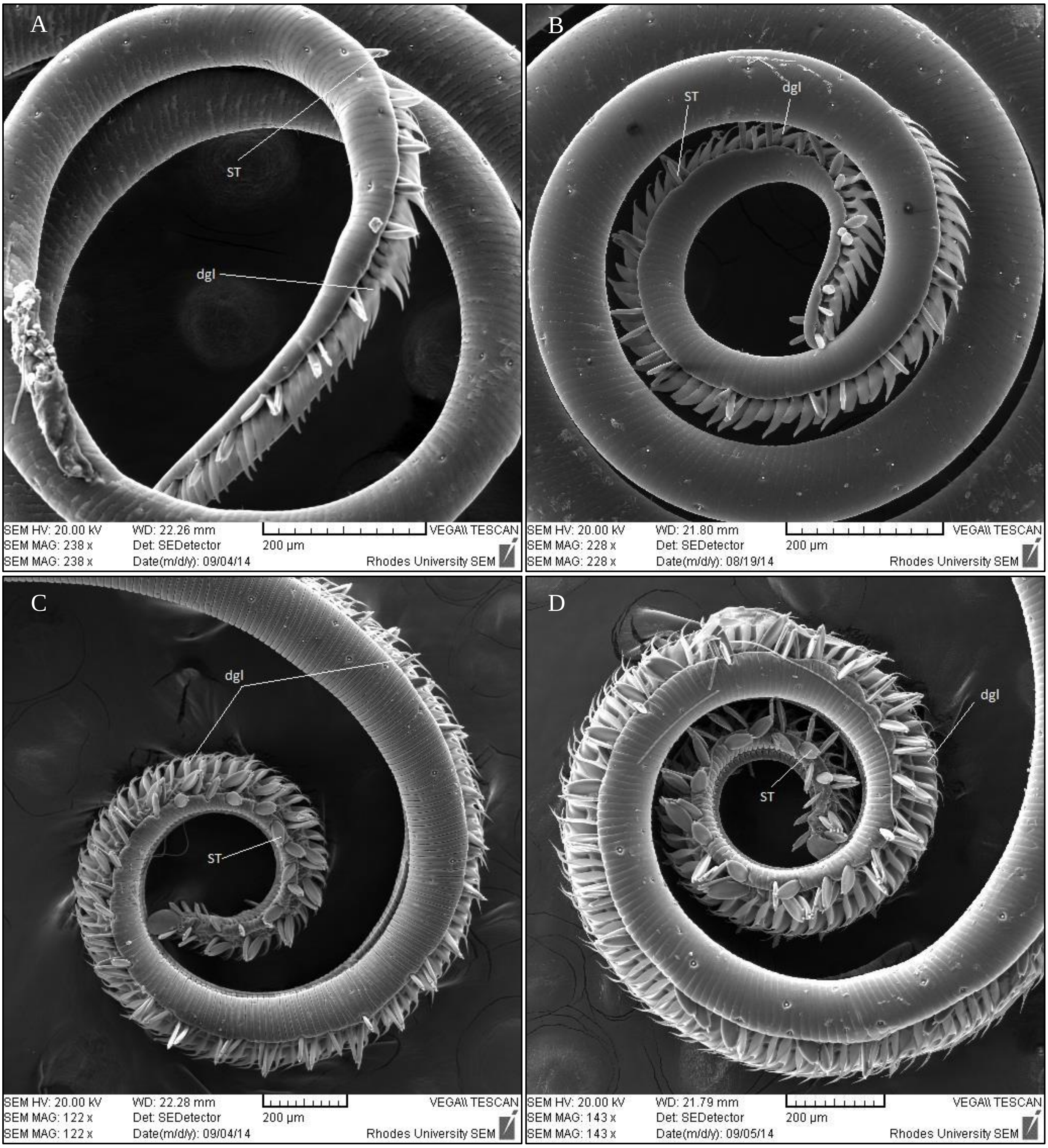


**Figure 3.7**: Scanning electron micrographs images of proboscides of *Ericeia ingulata* female (A) male (B) and *Sphingomorpha chlorea* female (C), male (D). Erectile barbs (eb) and tearing hooks (th), furcate erectile barbs (feb), sensilla styloconica (ST), serrate ridge (sr) and dorsal galeal linkages (dgl).

## 3.4 Discussion

The results of this study showed that, based on proboscis structure, *S. partita* and *Eudocima*, were the only fruit-piercing moths and that *A. lienardi, A. indeterminata, A. echo, S. chlorea, A. dianiris, E. inangulata* and *O. tirhaca* are fruit-sucking moths. However, there was no difference between the male and female proboscides for each species. This was not expected, as female moths need the extra nutrition for egg development, where males do not. However the energy required to migrate large distances each night would demand a high energy intake for both males and females; therefore this could explain why both male and female proboscides are morphologically the same. The presence of erectile barbs, furcate erectile barbs and tearing hooks, the former used for mechanoreception (Büttiker *et al.* 1996) and the latter for piercing soft-skinned fruit (Bänziger 1970), on the proboscides of both male and female *S. partita,* indicate that this species is a primary piercer of soft-skinned fruit. The presence of erectile barbs, serrate ridges and tearing hooks, the former used for mechanoreception (Büttiker *et al.* 1996) and the latter for piercing hard-skinned fruit (Bänziger 1970), on the proboscides of *Eudocima* sp., indicate that this species is a primary piercer of hard-skinned fruit. The lack of structures on the proboscides of both males and females of *A. lienardi, A. indeterminata, A. echo, S. chlorea, A. dianiris, E. inangulata* and *O. tirhaca* females indicate that none of these species is capable of piercing fruit and can therefore only access the fruit of citrus once the rind has already been pierced or damaged by other means. As *Achaea* spp. do not have the specialized proboscis to be a fruit-piercing moth, they are only able to feed on damaged fruit (Hattori 1969; Krenn 2010; Zaspel *et al.* 2011; Zenker *et al.* 2011; Büttiker *et al.* 1996).

The function of the dorsal galeal linkages (dgl) is to keep the two tubes of the proboscis sealed together. The length of the dgl, can be related to the proboscis strength and the intensity of the movement required of the proboscis to tear through the flesh of the fruit and access the juice (Büttiker *et al.* 1996). This is possibly why *S. partita* and *Eudocima* sp. are primary piercers of fruit, as their dgl are longer than the other species. The other species, *A. lienardi, A. indeterminata, A. echo, S. chlorea, A. dianiris, E. inangulata and O. tirhaca*, possess a shorter dgl, which could explain why these moths feed on damaged fruit and are thus regarded as fruit sucking moths, as their proboscides cannot exert the necessary extreme pressure to pierce healthy fruit. Therefore they cannot access their food by piercing the rind.

This relationship was also shown in the distal length of the proboscis, as *Eudocima* sp. had the longest proboscis and *S. partita* the second longest. The distal end of the proboscis showed a number of suction holes, which allow for fluid uptake and opened into the food canal (Krenn 1990, 1998; Paulus & Krenn 1996). This would allow for a higher volume of fluid to be taken up by fruit-piercing moths than by fruit-sucking moths.

The evidence reported in this chapter has demonstrated which species are fruit-piercing moths and which are fruit-sucking moths. *Serrodes partita* was shown to be the only fruit-piercing moth found within the Eastern Cape growing regions, where *Eudocima* sp. was the only fruit-piercing moth species in the Tshipise growing region (Chapter 2). However, although the proboscis structure is a diagnostic trait of fruit-piercing moths, it is not practical for growers to identify these traits in the field. It would be ideal for the growers to be able to identify which species are in fact fruit-piercing moths and which are fruit-sucking moths. However, these moths are hard to distinguish one from another and there is a need to produce a better identification guide for growers.

# Chapter 4

## DEVELOPING A SUITABLE ATTRACTANT FOR FRUIT-FEEDING MOTHS IN CITRUS ORCHARDS

### 4.1 Introduction

In the 1920s the most common practice for the control of fruit-feeding moths in orchards was to bait traps with poisoned fruit (Gunn 1929), but this method was not effective and killed few fruit-feeding moths and hardly any fruit-piercing moths (Johannsmeier 1998; Gunn 1929). In South Africa during the 1960s repellent lights were first used and were placed in the orchards to deter fruit-piercing moths from entering the orchards (Johannsmeier 1998; Whitehead & Rust 1967, 1971, 1972). However, baits such as fermenting fruit have been used in recent times to control a wide variety of fruit-feeding moths and as these baits are not specific there is often a substantial non-target effect (see Chapter 2) (Robinson *et al.* 2012; Johannsmeier 1998).

Reddy and Muniappan (2007) compared different fruit baits in order to attract the fruit-piercing moth *Eudocima* (*fullonia*) *phalonia* (Clerck, 1764) and showed that banana was the most attractive to this fruit-feeding moth. Therefore, in 2010 Robinson *et al.* (2012) attempted to develop a suitable attractant to monitor fruit-feeding moths in the Sundays River Valley growing region, where they compared banana, a variety of fruit baits and a registered attractant for fruit-piercing moths from Australia. These baits were, Magnet®, Texas Volatile™, molasses, banana and citrus. Magnet® and Texas Volatile™ were chosen as they were both commercially available products for monitoring *Helicoverpa* spp. (Lepidoptera) in a wide range of crops and the latter product is also used to monitor tomato semi-looper, *Chrysodeixis acuta* (Walker) (Lepidoptera: Noctuidae). Robinson *et al.* (2012) showed that banana was the most successful bait in attracting fruit-feeding moths in the Eastern Cape. However, banana does not stay fresh long enough in the orchards and it becomes laborious and hence costly to re-bait traps every 2-3 days during the growing season.

The aim of this chapter was thus to investigate a suitable attractant to monitor fruit-feeding moths. If such an attractant could be identified, its use could then be expanded to test for control of the moths as an attract and kill tactic.

## 4.2 Materials & Methods

During the 2013 growing season two regions were chosen to conduct the field trial, both based in the Eastern Cape. The first site was located within the Kat River Valley growing region, at Riverside (32°45’44”S, 26°36’50”E) and the second site, Mosslands fell within the Grahamstown growing region (33°23’55”S, 26°25’38”E), which is situated 20km outside of Grahamstown. The research continued in 2014 and 2015 in the Kat River Valley, with the addition of the Sundays River Valley region. Within the Sundays River Valley growing region, Dunbrody Estates-Enterprise (33°29’03”S, 25°34’30”E) was selected and Blinkwater (32°39’34”S, 26°32’35”E) was selected in the Kat River Valley growing region. All orchards grew the same variety of citrus, Satsuma Mandarin, as this is an early ripening variety of citrus fruit and has been affected by *S. partita* in the past.

The traps used were yellow bucket funnel traps (Fig. 4.1) (Insect Science, Tzaneen, South Africa), and were placed in the orchards at the end of January 2013 and 2014, and at the end of February 2015. Each trap had a dichlorovos block (Vapona) placed inside it to kill any attracted insects without damaging them, so they could be pinned and identified.

### 4.2.1 Comparing fresh banana to a variety of artificial banana baits

Banana was shown by Robinson *et al.* (2012), to be the most successful bait in attracting fruit-feeding moths, *S. partita* and *A. lienardi*. In this study banana was compared to a variety of artificial baits in the hope of finding an artificial replacement for fresh banana, as such a bait would be preferable due to its longer field life. In 2013 (Table 4.1) isopentyl acetate, an artificial flavour for processed banana foods was compared to fresh banana and used to monitor fruit-feeding moths in the Kat River Valley area and Grahamstown growing region. The study continued into 2014 and 2015, where in 2014 fresh banana was compared to frozen banana, four artificial carp baits (which are used for fishing; each bait contained a different artificial banana flavour), a banana weevil (*Cosmopolites sordidus* (Germar, 1824)

(Coleoptera: Curculionidae)) lure and a control (no bait) (Table 4.1). In the 2015 growing season, fresh banana was compared to three different ripening stages of banana, made from a suite of chemicals that represented each of the ripening stages and a control (Table 4.1).

**Table 4.1:** Bait types used in field sampling from 2013 – 2015.

| Bait Type | Description | Year |
|---|---|---|
| Fresh banana | Freshly squashed banana | 2013-2015 |
| Isopentyl acetate | Banana oil/essence | 2013 |
| Frozen banana | Squashed banana, frozen for 24 hours | 2014 |
| B.W Lure | Banana weevil lure (B.W PheroLure) from Insect Science | 2014 |
| BC | Carp bait | 2014 |
| BS | Carp bait | 2014 |
| BD | Carp bait | 2014 |
| BB | Carp bait | 2014 |
| R 1 | % Peak area ripening stage 6 of banana | 2015 |
| R 2 | % Peak area ripening stage 7 of banana | 2015 |
| R 3 | % Peak area ripening stage 8 of banana | 2015 |
| Control | Empty | 2014-2015 |

* R 1, R 2, R 3 - Thaiphanit & Anprung 2010

### 4.2.2 Trap numbers and placement within the orchards

The traps were placed on trees in the north-eastern side of each orchard (Fig. 4.2) because these trees are the most affected by *S. partita*, as the moths generally come from the north of the orchards, as the moths tend to fly into the prevailing wind in the Eastern Cape, which is generally southerly. The traps were placed on the southern side of the selected trees so that they could be shaded from rapid desiccation. Each trap was secured at approximately 2 m high (Fig. 4.2). In order to protect traps from undesirable environmental effects, such as excessive wind and dust, the traps were placed in the third row from the northern edge and four trees in, so they would all have an equal chance of attracting moths. Traps were placed 12 m apart, with traps being evenly spaced in each orchard. This spacing was used (Fig. 4.2) to reduce the chance of competition between baits but still close enough to expose the baits to the same moth population, making a fair comparison between baits. The baits were placed inside an open plastic cage that attached to the lid of the yellow bucket funnel trap (Fig. 4.1).

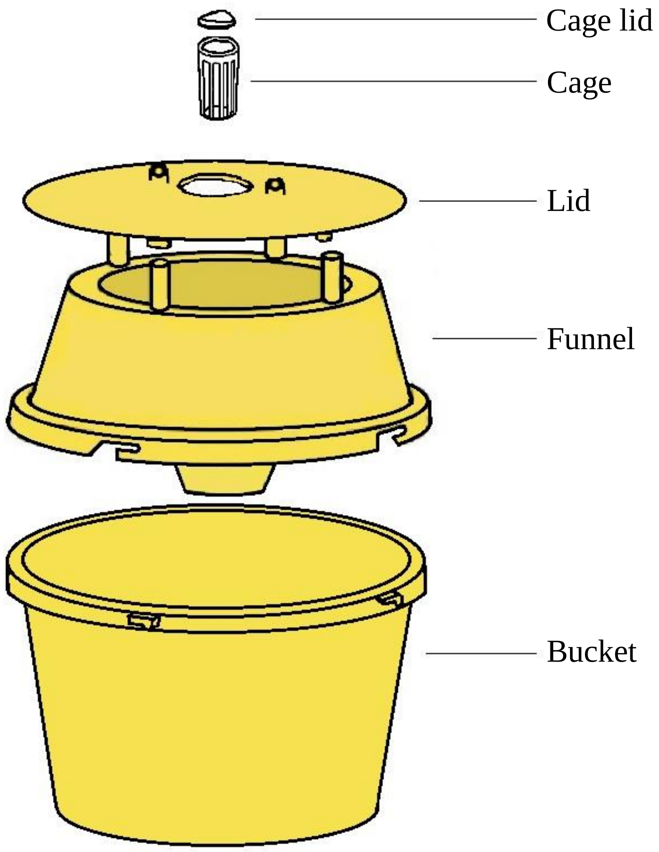


**Figure 4.1**: Layout of the yellow bucket funnel trap.

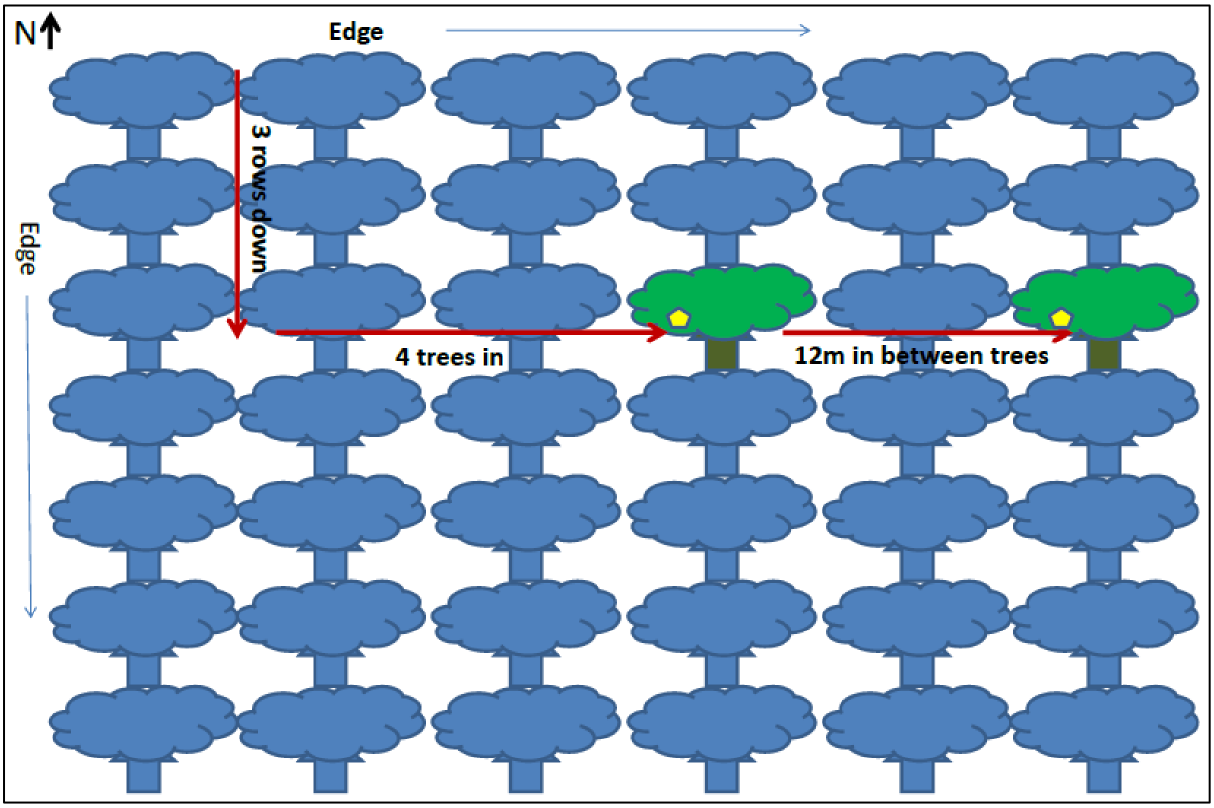


**Figure 4.2**: Layout of trap trees in orchards for monitoring of fruit feeding moths.

Traps were monitored weekly in each of the three consecutive years, where the moths sampled in each trap were collected, so they could be identified at a later stage. Once the moths were removed from the traps, the baits were replaced weekly.

During the 2013 season, traps were placed in the orchards in the Kat River and Grahamstown growing regions (Table 4.2). A total of 24 traps were used: 12 traps were placed in the Kat River Valley Growing region at Riverside; 12 traps were placed in the Grahamstown growing region at Mossland. These traps were placed alternately, banana and then isopentyl acetate, with six traps for each. This was done to reduce the chance of competition between baits, making a fair comparison.

For the 2014 season, a total of 96 traps were set up to compare the variety of baits: 48 traps were placed in the Kat River Valley growing region, at Blinkwater; 48 traps were set up in the Sundays River Valley growing region at Dunbrody Estates-Enterprise. The six replicates of each of the eight baits (Table 4.1) were positioned in a regular order in the orchards (Table 4.2).

In 2015, a total of 60 traps were used to compare the bait types to banana, 30 of which were used in the Kat River Valley region, at Blinkwater and 30 traps were placed in the Sundays River Valley region at Dunbrody Estates-Enterprise. The six replicates of each of the five baits (Table 4.1) were positioned in a regular order in the orchards (Table 4.2).

**Table 4.2:** The dates when traps were placed in each orchard, with the total number of baits and traps used in each orchard during the sampling periods from 2013 – 2015.

| **Traps** | | | | **Sampling Area** | |
|---|---|---|---|---|---|
| **Placed** | **Removed** | **Total Used** | **Number of Baits** | **Orchard** | **Growing region** |
| 31/01/2013 | - 25/04/2013 | 12 | 2 | Mosslands | Grahamstown |
| | | | | Riverside | Kat River Valley |
| 29/01/2014 | - 29/04/2014 | 48 | 8 | Blinkwater | Kat River Valley |
| 25/02/2015 | - 09/04/2015 | 30 | 5 | Blinkwater | Kat River Valley |
| 30/01/2014 | - 30/04/2014 | 48 | 8 | Dunbrody Estates-Enterprise | Sundays River Valley |
| 26/02/2015 | - 02/04/2015 | 30 | 5 | Dunbrody Estates-Enterprise | Sundays River Valley |

### 4.2.3 Statistical analysis

For the 2013 data, a Mann-Whitney U test was used to compare the moth numbers sampled with the two bait types, as the data were not normally distributed. For the 2014 and 2015 data, a Kruskal-Wallis test was used to compare moth numbers sampled using the different bait types between orchards, as this is the appropriate analysis for non-normally distributed multiple treatments. All Statistical analyses were conducted using Statistica 12 (2014).

## 4.3 Results

In the following section all statistical differences are shown by letters on the graphs. Where the letters differ, differences are significant; where the letters are the same, differences are not significant. Tables of statistical values are presented in Appendix IV.

### 4.3.1 Comparing fresh banana to a variety of artificial banana baits

#### 4.3.1.1 Kat River Valley and Grahamstown

During 2013, banana was significantly more attractive to fruit-feeding moths than isopentyl acetate ($p = 0.0001$) (Fig. 4.3) (Table IV.1).This applied to both *S. partita* ($p = 0.0109$) (Table IV.2) and *Achaea* spp. ($p = 0.0001$) (Table IV.2).

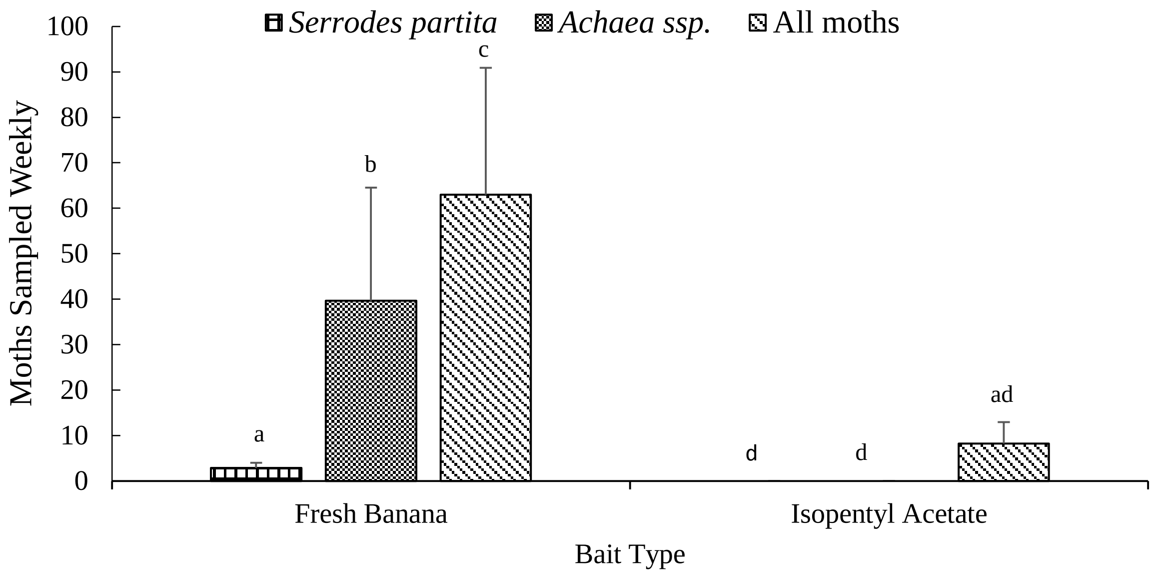


**Figure 4.3:** Mean ± SE number of moths (*Serrodes partita*, *Achaea* spp. and total moths) sampled in 6 traps per bait type (banana and isopentyl acetate), per week over a 12 week sampling period at both Mosslands and Riverside during 2013.

During 2014 in Kat River Valley, fresh banana was significantly more attractive to fruit-feeding moths than any other bait type (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Fig. 4.4) (Table IV.3). There was no significant difference in the attraction of *S. partita* and *Achaea* spp. to frozen and fresh banana. However, the other bait types attracted significantly fewer *S. partita* (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Table IV.4) and *Achaea* spp. (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Table IV.4).

The results obtained in 2015 were similar to those of 2014 in Kat River Valley. Banana was significantly more attractive to fruit-feeding moths than any other bait type (R1, p = 0.0001; R2, p = 0.0001; R3, p = 0.0001; Control, p = 0.0001) (Fig. 4.5) (Table IV.5). Furthermore, banana was significantly more attractive to *S. partita* (R1, p = 0.0236; R2, p = 0.0127; R3, p = 0.0429; Control, p = 0.0127) (Table IV.6) and *Achaea* spp. (R1, p = 0.0050; R2, p = 0.0004; R3, p = 0.0002; Control, p = 0.0001) (Fig. 4.5) (Table IV.6) than the other bait types.

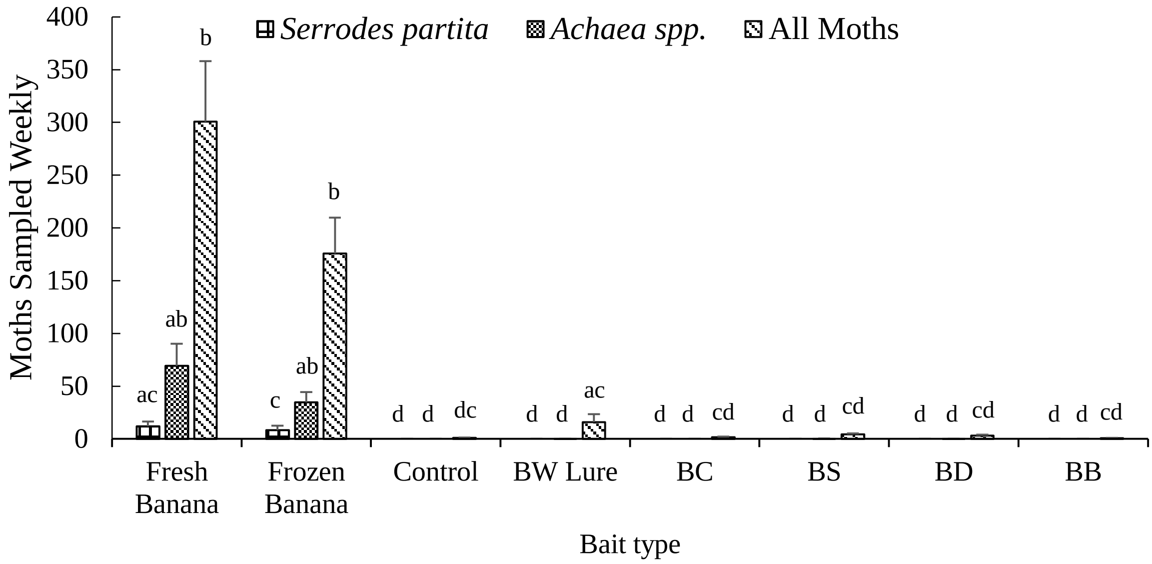


**Figure 4.4:** Mean (± SE) number of moths (*Serrodes partita, Achaea* spp. and total moths) sampled in 6 traps per bait type per week over a 12 week sampling period at Blinkwater during 2014. Baits compared were banana (fresh and frozen) and BW Lure, BC, BS, BD, BB and a control.

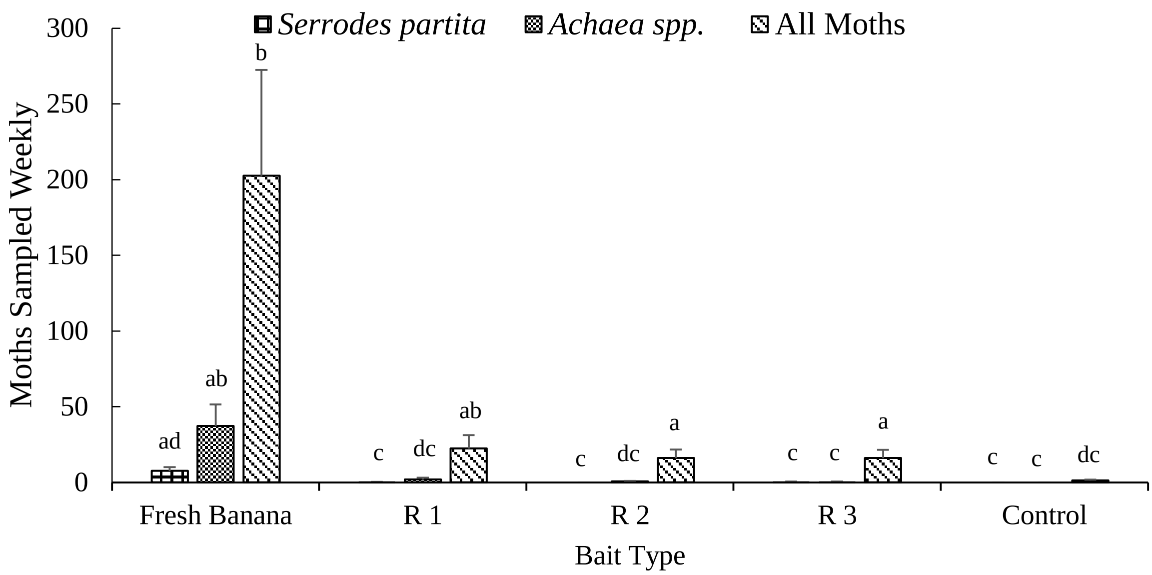


**Figure 4.5:** Mean (± SE) number of moths (*Serrodes partita, Achaea* spp. and total moths) sampled in 6 traps per bait type per week over a 5 week sampling period at Blinkwater during 2015. Baits compared were fresh banana, R 1, R 2, R 3 and a control.

#### 4.3.1.3 Sundays River Valley

In Sundays River Valley in 2014, banana (fresh and frozen) was significantly more attractive to fruit-feeding moths than any other bait type (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Fig. 4.6) (Table IV.7). Similar to the results at Kat River Valley, there was no significant difference in the attraction of *S. partita* and *Achaea* spp. to fresh or frozen banana. However, the other bait types attracted significantly fewer *S. partita* (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Table IV.8) and *Achaea* spp. (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Table IV.8).

The results obtained in 2015 were shown to be similar to 2014 as banana was once again attracted significantly more fruit-feeding moths than the other bait types (R1, p = 0.0001; R2, p = 0.0001; R3, p = 0.0001; Control, p = 0.0001) (Table IV.9). However, there were fewer *S. partita* sampled during this year than the previous year, resulting in there being no significant difference between banana and other bait types (Fig. 4.7) (Table IV.10). Similarly, this was also shown for *Achaea* spp. (Fig. 4.7) (Table IV.10).

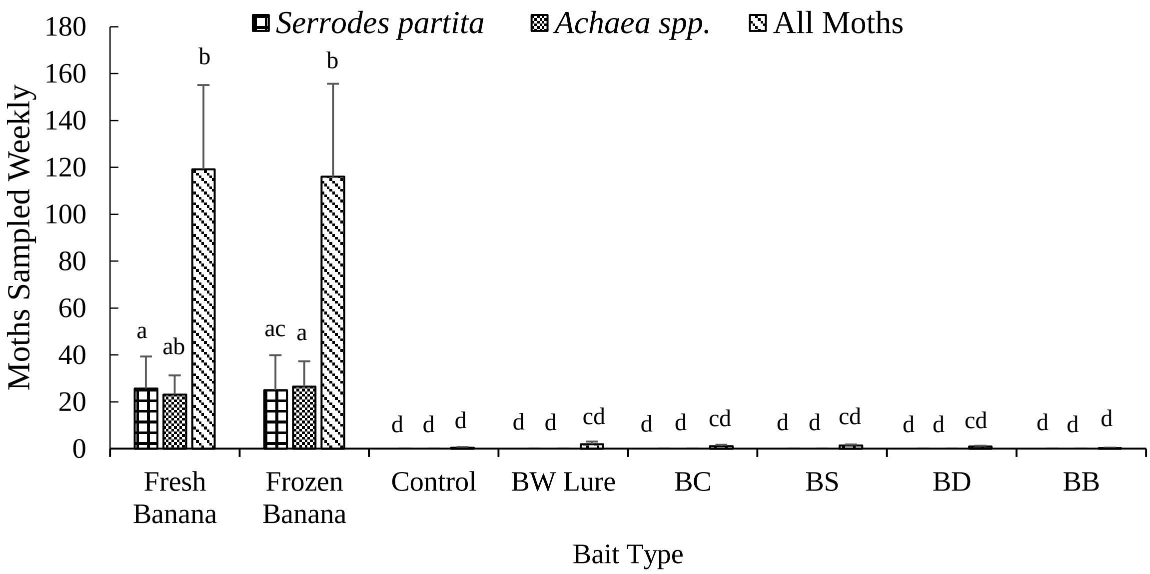


**Figure 4.6:** Mean (± SE) number of moths (*Serrodes partita*, *Achaea* spp. and total moths) sampled in 6 traps per bait type per week over a 12 week sampling period at Dunbrody Estate - Enterprise for 2014. Baits compared were banana (fresh and frozen) and BW Lure, BC, BS, BD, BB and a control.

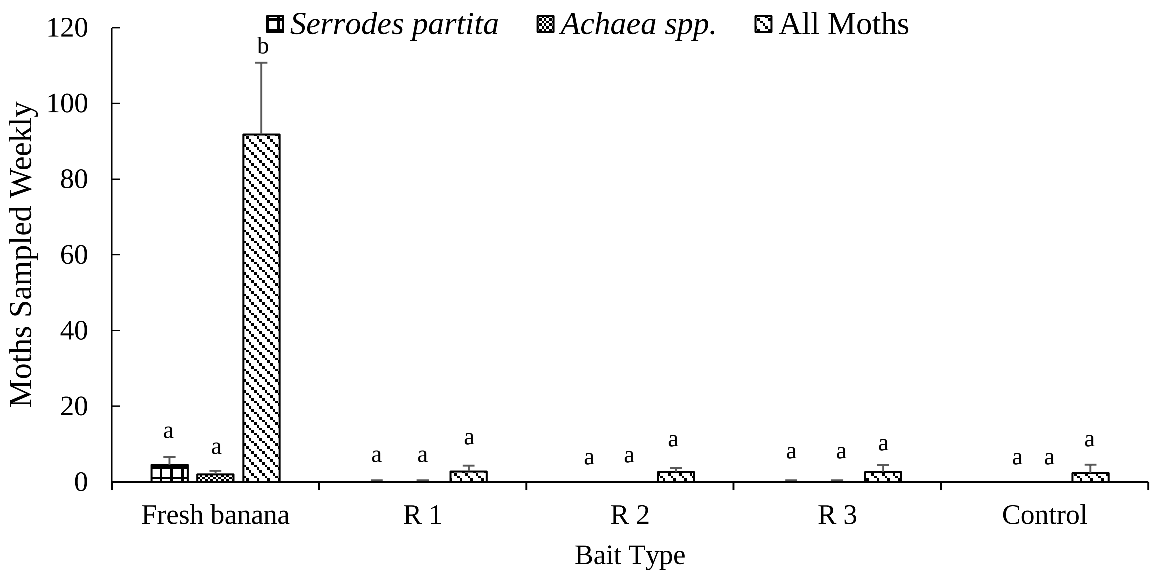


**Figure 4.7:** Mean (± SE) number of moths (*Serrodes partita, Achaea* spp. and total moths) sampled in 6 traps per bait type per week over a 5 week sampling period at Dunbrody Estate-Enterprise for 2015. Baits compared were fresh banana, R 1, R 2, R 3 and a control.

#### 4.3.1.3 Kat River Valley and Sundays River Valley

In 2014, the combined trap catches from Kat River Valley and Sundays River Valley showed that banana (fresh and frozen) was significantly more attractive to fruit-feeding moths than any other bait type (BW Lure, p = 0.0001; BC, p = 0.0001; BS, p = 0.0001; BD, p = 0.0001; BB, p = 0.0001; Control, p = 0.0001) (Table IV.11). There was no significant between fresh or frozen banana. However, when comparing Kat River Valley and Sundays River Valley, there was no significant difference in trap catches of *S. partita* (Table IV.12). Similarly, there was no significant difference in trap catches of *Achaea* spp. between Kat River Valley and Sundays River Valley.

The results obtained in 2015 were shown to be similar to 2014 as banana was once again attracted significantly more fruit-feeding moths than the other bait types (R1, p = 0.0001; R2, p = 0.0001; R3, p = 0.0001; Control, p = 0.0001) (Table IV.13). There was also no significant difference, when comparing the trap catches of *S. partita* and *Achaea* spp. between Kat River Valley and Sundays River Valley (Table IV.14).

## 4.4 Discussion

The aim of this study was to find a cost effective and practical method for attracting fruit-feeding moths to traps as a monitoring tool, and possibly an attract and kill tactic. The best attractant for fruit-feeding moths was banana, as was the finding by Robinson *et al*. (2012) and consistent with the finding by Reddy and Muniappan (2007) and Johannsmeier (1998), who mentioned that fruit-piercing moths are attracted to ripe bananas. Reddy and Muniappan (2007) compared the attraction of 15 fruit baits (banana, guava, orange, kiwi, apple, pineapple, pear, papaya, mango, grapefruit, tomato, green grape, star fruit, plum and soursop), to *E. phalonia*, which is a major pest on citrus and other commercial fruit crops throughout the tropics, mainly in Asia, Africa and Australia. *Eudocima phalonia* was shown to prefer to feed on banana baits more than on any other. Reddy and Muniappan (2007) and Johannsmeier (1998) both suggest that these studies identified valuable attractants which may be used as part of a lure and kill strategy for this important pest and also form a foundation upon which future bioassay-driven fractionation and chemical structure elucidation can be developed.

In the current study, bait types other than banana showed little or no attraction to fruit-feeding moths. Even though isopentyl acetate, commonly known as banana oil or banana essence, gives off a banana smell and is used in banana and other fruit sweets (Jordán *et al.* 2001), it was not attractive to fruit-feeding moths. In 2014 when fresh banana was compared to frozen banana, there was no significant difference in their attractiveness. There must therefore be a fundamental volatile or bouquet of volatiles found within fresh banana or either formed during the fermenting process or once the banana has fermented. Confirming this, when fresh banana was compared to the other attractants in 2014, fresh banana was the most attractive to fruit-feeding moths and particularly *S. partita*. During the 2015 season, fresh banana was again shown to be the most attractive, even though *S. partita* has never been recorded as a pest on bananas. This could be due to the fact that bananas are harvested when green and then ripened artificially after harvest and thus not exposed to moth damage (Grierson 1995; Marriott & Palmer 1980).

Adult fruit-feeding lepidopterans are attracted more too ripe fruit than unripe fruit, as ripe fruit has a higher percentage of carbohydrates than unripe fruit (Bauerfeind *et al*. 2007), and carbohydrates have been shown to help with egg development (Reddy & Muniappan 2007;

Fay & Halfpapp 2001). This could explain why fruit-feeding moths found banana more attractive than the synthetic alternatives, as banana consists 33.8 % of carbohydrates (dry weight) (Waliszewski *et al.* 2002). However there could possibly be no immediate attraction of these moths to fresh banana, but only after a period of days once fermentation of banana has begun (this might have been establish if traps were monitored daily rather than weekly). Furthermore, as banana ferments, it produces ethanol, which has been recorded to be an olfactory cue for the attraction of moths (Bauerfeind *et al*. 2007).

Neither of the sampling seasons were regarded as an outbreak year, as an average of 4.0 *S. partita* were sampled on a weekly basis during the three sampling seasons in both growing regions. The highest trap catch of *S. partita* occurred during the 2014 sampling season with an average of 5.5 *S. partita* sampled weekly. The region that had the highest trap catch was the Sundays River Valley growing region as it sampled an average of 8.0 *S. partita* in 2014 and 2.0 in 2015, where all the other regions sampled a weekly average of less than 5.0 *S. partita* in 2014 and 1.8 *S. partita* in 2015. These numbers can be considered as a medium infestation as it has been documented that a trap catch of 1000 *S. partita* per 40 data tree was described to be a heavy infestation (Johannsmeier, 1998).

*Achaea* spp. were also monitored using the same baits that were used for *S. partita*, as these two species showed similar peaks in activity throughout the monitoring period, but at higher abundances for *Achaea* spp. This pattern has been observed in outbreak years where both *S. partita* and *Achaea* spp. have been recorded feeding in orchards on fruit at the same time (Moore 2010; Johannsmeier 1998). An average of 6.2 *Achaea* spp. were sampled on a weekly basis during the three sampling seasons in both growing regions. The highest trap catch of *Achaea* spp. occurred during the 2014 sampling season with an average of 9.5 *Achaea* spp. sampled weekly. The region that had the highest trap catch was the Kat River Valley growing region as it sampled an average of 9.4 *Achaea* spp. in 2014 and 3.0 in 2015, where all the other regions sampled a weekly average of 6.0 *Achaea* spp. in 2014 and 1.8 *Achaea* spp. in 2015.

The results presented in this chapter provide useful information for further development of an attractant for monitoring *S. partita* within citrus orchards. However to determine which volatiles within the baits R1 and R3 are attracting *S. partita*, laboratory tests, determining which specific volatile or suite of volatiles from R1 and R3 are attracting *S. partita*, should be conducted so that these could be compared to banana in the field. Furthermore, a better release method for these volatiles should be determined before conducting more field trials.

# Chapter 5

## THE RELATIONSHIP BETWEEN CLIMATE, *SERRODES PARTITA* ACTIVITY AND DAMAGE

### 5.1 Introduction

*Serrodes partita* is a damaging moth in citrus orchards and is the main fruit-piercing moth in South Africa (Robinson *et al.* 2012). The fruit is pierced for its sap by both the male and female adult moths using a strongly sclerotized proboscis (Chapter 3) (Robinson *et al.* 2012; Zaspel *et al.* 2011; Zenker *et al.* 2011; Krenn 2010; Reddy & Muniappan 2007; Büttiker *et al.* 1996; King & Thompson 1958) and the moth will attack green and ripe fruit, but most damage is caused when the moths puncture mature fruit (Ngampongsai *et al.* 2005). The moths only start feeding after sunset and continue until around midnight (Robinson *et al.* 2012). Fruit-piercing moths are also vectors of fruit rot diseases and several types of bacteria (Ngampongsai *et al.* 2005; Bänziger 1982). Damaged fruit is unmarketable and if damaged fruit is packed undetected, it could pose a threat to other fruit through the transfer of pathogens (Fay & Halfpapp 2006, 1999).

Climatic conditions have been shown to affect the activity of moth species and the number of specimens sampled in traps (Yela & Holyoak 1997; Williams 1940). The most important environmental effect on the number of individuals sampled is that of temperature, where the number of individuals sampled increased for every 2.8°C rise in temperature (Yela & Holyoak 1997; Williams 1940). However, temperature has also been reported to have a nonlinear relationship between the number of individuals sampled in traps and temperature and, in some studies, there has also been shown to be no relationship (Yela & Holyoak 1997; Williams 1940). Wind has been shown to reduce the number of individuals sampled in traps, while precipitation can have both positive and negative effects on the number of individuals sampled in trap, depending on the species (Williams 1940, 1961; Yela & Holyoak 1997).

The aims of this chapter were to (1) determine the level of damage caused to fruit in citrus orchards (particularly Satsuma Mandarins) over three seasons (2) determine the relationship between moth activity and the level of damage which they cause to fruit; and (3) establish a relationship between climate and *S. partita* activity in citrus orchards.

## 5.2 Materials & Methods

### 5.2.1 Damage types and the relationship between trap catches of *Serrodes partita* in orchards and fruit damage

Fruit damage on the tree was monitored weekly, for six weeks (Grahamstown and Kat River Valley) in 2013, eight (Sundays River Valley) and 10 (Kat River Valley) weeks in 2014 and four (Sundays River Valley) and five (Kat River Valley) weeks in 2015, after the first signs of ripening until harvest. In the Tshipise growing region, for both 2014 and 2015, fruit were assessed for damage one week before harvest, in the same 10 grapefruit orchards as in Chapter 2 (B2, B3, E2, E5, E11, F1, F2, F8, M2, M7, M9 and M14). The fruit damage survey consisted of inspecting 20 fruit on each of 10 trees in five orchards in 2013 and 10 orchards in both 2014 and 2015, which is similar to the method used by Robinson *et al.* (2012) and King and Thompson (1958). Rows and trees were chosen by using a random number generator. Two minutes was spent at each tree, where fruit were sampled from around the whole tree and the fruit were chosen at random.

A damage guide, similar to that used by Robinson *et al.* (2012) was employed (Fig. 5.1). Damage was recorded and categorised, as being caused by fruit-piercing moth, snails, birds, mechanical (fruit split, damage caused by tractors or by other machinery), diseased fruit (such as citrus scab and misshapen fruit) or other (which was undefined damage, sunburn or other pests, such as red scale or mealybug). However, precise categorisation of damage may not have been 100% accurate, for example, some "snail damage" might have been caused by locusts, and what was defined as diseased fruit might actually have been light chemical burn. However, the identification of fruit-piercing moth damage was accurate, as damage is symptomatically specific to fruit-piercing moths (Fig. 5.2). Fruit-piercing moth damage in each orchard was then compared with the weekly trap catches of *S. partita* reported in Chapter 2.

Orchard:

Row: Tree:

| | Damage Types | | | | | |
|---|---|---|---|---|---|---|
| Tree | Snail | fruit-piecring moth | Bird | Mechanical | Diseased | Other |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |

**Figure 5.1**: Illustration of the data sheet used to differentiate between damage types.

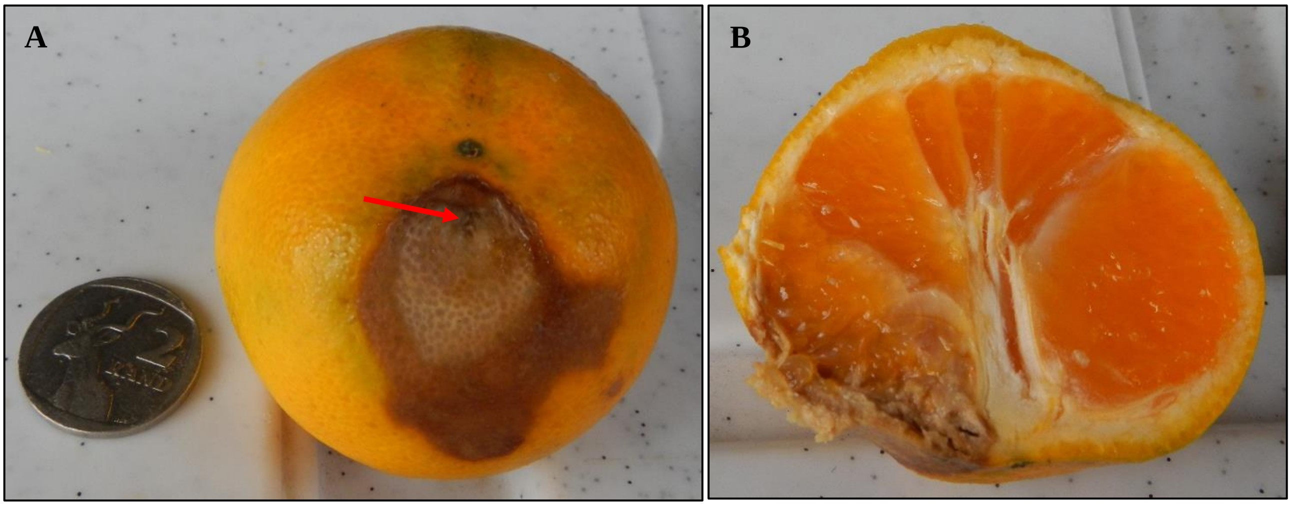


**Figure 5.2:** Fruit-piercing moth damage with distinctive soft brown damaged area (**A**), with the piercing hole indicated by the red arrow; (**B**) dissected fruit showing the damage caused by fruit-piercing moth.

#### 5.2.1.1 Statistical analysis

The data collected was analysed using Statistica 12 (2014) and were not normally distributed and thus failed to meet the assumptions to allow parametric analysis. A Kruskal-Wallis test was thus used to compare the percent damage of each damage type within orchards and fruit-piercing moth damage between orchards in the Grahamstown and Kat River Valley growing regions for the three growing seasons. Further Kruskal-Wallis tests were done to compare the percent damage of each damage type within orchards between the years and fruit-piercing moth damage between the 2014 and 2015 growing seasons in the Kat River Valley and the Sundays River Valley. A Kruskal-Wallis test was done to compare the percent damage of each damage type between the 2014 and 2015 growing seasons in the Tshipise growing region.

The fruit-piercing moth damage observed weekly and the activity of weekly trap catches of *S. partita* in each orchard for all three growing regions in the Grahamstown, Kat River Valley and Sundays River Valley growing region, was not normally distributed, so a non-parametric correlation test was performed to determine if there was a relationship between trap catches of *S. partita* and fruit-piercing moth damage. A Spearman Rank Order Correlation was conducted in Statistica 12 (2014) in order to determine if these relationships were significant.

### 5.2.2 Weather data

Weather data (rainfall, temperature (minimum and maximum), wind speed and direction) for the 2013, 2014 and 2015 growing seasons was obtained from the South African Weather Service. Weather data was compared with the activity of weekly trap catches of *S. partita* in each orchard (from Chapter 2).

#### 5.2.2.1 Statistical analysis

The weather data for each week and the weekly trap catches of *S. partita* in each orchard was not normally distributed so a non-parametric correlation test was done to determine if there was a relationship between trap catches of *S. partita* and the weather data. A Spearman Rank Order Correlation was conducted in Statistica 12 (2014) to determine if these relationships were significant for the three growing seasons in the Kat River Valley growing region and two growing seasons in the Sundays River Valley.

## 5.3 Results

In the following section all statistical differences are shown by letters on the graphs, where the letters differ shows significant difference and where they are the same shows no significance. Tables of statistical values are presented in Appendix V.

### 5.3.1 Damage observed within the orchards

#### 5.3.1.1 Kat River Valley and Grahamstown

During 2013 in Kat River Valley and Grahamstown (Fig. 5.3) there was significantly more fruit-piercing moth damage in Riverside A ($p = 0.0242$) and Riverside B ($p = 0.0016$) than that of Mosslands B (Table V.1), there was no significant difference between fruit-piercing moth damage between the other orchards. There was significantly more fruit-piercing moth damage within Riverside B (Fig. 5.3 D) (Table V.4) than snail ($p = 0.0222$), mechanical ($p = 0.0367$) and other damage ($p = 0.0193$). There were significantly more diseased fruit within Mosslands A (Fig. 5.3 A) (Table V.5) than snail damage ($p = 0.0281$). However, there was no significant difference between damage types within orchards. The overall comparison of damage types for 2013, showed that there was significantly more fruit-piercing moth damage (Table V.7) in the orchards than snail (p = 0.0226) and mechanical damage (p = 0.0051). There were also significantly more diseased fruit (Table V.7) than mechanically damaged (p = 0.0239) fruit within the orchards.

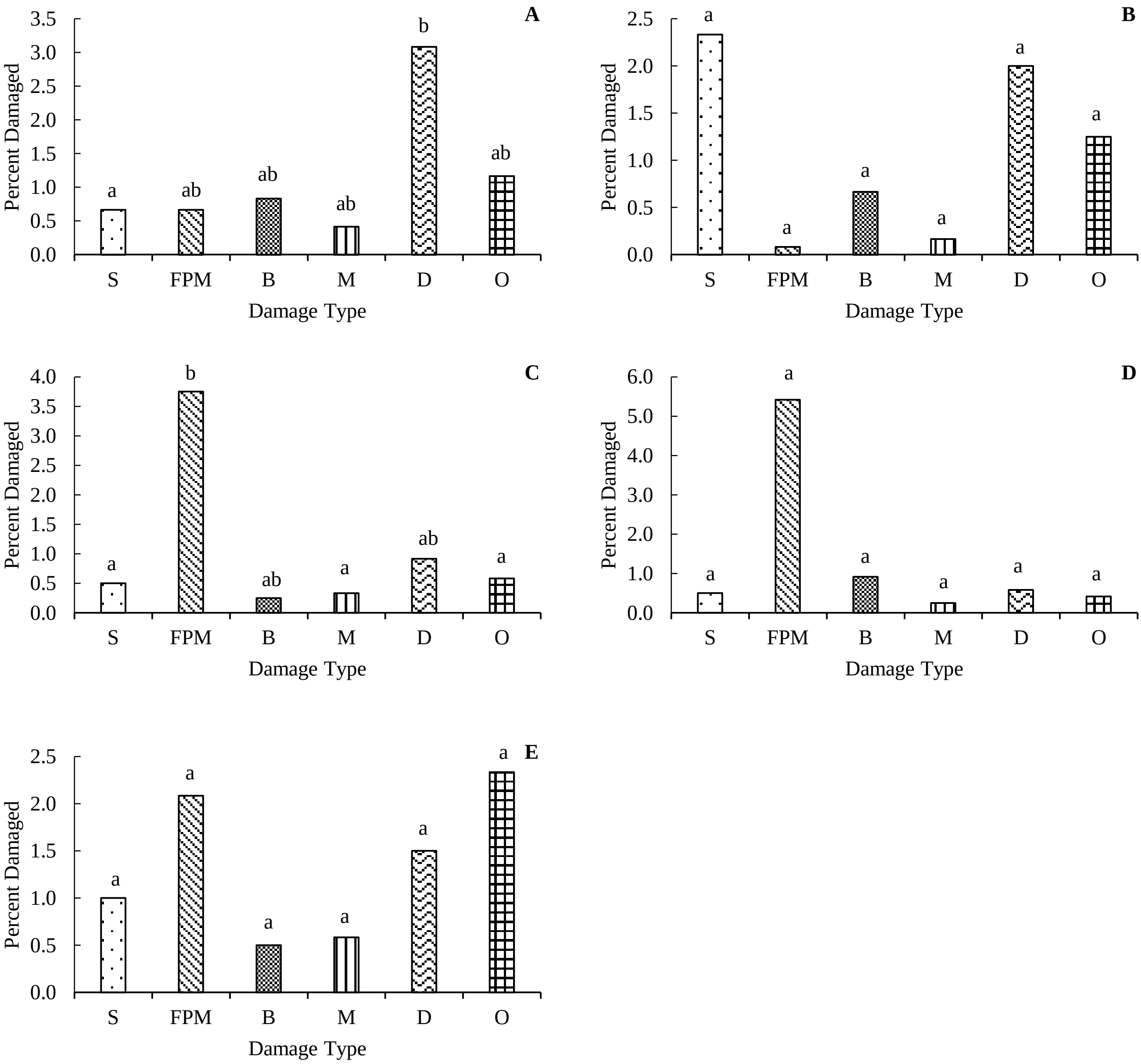


**Figure 5.3**: The total percent damage observed within each damage category over a 5 week period within the orchards in the Kat River Valley and Grahamstown in 2013. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** – Mosslands A; **B** – Mosslands B; **C** – Riverside A; **D** – Riverside B; **E** – Blinkwater.

During 2014 in Kat River Valley (Fig. 5.4) there was significantly more fruit-piercing moth damage (Table V.8) in Riverside B ($p = 0.0083$) and Bath Farm B ($p = 0.0320$) than that of Glinkwater Farm B. However, there was no significant difference between fruit-piercing moth damage between the other orchards. There was significantly more other damage within Bath Farm A (Fig. 5.4 A) (Table V.13) than diseased fruit ($p = 0.0474$). There was significantly more fruit-piercing moth damage within Bath Farm B (Fig. 5.4 B) (Table V.14) than snail ($p = 0.0066$), bird ($p = 0.0362$) and diseased fruit damage ($p = 0.0362$). However, there was no significant difference between damage types within orchards. The overall comparison of damage types for 2014, showed significantly more fruit-piercing moth damage (Table V.15) than snail ($p = 0.0060$) and bird damage ($p = 0.0192$). There was also significantly more other fruit damage (Table V.15) than snail damaged fruit ($p = 0.0341$).

The Kat River Valley in 2015 (Fig. 5.5) there was significantly more fruit-piercing moth damage (Table V.16) in Riverside B ($p = 0.0251$) and Bath Farm A ($p = 0.0097$) than that of Glinkwater Farm B. There was no significant difference between fruit-piercing moth damage between the other orchards. There was significantly more fruit-piercing moth damage than snail damage ($p = 0.0097$), but significantly less than bird damage ($p = 0.0320$) within Glinkwater Farm A (Fig. 5.5 E) (Table V.17). Within Glinkwater Farm B (Fig. 5.5 F) (Table V.18), there was significantly more fruit-piercing moth damage than snail ($p = 0.0049$) and diseased fruit damage ($p = 0.0143$). There was significantly more fruit-piercing moth damage within Riverside A ($p = 0.0236$) (Fig. 5.4 C) (Table V.19) and Bath farm B ($p = 0.0208$) (Fig. 5.5 B) (Table V.22) than snail damage. Whereas in Riverside B (Fig. 5.5 D) (Table V.20) there was significantly more other damage than snail damage ($p = 0.0283$). However, there was no significant difference between damage types within orchards. The overall comparison of damage types indicated that there was significantly more fruit-piercing moth damage (Table V.23) than snail ($p = 0.0001$), bird ($p = 0.0001$) and diseased fruit damage ($p = 0.0001$). Other fruit damage (Table V.23) was significantly more than snail ($p = 0.0001$), bird ($p = 0.0175$) and diseased fruit damage ($p = 0.0004$). Furthermore, mechanical damage (Table V.23) was significantly more than snail damage ($p = 0.0004$).

During 2013, 2014 and 2015 (Table V.24), 2015 had significantly more fruit-piercing moth damage than 2014 ($p = 0.0089$), where there was no significant difference between the other years. When looking if there was an increase in damage within the orchards, Glinkwater

Farm B (Table V.25) showed a significant increase in fruit-piercing moth damage from 2014 to 2015 (p = 0.0024), whereas the other orchards showed no significant increase.

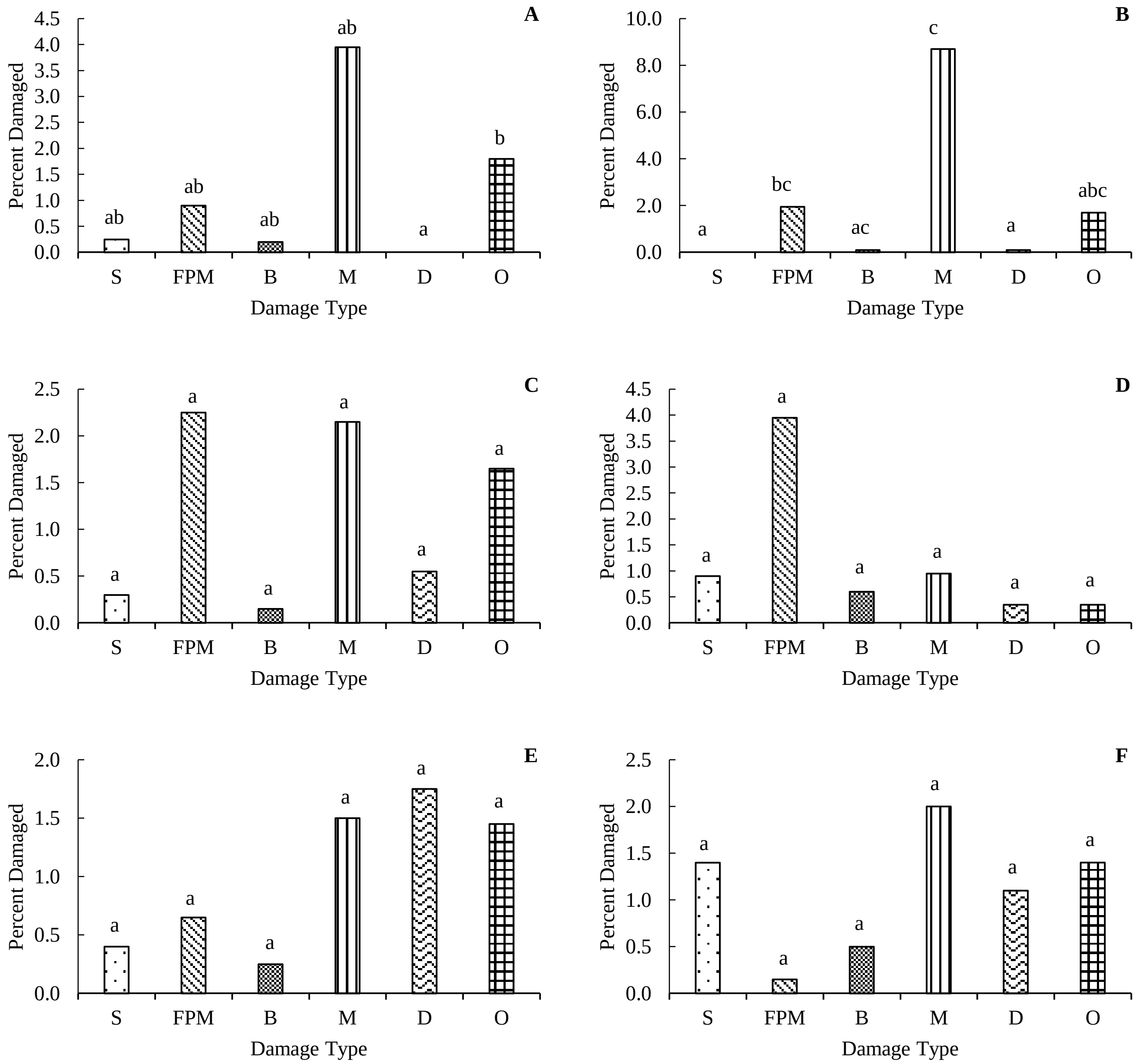


**Figure 5.4**: The total percent damage observed within each damage category over a 10 week period within the orchards in the Kat River Valley in 2014. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

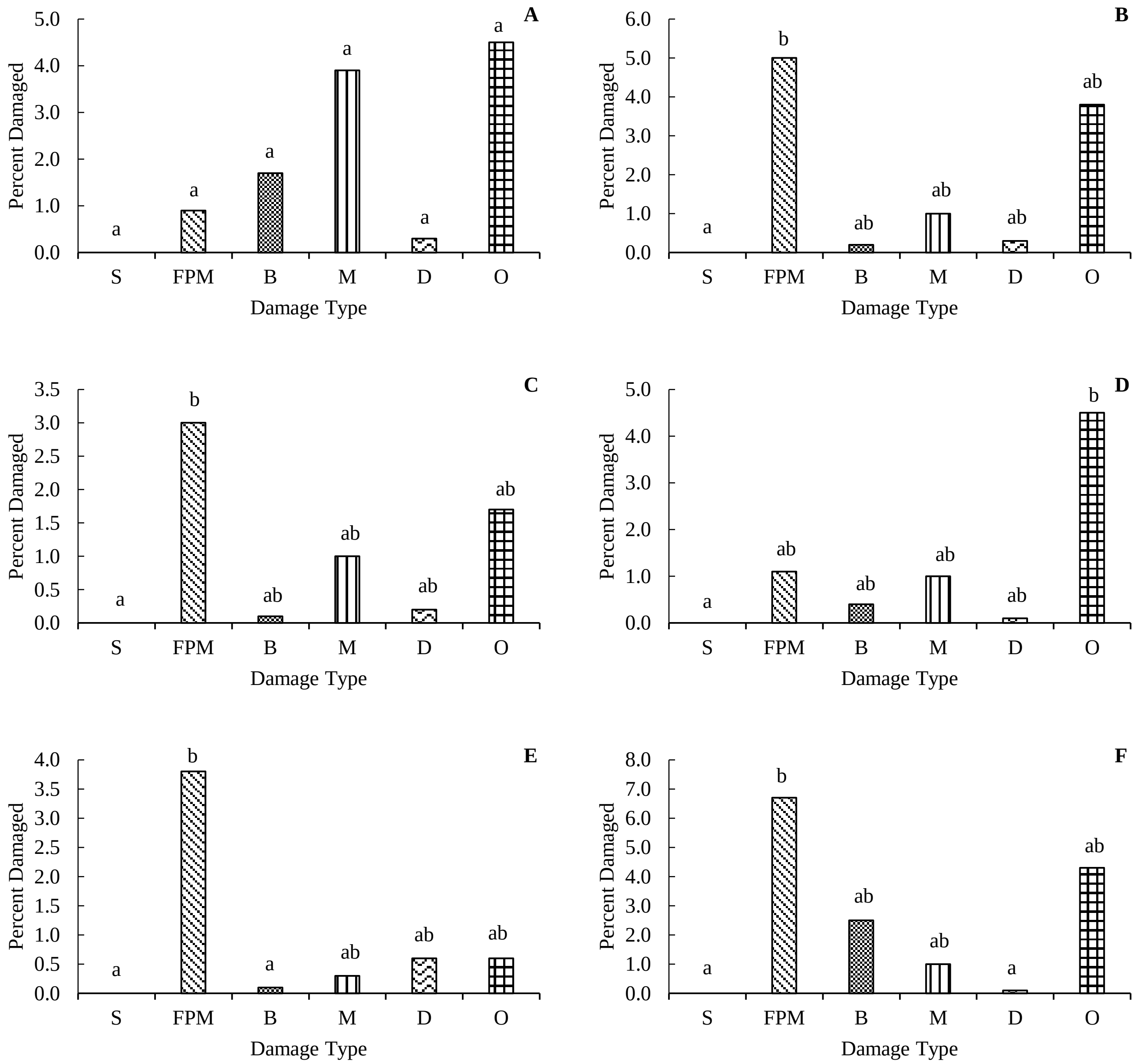


**Figure 5.5**: The total percent damage observed within each damage category over a 5 week period within the orchards in the Kat River Valley in 2015. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other.. **A** Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

#### 5.3.1.2 Sundays River Valley

For 2014 in Sundays River Valley (Fig. 5.6) there was significantly more fruit-piercing moth damage in Hitgeheim than Dunbrody Estates - Riverside B ($p = 0.0173$) (Table V.26). There was no significant difference between fruit-piercing moth damage between the other orchards. Within Hitgeheim (Fig. 5.6 A) (Table V.27), there was significantly more fruit-piercing moth damage than snail ($p = 0.0124$), bird ($p = 0.0423$) and diseased fruit damage ($p = 0.0370$). There was significantly more fruit-piercing moth damage (Table V.28) to that of snail ($p = 0.0052$) and mechanical damage ($p = 0.0443$) within Halaron Farm (Fig. 5.6 B). However, there was no significant difference between damage types within orchards. The overall comparison for 2014 (Table V.31), showed that there was significantly more fruit-piercing moth damage than snail ($p = 0.0001$), bird ($p = 0.0077$), mechanical ($p = 0.0154$) and diseased fruit damage ($p = 0.0006$). Furthermore, there was significantly more other damage than snail damage ($p = 0.0027$).

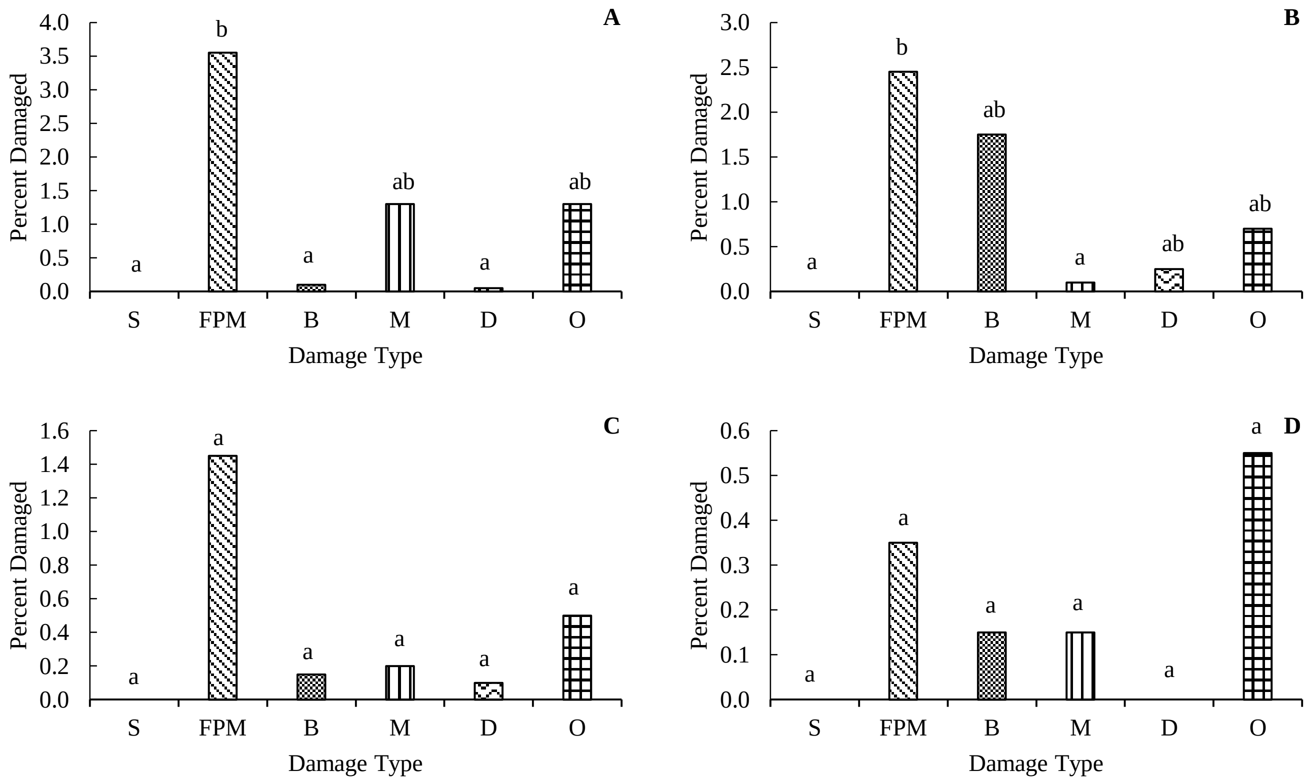


**Figure 5.6**: The total percent damage observed within each damage category over a 10 week period within the orchards in Sundays River Valley in 2014. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** – Hitgeheim; **B** – Halaron Farm; **C** – Dunbrody Estates - Riverside A; **D** – Dunbrody Estates - Riverside B.

During 2015 (Table V.32), there was no significant difference between fruit-piercing moth damage between the orchards (Fig. 5.7). Furthermore there was no significant difference between damage types within the orchards (Table V.33, V.34, V.35, and V.36). The overall comparison for 2015 (Table V.37), showed no significant difference between damage types

During 2014 and 2015, there was no significant difference in fruit-piercing moth damage between the other years (Table V.38). When looking if there was an increase in damage within the orchards, there was no significant increase in any of the orchards (Table V.39).

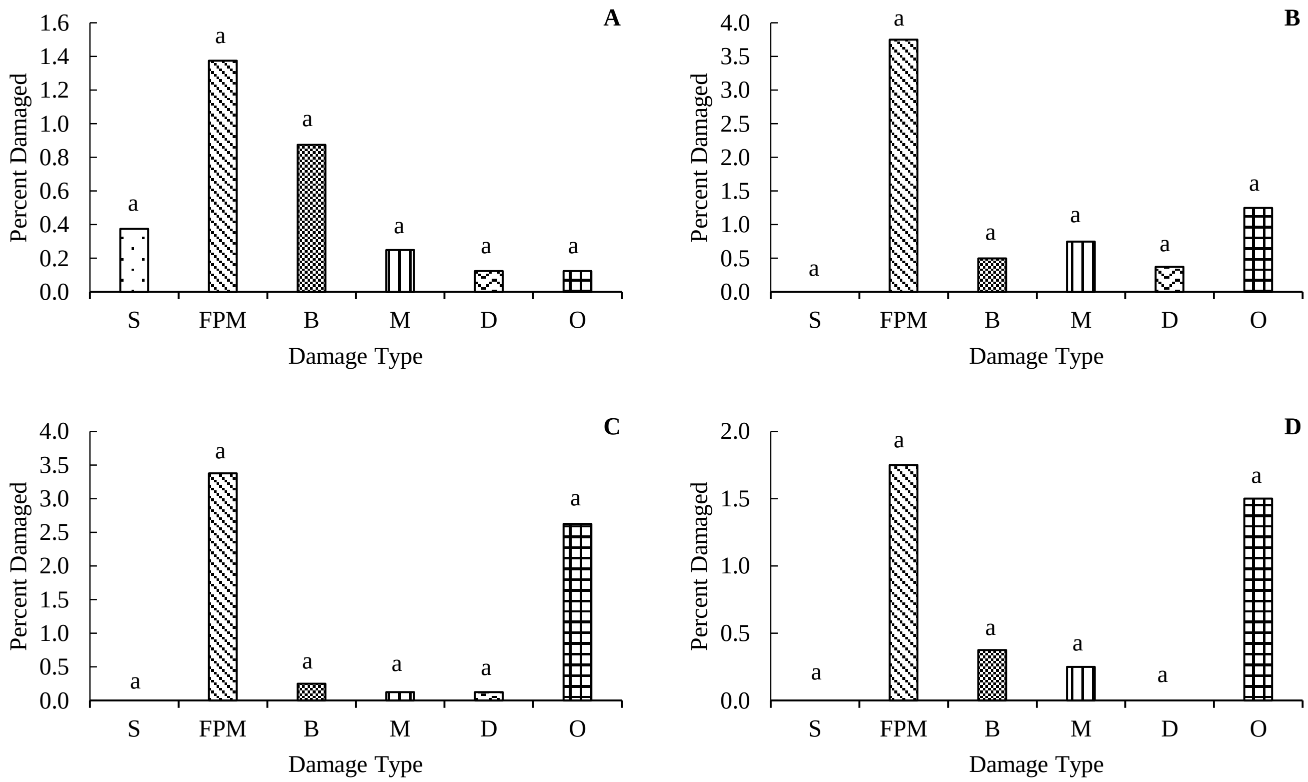


**Figure 5.7**: The total percent damage observed within each damage category over a 4 week period within the orchards in the Sundays River Valley in 2015. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** – Halaron farm; **B** – Dunbrody Estates – Riverside A; **C** – Dunbrody Estates – Riverside B; **D** – Dunbrody Estates – Riverside C.

#### 5.3.1.3 Kat River Valley and Sundays River Valley

There was significantly no difference shown between the orchards of Kat River Valley and Sundays River Valley (Table V.40), except for Hitgeheim 2014 (Fig. 5.6 A) which had significantly more fruit-piercing moth damage than Glinkwater B 2014 ($p = 0.0100$) (Fig. 5.4

F). The overall comparison of the combined damage types for 2014 and 2015 and Kat River Valley and Sundays River Valley (Table V.41), showed that fruit-piercing moth damage was significantly more than snail (p = 0.0001), bird ((p = 0.0001), mechanical (p = 0.0005) and diseased fruit damage (p = 0.0001). Whereas, mechanical damage was significantly more than diseased fruit (p = 0.0160) and snail (p = 0.0001) (Table V.41). Other damage (Table V.41) was significantly more than snail (p = 0.0001), bird (p = 0.0001) and diseased fruit damage (p = 0.0001).

#### 5.3.1.4 Tshipise

The damage observed in Tshipise for 2014 (Fig. 5.8) (Table V.42) showed that there was hardly any fruit-piercing moth damage observed on the fruit. There was significantly more mechanical damage (Table V.42) than snail (p = 0.0062), fruit-piercing moth (p = 0.0314) and bird damage (p = 0.0372). There was also significantly more diseased fruit (Table V.42) than snail (p = 0.0097) and fruit-piercing moth damage (p = 0.0471). Furthermore, for 2014 there was significantly more other damage (Table V.42) than snail (p = 0.0003), fruit-piercing moth (p = 0.0019) and bird damage (p = 0.0024). The same was observed for 2015 (Fig. 5.9) (Table V.42), as there was hardly any fruit-piercing moth damage observed on the fruit. There was significantly more mechanical damage (Table V.42) than snail (p = 0.0002), fruit-piercing moth (p = 0.0006) and bird damage (p = 0.0022). Furthermore, for 2015 there was significantly more other damage (Table V.42) than snail (p = 0.0013), fruit-piercing moth (p = 0.0031) and bird damage (p = 0.0098).

When comparing the 2014 and 2015 seasons in Tshipise, there was no observed increase in any damage type. However, there was significantly more mechanical damage (Table V.42) in 2015 (Fig. 5.9) than snail (p = 0.0002), fruit-piercing moth (p = 0.0016) and bird damage (p = 0.0020) in 2014 (Fig. 5.8). There was significantly more diseased fruit (Table V.42) in 2014 than snail (p = 0.0097) and fruit-piercing moth damage (p = 0.0218) in 2015. Furthermore, there was significantly more other damage (Table V.42) in 2014 than snail (p = 0.0003), fruit-piercing moth (p = 0.0008) and bird damage (p = 0.0026) in 2015.

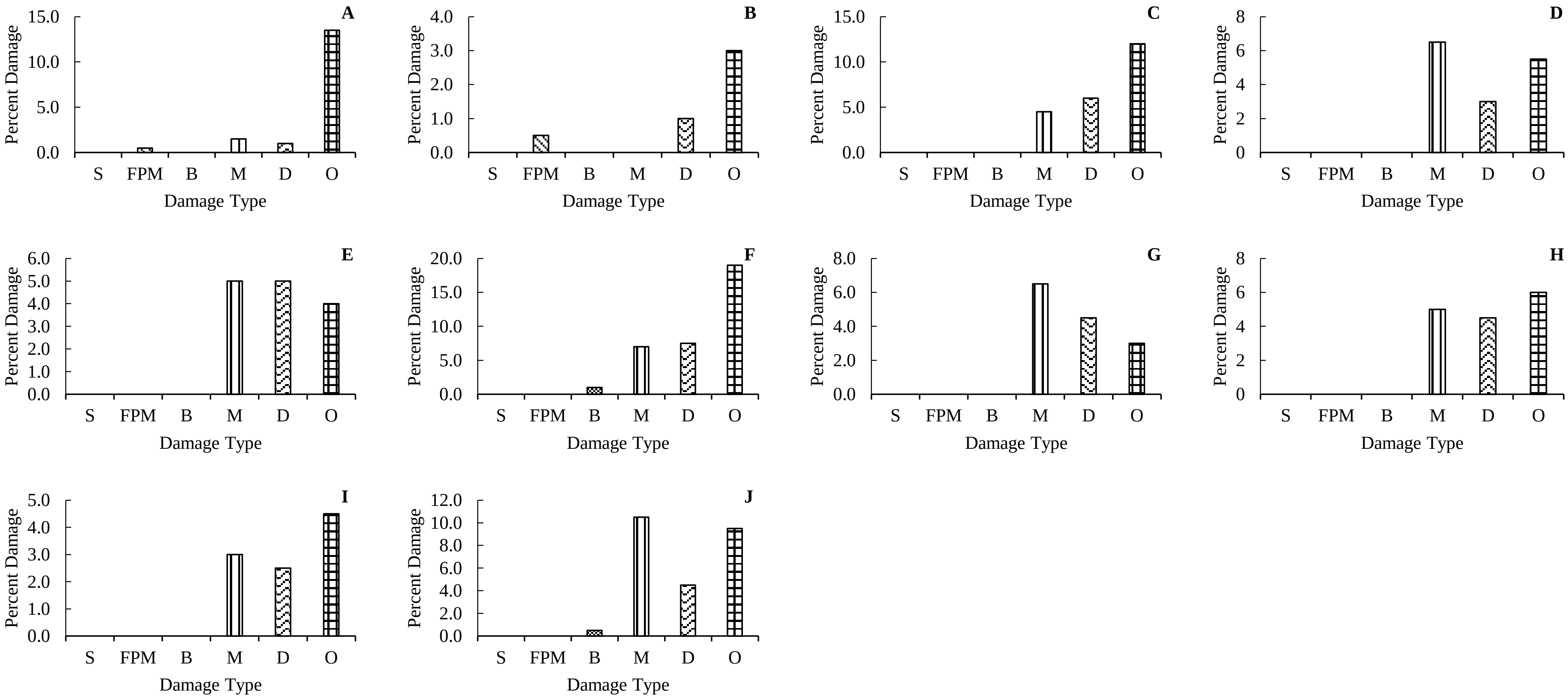


**Figure 5.8**: The total percent damage observed within each damage category in the orchards in the Tshipise in 2014. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** - B2; **B** – B3; **C** - M2; **D** - M7; **E** - M9; **F** - M14; **G** - F2; **H** - F8; **I** - E5; **J** - E11.

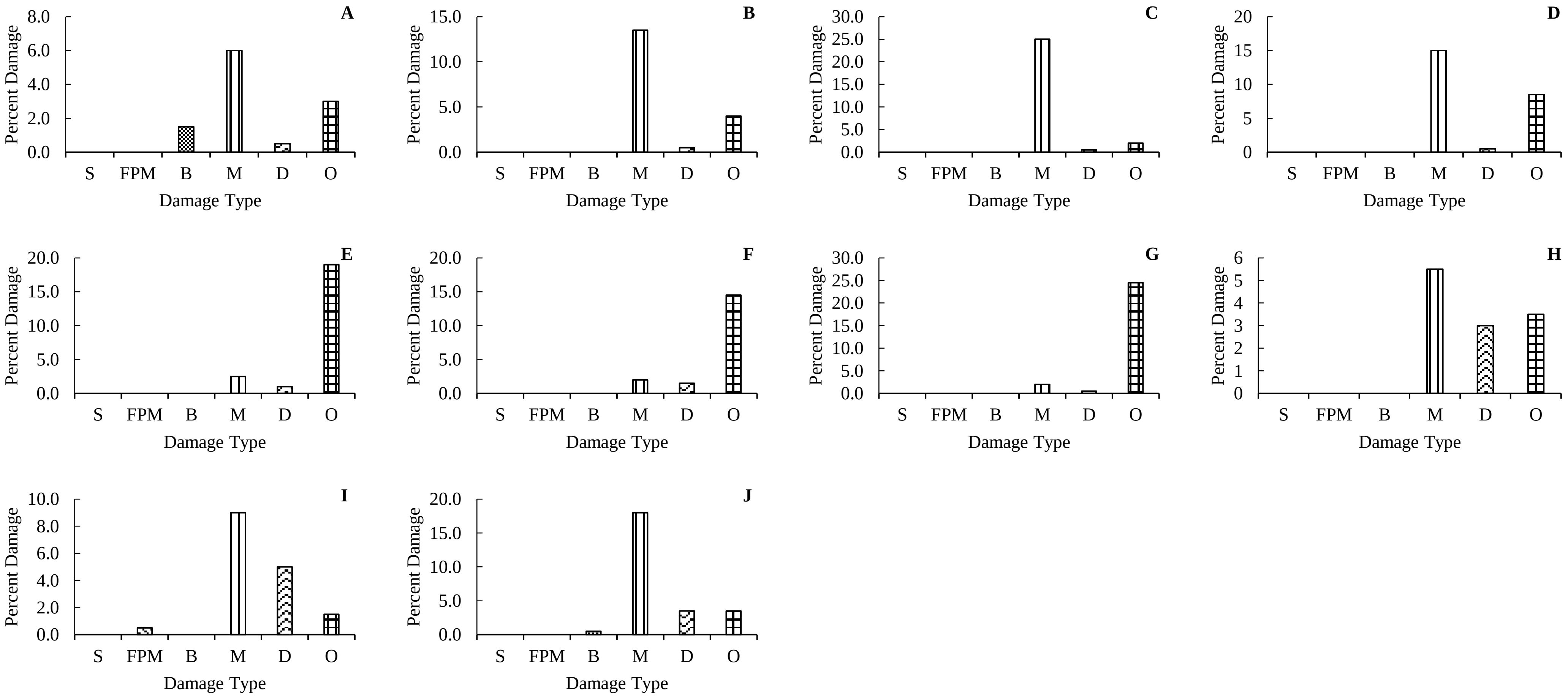


**Figure 5.9**: The total percent damage observed within each damage category in the orchards in the Tshipise in 2015. S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other. **A** - M2; **B** - M7; **C** - M9; **D** - M14; **E** - F1; **F** - F2; **G** - F8; **H** - E2; **I** - E5; **J** - E11.

### 5.3.2 Determining the relationship between trap catches of *Serrodes partita* in orchards and the level of fruit damage

#### 5.3.2.1 Kat River Valley and Grahamstown

During 2013 (Fig. 5.10), 2014 (Fig. 5.11) and 2015 (Fig. 5.12) there was no correlation between trap catches of *S. partita* in the orchards and fruit-piercing moth damage (Table 5.1).

**Table 5.1**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita,* and damage within orchards in the Grahamstown and Kat River Valley growing region during the 2013, 2014 and 2015 growing season.

| | | Valid (N) | Spearman (R ) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **2013** | **Overall** | 30 | 0.0504 | 0.2244 | 0.2669 | 0.7915 |
| | **Blinkwater** | 6 | -0.2772 | 0.5265 | -0.5771 | 0.5948 |
| | **Mosslands A** | 6 | 0.5000 | 0.7071 | 1.1547 | 0.3125 |
| | **Mosslands B** | 6 | -0.2000 | 0.4472 | -0.4082 | 0.7040 |
| | **Riverside B** | 6 | 0.0676 | 0.2600 | 0.1355 | 0.8987 |
| | **Riverside A** | 6 | | | | |
| **2014** | **Overall** | 48 | 0.0406 | 0.2016 | 0.2759 | 0.7839 |
| | **Bath Farm A** | 8 | 0.1890 | 0.4347 | 0.4714 | 0.6540 |
| | **Bath Farm B** | 8 | -0.4208 | 0.6487 | -1.1363 | 0.2992 |
| | **Riverside A** | 8 | 0.0160 | 0.1263 | 0.0391 | 0.9701 |
| | **Riverside B** | 8 | | | | |
| | **Glinkwater Farm A** | 8 | 0.0068 | 0.0822 | 0.0166 | 0.9873 |
| | **Glinkwater Farm B** | 8 | -0.1429 | 0.3780 | -0.3536 | 0.7358 |
| **2015** | **Overall** | 30 | -0.1698 | 0.4121 | -0.9118 | 0.3697 |
| | **Bath Farm A** | 5 | | | | |
| | **Bath Farm B** | 5 | -0.7071 | 0.8409 | -1.7321 | 0.1817 |
| | **Riverside A** | 5 | | | | |
| | **Riverside B** | 5 | 0.0574 | 0.2395 | 0.0995 | 0.9270 |
| | **Glinkwater Farm A** | 5 | -0.1814 | 0.4259 | -0.3194 | 0.7704 |
| | **Glinkwater Farm B** | 5 | 0.5441 | 0.7376 | 1.1233 | 0.3431 |

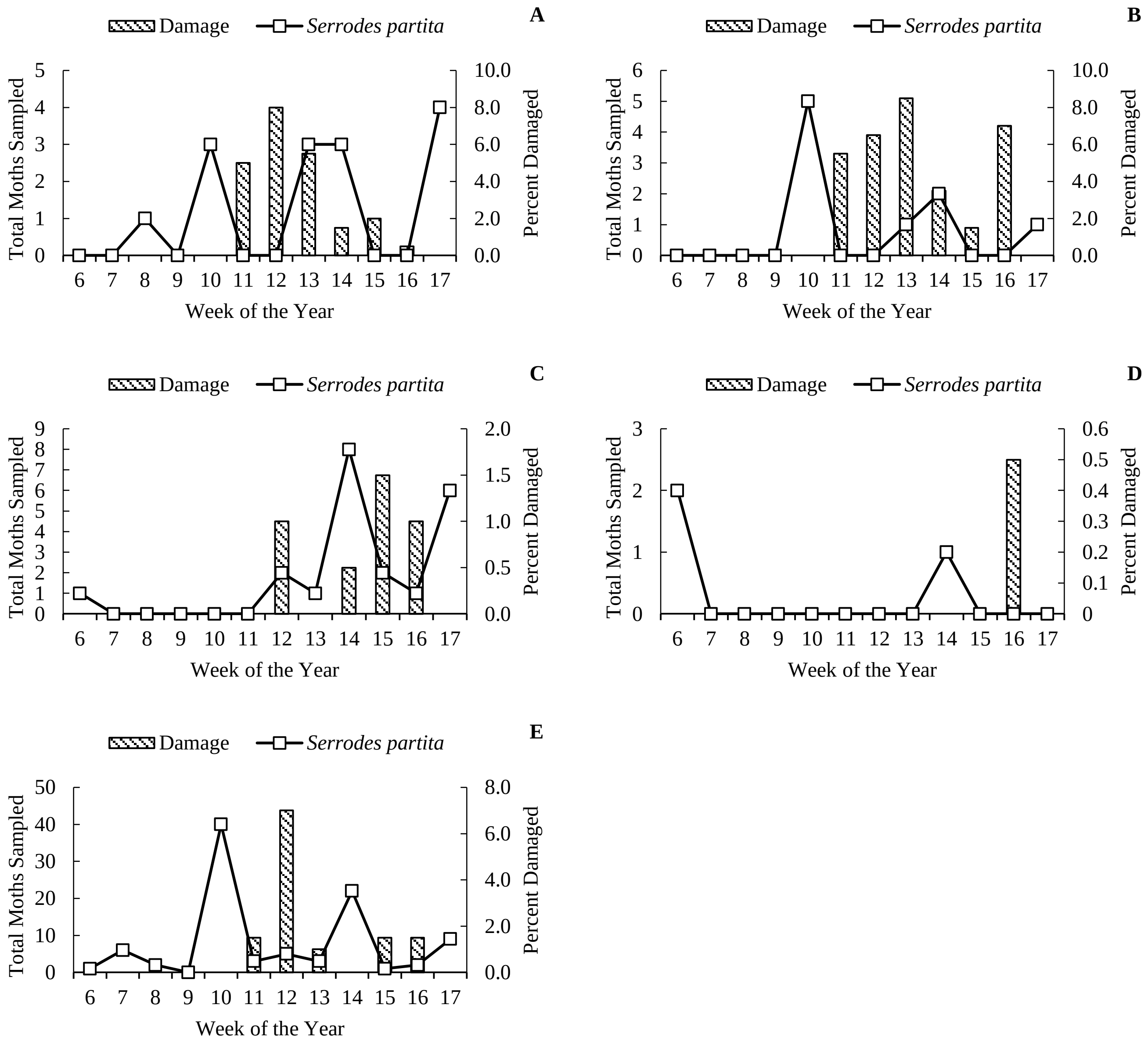


**Figure 5.10**: The weekly trap catches of *Serrodes partita* compared to the weekly damage caused by *Serrodes partita* to the fruit over a 12 week period in the orchards in the Kat River Valley and Grahamstown in 2013. **A** – Riverside A; **B** – Riverside B; **C** – Mosslands A; **D** – Mosslands B; **E** – Blinkwater.

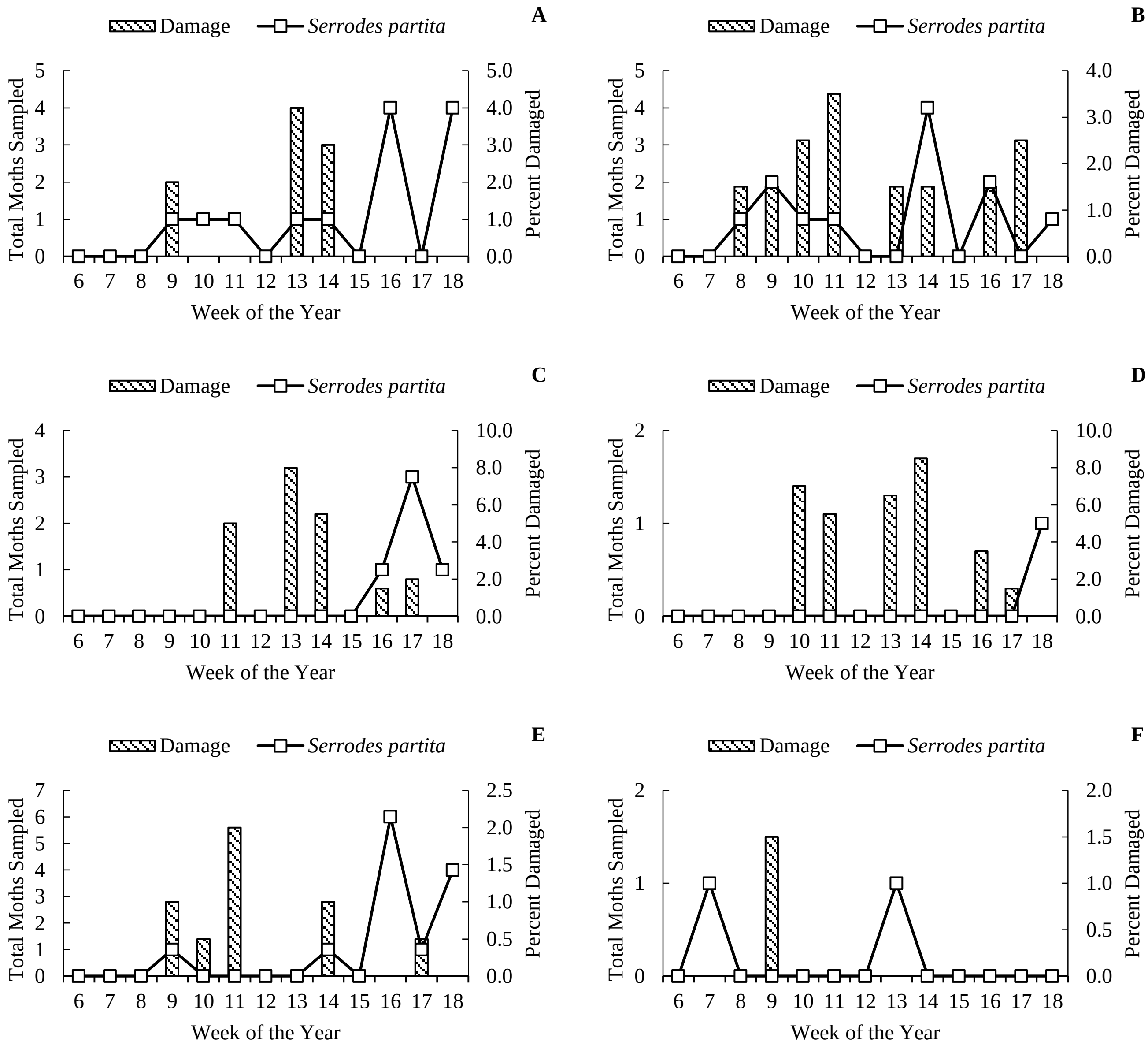


**Figure 5.11**: The weekly trap catches of *Serrodes partita* compared to the weekly damage caused by *Serrodes partita* to the fruit over a 13 week period in the orchards in the Kat River Valley in 2014. **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Bath Farm A; **F** – Bath Farm B.

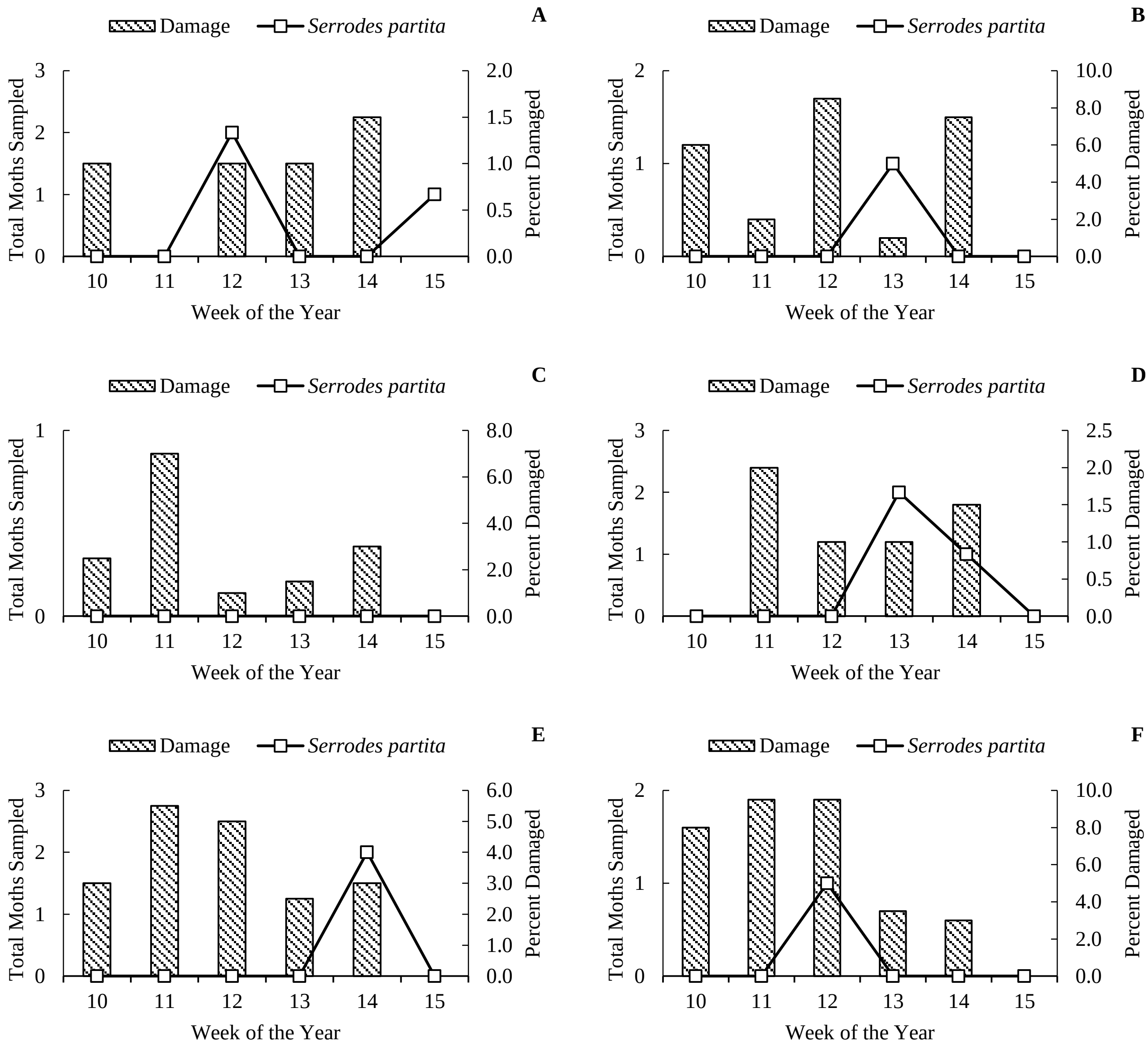


**Figure 5.12**: The trap catches of *Serrodes partita* compared to the weekly damage caused by *Serrodes partita* to the fruit over a 6 week period in the orchards in the Kat River Valley in 2015. **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Bath Farm A; **F** – Bath Farm B.

#### 5.3.2.2 Sundays River Valley

In 2014 (Fig. 5.13) and 2015 (Fig. 5.14) there was no correlation between the activity of *S. partita* in the orchards and the damage it caused (Table 5.2).

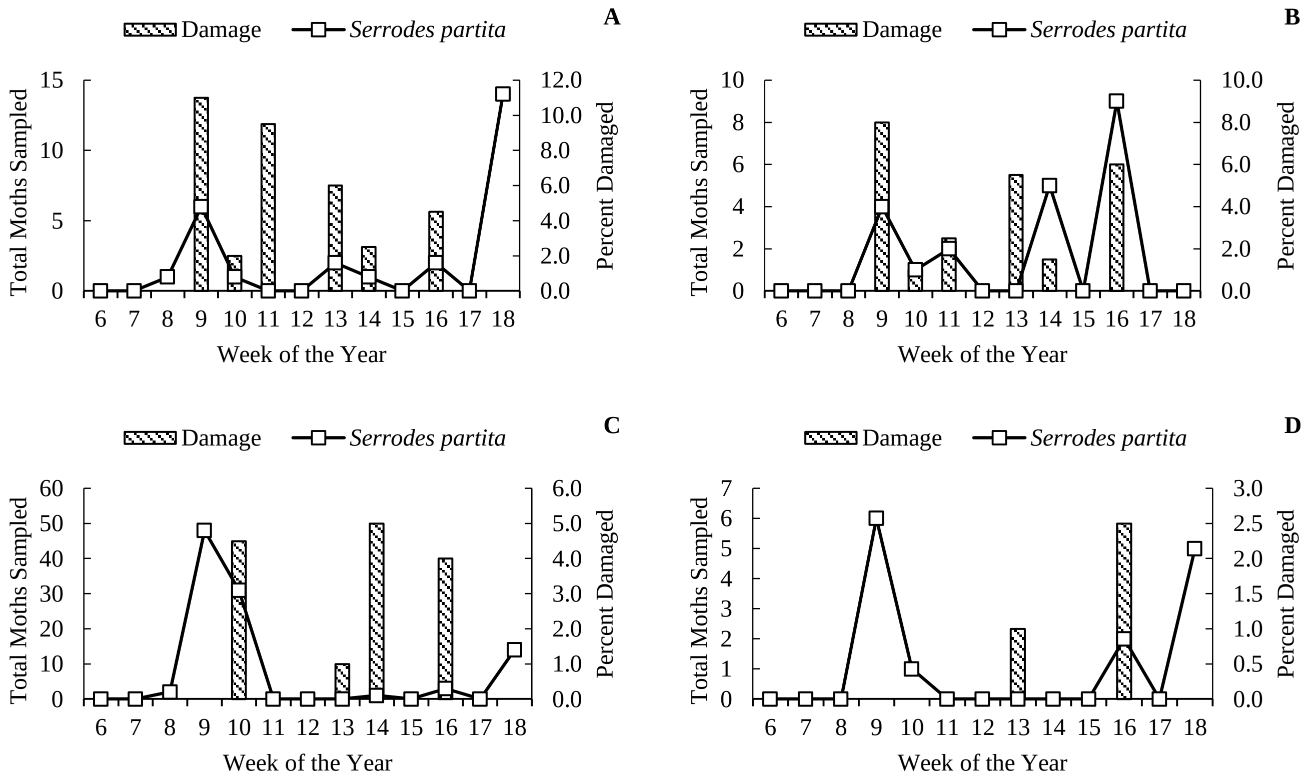


**Figure 5.13**: The weekly trap catches of *Serrodes partita* compared to the weekly damage caused by *Serrodes partita* to the fruit over a 13 week period in the orchards in Sundays River Valley in 2014. **A** – Hitgeheim; **B** – Halaron Farm; **C** – Dunbrody Estates - Riverside A; **D** – Dunbrody Estates - Riverside B.

**Table 5.2**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and damage within orchards in the Sundays River Valley growing region during the 2014 and 2015 growing season.

| | | **Valid (N)** | **Spearman (R)** | **Spearman ($R^2$)** | **t(N-2)** | **p-value** |
|---|---|---|---|---|---|---|
| **2014** | **Overall** | 24 | 0.2612 | 0.5111 | 1.2692 | 0.2176 |
| | **Dunbrody estates - Riverside A** | 6 | 0.0735 | 0.2712 | 0.1475 | 0.8899 |
| | **Dunbrody estates - Riverside B** | 6 | 0.1078 | 0.3283 | 0.2168 | 0.8390 |
| | **Halaron Farm** | 6 | 0.3143 | 0.5606 | 0.6621 | 0.5441 |
| | **Hitgeheim** | 6 | 0.3825 | 0.6185 | 0.8280 | 0.4542 |
| **2015** | **Overall** | 16 | 0.2362 | 0.4860 | 0.9095 | 0.3785 |
| | **Dunbrody estates - Riverside A** | 4 | 0.2108 | 0.4592 | 0.3050 | 0.7892 |
| | **Dunbrody estates - Riverside B** | 4 | | | | |
| | **Dunbrody estates - Riverside C** | 4 | 0.5774 | 0.7598 | 0.9999 | 0.4227 |
| | **Halaron Farm** | 4 | 0.2582 | 0.5081 | 0.3780 | 0.7418 |

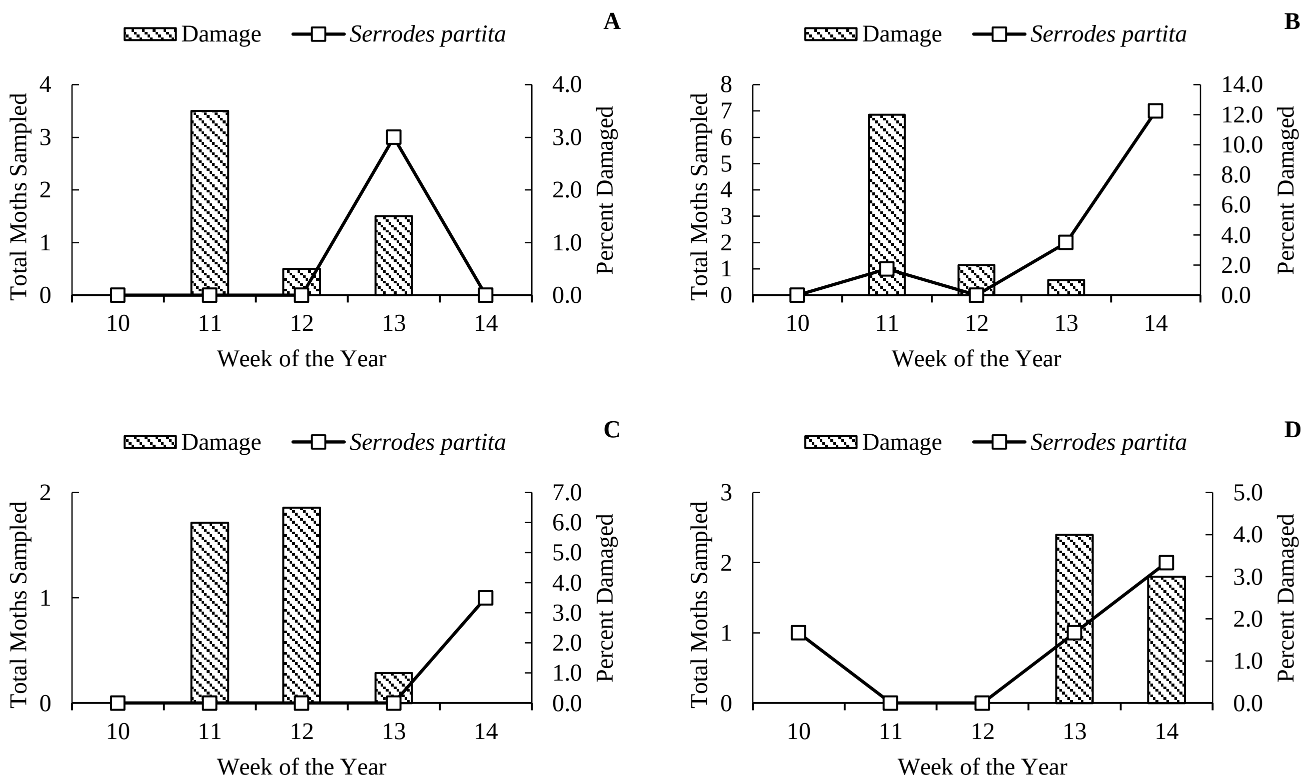


**Figure 5.14**: The weekly trap catches of *Serrodes partita* compared to the weekly damage caused by *Serrodes partita* to the fruit over a 5 week period in the orchards in the Sundays River Valley in 2015. **A** – Halaron Farm; **B** – Dunbrody Estates - Riverside A; **C** – Dunbrody Estates - Riverside B; **D** – Dunbrody Estates - Riverside C.

### 5.3.3 The relationship between trap catches of *Serrodes partita* in orchards and climatic conditions

#### 5.3.3.1 Kat River Valley and Grahamstown

In 2013 (Fig. 5.15) there was no relationship between *S. partita* trap catches per week and the maximum temperature recorded during the week (Table 5.4), however, there was such a relationship at Mosslands A (p = 0.0001, $R^2$ =0.9450) (Table 5.4), although the number of *S. partita* was very low at this site (Fig. 5.16). There was no relationship between minimum temperature recorded in a week and *S. partita* trap catches during that week in any of the orchards (Fig. 5.16). However, there was a relationship between precipitation (Fig. 5.17) and the total trap catch of *S. partita* in Kat River Valley (p = 0.0001, $R^2$ =0.7039) (Table 5.4) and the orchards Blinkwater (p = 0.0165, $R^2$ =0.8202) (Table 5.4) (Fig. 5.17 E), Riverside A (p = 0.0001, $R^2$ =0.9395) (Table 5.4) (Fig. 5.17 C) and Riverside B (p = 0.0023, $R^2$ =0.8827)

(Table 5.4) (Fig. 5.17 D), but there was no such relationship for Mosslands A or Mosslands B (Table 5.4). There was a relationship between trap catches and wind direction (Table 5.3) for Mosslands A ($p = 0.0102$, $R^2 = 0.8405$) (Table 5.4), but no other orchards (Table 5.4). However, there was no relationship between trap catches and wind speed (Table 5.3) for any orchard (Table 5.4).

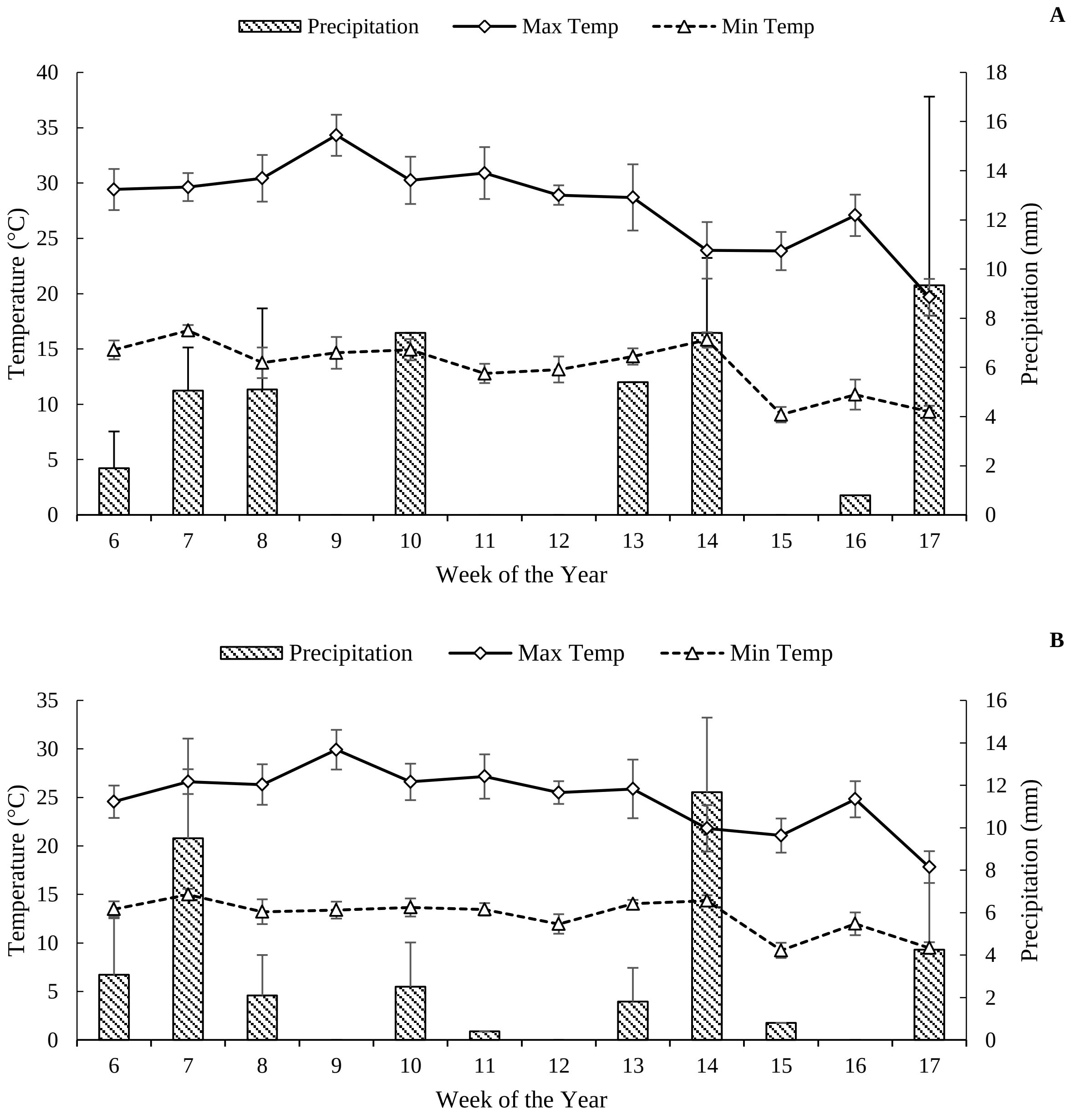


**Figure 5.15**: The weekly mean daily maximum and minimum temperatures (°C) and precipitation (mm), during 2013 at Kat River Valley (A) and Grahamstown (B), during a 12 week sampling period.

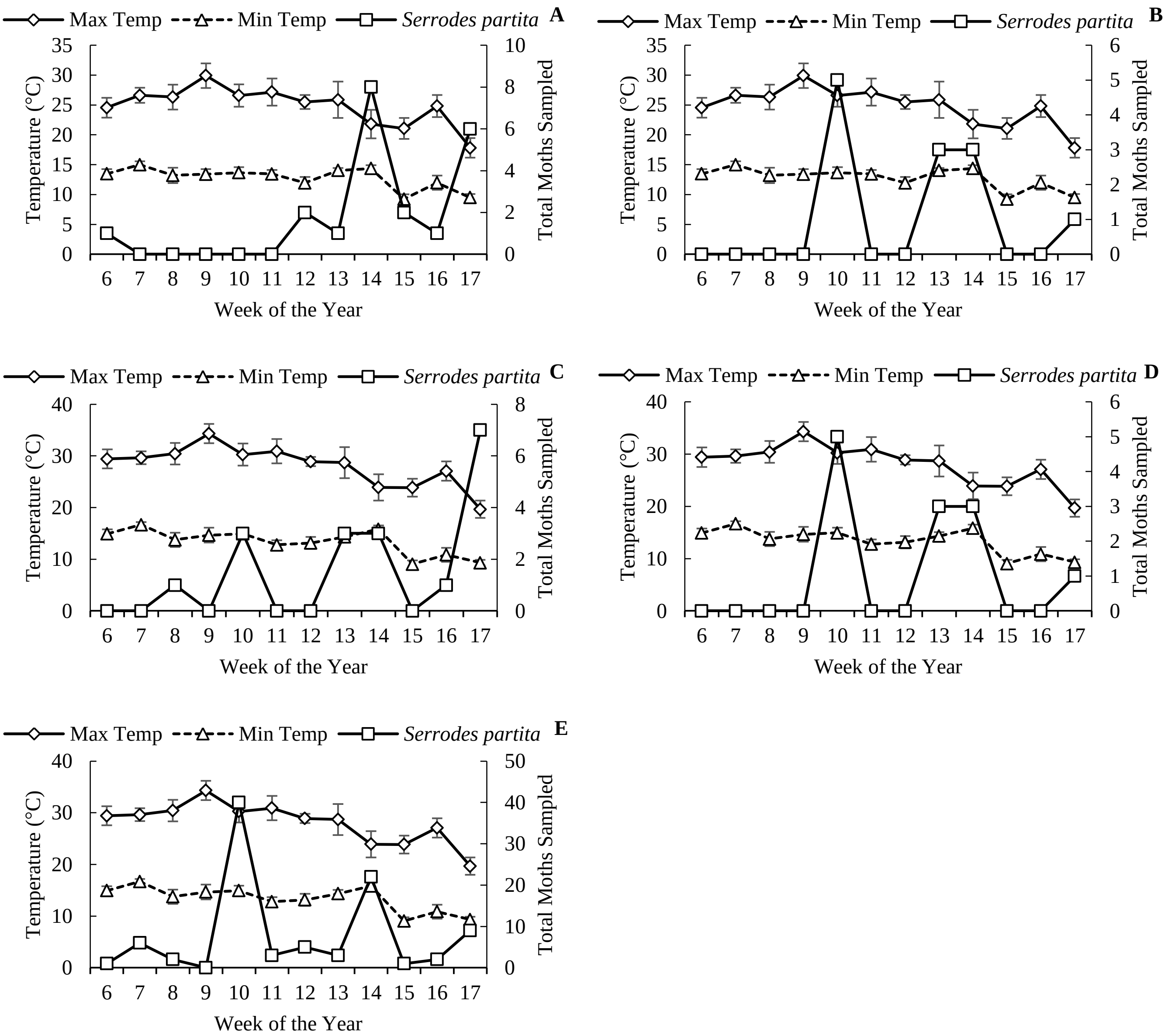


**Figure 5.16**: Weekly *Serrodes partita* trap catches within the orchards and the mean daily maximum and minimum temperatures (°C) per week, during 2013 at Kat River Valley and Grahamstown, during 12 week sampling period. **A** – Mosslands A; **B** – Mosslands B; **C** – Riverside A; **D** – Riverside B; **E** – Blinkwater.

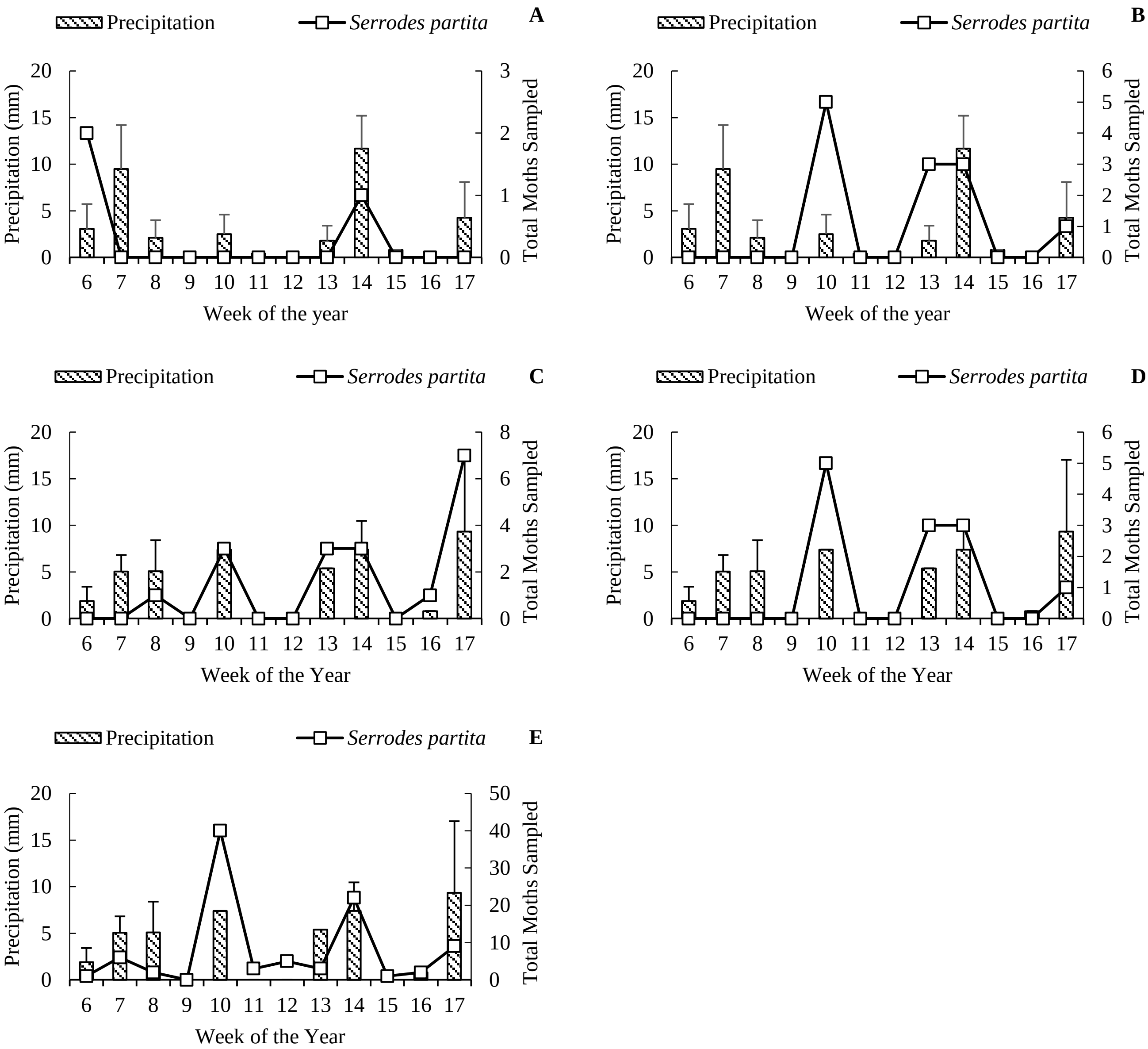


**Figure 5.17**: The weekly *Serrodes partita* activity within the orchards compared with the mean precipitation (mm) per week, during 2013 at Kat River Valley and Grahamstown, during 12 week sampling period. **A** – Mosslands A; **B** – Mosslands B; **C** – Riverside A; **D** – Riverside B; **E** – Blinkwater.

**Table 5.3**: The weekly mean wind speed (m/s) and wind direction, during 2013 at Kat River Valley and Grahamstown, during 12 week sampling period.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Kat River Valley growing region** | | | | | | | | | | | |
| **Week of the Year** | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| **Wind Direction** | | SSE | SE | SSE | SE | SE | SE | SSW | S | SSW | SSW | SW | S |
| **Wind speed (m/s) (± SE)** | | 12.16 (± 0.47) | 12,16 (± 1.18) | 12,9 (± 0.84) | 9,64 (± 0.82) | 11,69 (± 0.82) | 12,34 (± 0.60) | 10,56 (± 1.29) | 10.86 (± 0.89) | 11.04 (± 1.01) | 8.91 (± 0.55) | 9.77 (± 0.79) | 8.76 (± 1.41) |
| **Total Moths Sampled** | **Blinkwater** | 1 | 6 | 2 | 0 | 40 | 3 | 5 | 3 | 22 | 1 | 2 | 9 |
| | **Riverside A** | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 3 | 3 | 0 | 1 | 7 |
| | **Riverside B** | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 3 | 3 | 0 | 0 | 1 |
| | | **Grahamstown growing region** | | | | | | | | | | | |
| **Week of the Year** | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| **Wind Direction** | | SSE | S | SSE | SSW | S | SE | S | SSW | WSW | W | SW | SW |
| **Wind speed (m/s) (± SE)** | | 11.61 (± 0.93) | 13.17 (± 1.95) | 12.73 (± 1.55) | 11.42 (± 0.72) | 11.54 (± 0.84) | 15.09 (± 1.06) | 13.08 (± 2.28) | 12.74 (± 0.87) | 13.69 (± 0.76) | 12.03 (± 1.06) | 10.29 (± 0.87) | 11.39 (± 1.27) |
| **Total Moths Sampled** | **Mosslands A** | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 8 | 2 | 1 | 6 |
| | **Mosslands B** | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

**N** - North; **NNE** - North North East; **NE** - North East; **ENE** - East North East; **E** - East; **ESE** - East South East; **SE** - South East; **SSE** - South South East; **S** - South; **SSW** - South South West; **SW** - South West; **WSW** - West South West; **W** - West; **WNW** - West North West; **NW** - North West; **NNW** - North North West

**Table 5.4**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and climatic conditions within orchards in the Kat River Valley growing region during 2013.

| | | Valid (N) | Spearman (R ) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **Max Temp** | **Overall** | 60 | -0.2114 | 0.4598 | -1.6472 | 0.1049 |
| | **Blinkwater** | 12 | -0.2425 | 0.4925 | -0.7906 | 0.4475 |
| | **Mosslands A** | **12** | **-0.8930** | **0.9450** | **-6.2771** | **0.0001** |
| | **Mosslands B** | 12 | -0.3817 | 0.6178 | -1.3058 | 0.2209 |
| | **Riverside B** | 12 | -0.3003 | 0.5480 | -0.9956 | 0.3429 |
| | **Riverside A** | 12 | -0.4449 | 0.6670 | -1.5708 | 0.1473 |
| **Min Temp** | **Overall** | 60 | 0.1103 | 0.3321 | 0.8452 | 0.4015 |
| | **Blinkwater** | 12 | 0.3304 | 0.5748 | 1.1070 | 0.2942 |
| | **Mosslands A** | 12 | -0.3221 | 0.5675 | -1.0759 | 0.3073 |
| | **Mosslands B** | 12 | 0.3709 | 0.6090 | 1.2630 | 0.2352 |
| | **Riverside B** | 12 | 0.3003 | 0.5480 | 0.9956 | 0.3429 |
| | **Riverside A** | 12 | 0.0075 | 0.0868 | 0.0239 | 0.9815 |
| **Precipitation** | **Overall** | **60** | **0.4955** | **0.7039** | **4.3445** | **0.0001** |
| | **Blinkwater** | **12** | **0.6727** | **0.8202** | **2.8749** | **0.0165** |
| | **Mosslands A** | 12 | 0.2101 | 0.4584 | 0.6796 | 0.5122 |
| | **Mosslands B** | 12 | 0.5035 | 0.7096 | 1.8427 | 0.0952 |
| | **Riverside B** | **12** | **0.7897** | **0.8887** | **4.0705** | **0.0023** |
| | **Riverside A** | **12** | **0.8827** | **0.9395** | **5.9394** | **0.0001** |
| **Wind Direction** | **Overall** | 60 | 0.1181 | 0.3437 | 0.9059 | 0.3687 |
| | **Blinkwater** | 12 | 0.0211 | 0.1452 | 0.0667 | 0.9481 |
| | **Mosslands A** | **12** | **0.7064** | **0.8405** | **3.1560** | **0.0102** |
| | **Mosslands B** | 12 | 0.0215 | 0.1466 | 0.0680 | 0.9471 |
| | **Riverside B** | 12 | 0.1627 | 0.4033 | 0.5213 | 0.6135 |
| | **Riverside A** | 12 | 0.3242 | 0.5694 | 1.0838 | 0.3039 |
| **Wind Speed** | **Overall** | 60 | -0.1525 | 0.3905 | -1.1751 | 0.2447 |
| | **Blinkwater** | 12 | 0.0879 | 0.2964 | 0.2790 | 0.7860 |
| | **Mosslands A** | 12 | -0.0329 | 0.1815 | -0.1042 | 0.9191 |
| | **Mosslands B** | 12 | 0.1613 | 0.4016 | 0.5167 | 0.6166 |
| | **Riverside B** | 12 | -0.1126 | 0.3356 | -0.3584 | 0.7275 |
| | **Riverside A** | 12 | -0.1885 | 0.4342 | -0.6070 | 0.5574 |

For 2014 (Fig. 5.18) there was no relationship between trap catches for either maximum or minimum temperature in any of the orchards (Fig. 5.19) (Table 5.6). There was a relationship shown for precipitation (Fig. 5.20) for the overall trap catches of *S. partita* in the Kat River Valley ($p = 0.0159$, $R^2 = 0.5217$) (Table 5.6), but there wasn't any relationship shown for the orchards (Table 5.6). There was no relationship shown for wind direction (Table 5.5) in any of the orchards (Table 5.6), but there was a relationship shown for wind speed (Table 5.5) for the overall trap catches of *S. partita* in Kat River Valley (p = 0.0007, $R^2$ =0.6147) (Table 5.6), Riverside A (p = 0.0049, $R^2$ =0.8523) (Table 5.6) and Glinkwater Farm A (p = 0.0119, $R^2$ =0.8198) (Table 5.6), but no other orchard (Table 5.6).

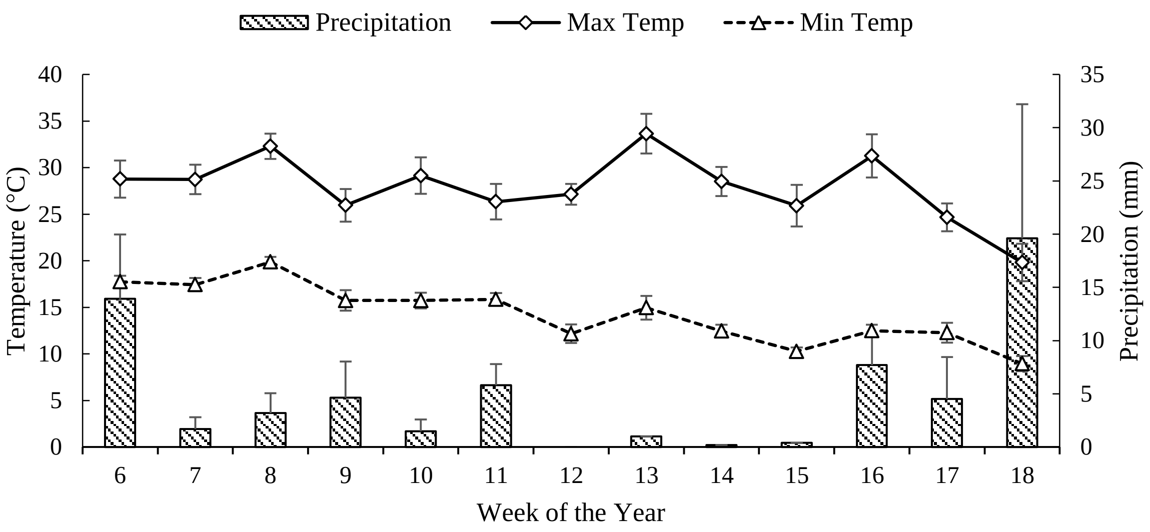


**Figure 5.18**: The weekly mean daily maximum and minimum temperatures (°C) and precipitation (mm), during 2014 at Kat River Valley, during 12 week sampling period.

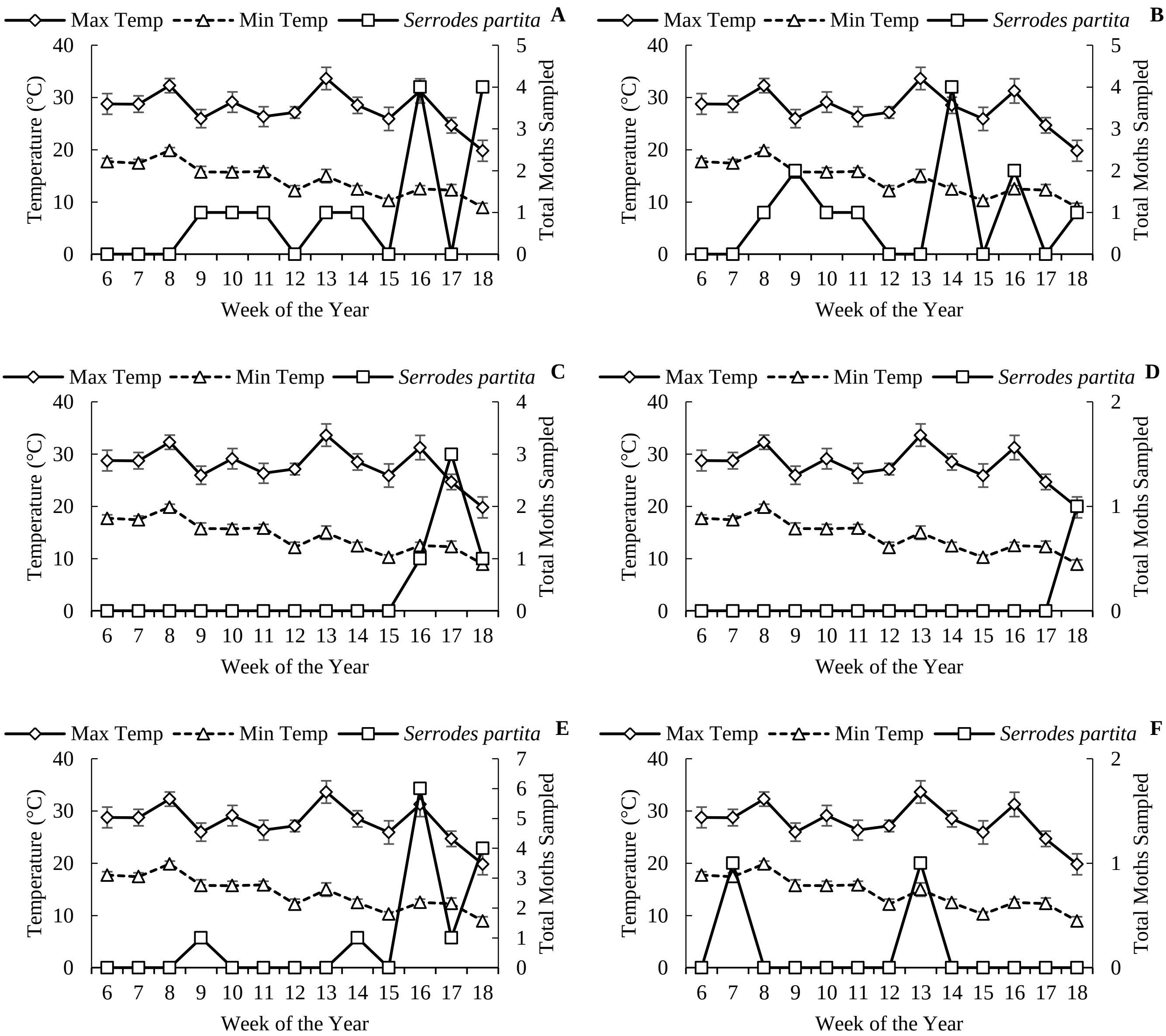


**Figure 5.19**: The weekly *Serrodes partita* activity within the orchards compared with the mean daily maximum and minimum temperatures (°C) per week, during 2014 at Kat River Valley, during 13 week sampling period. **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

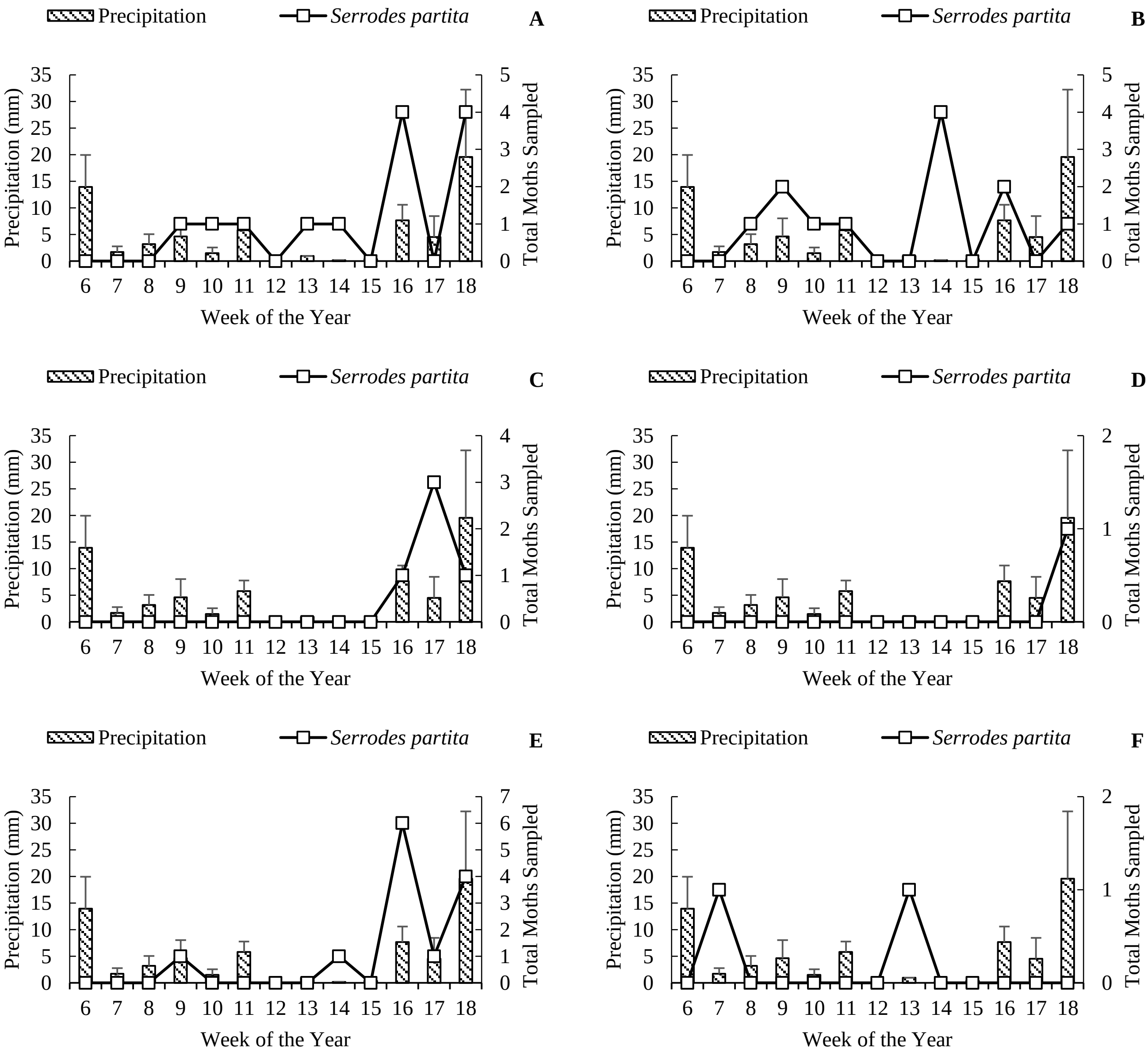


**Figure 5.20**: The weekly *Serrodes partita* activity within the orchards compared with the mean precipitation (mm) per week, during 2014 at Kat River Valley, during 13 week sampling period **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

**Table 5.5**: The weekly mean wind speed (m/s) and wind direction, during 2014 at Kat River Valley, during 13 week sampling period.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week of the Year** | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **Wind Direction** | | SSE | SSE | SSE | SE | SW | SE | SSE | SSW | S | SSW | S | S | SW |
| **Wind speed (m/s) (± SE)** | | 11.86 (± 1.62) | 10.1 (± 0.37) | 10.41 (± 0.74) | 10.07 (± 1.12) | 10.3 (± 0.83) | 10.86 (±0.76) | 10.87 (± 1.01) | 11.79 (± 1.44) | 11 (± 0.93) | 11.13 (± 1.58) | 8.63 (± 0.72) | 7.81 (± 0.43) | 7.38 (± 1) |
| **Total Moths Sampled** | **Bath Farm A** | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 4 | 0 | 4 |
| | **Bath Farm B** | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 4 | 0 | 2 | 0 | 1 |
| | **Riverside A** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 |
| | **Riverside B** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | **Glinkwater Farm A** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 1 | 4 |
| | **Glinkwater Farm B** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

**N** - North; **NNE** - North North East; **NE** - North East; **ENE** - East North East; **E** - East; **ESE** - East South East; **SE** - South East; **SSE** - South South East; **S** - South; **SSW** - South South West; **SW** - South West; **WSW** - West South West; **W** - West; **WNW** - West North West; **NW** - North West; **NNW** - North North West

**Table 5.6**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and climatic conditions within orchards in the Kat River Valley growing region during 2014.

| | | Valid (N) | Spearman (R) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **Max Temp** | **Overall** | 78 | -0.1008 | 0.3175 | -0.8832 | 0.3799 |
| | **Bath Farm A** | 13 | 0.0239 | 0.1546 | 0.0793 | 0.9382 |
| | **Bath Farm B** | 13 | 0.0470 | 0.2169 | 0.1562 | 0.8788 |
| | **Riverside A** | 13 | -0.3688 | 0.6073 | -1.3158 | 0.2150 |
| | **Riverside B** | 13 | -0.4629 | 0.6804 | -1.7321 | 0.1112 |
| | **Glinkwater Farm A** | 13 | -0.3471 | 0.5891 | -1.2273 | 0.2453 |
| | **Glinkwater Farm B** | 13 | 0.3989 | 0.6316 | 1.4426 | 0.1770 |
| **Min Temp** | **Overall** | 78 | -0.1873 | 0.4328 | -1.6626 | 0.1005 |
| | **Bath Farm A** | 13 | -0.2449 | 0.4949 | -0.8378 | 0.4200 |
| | **Bath Farm B** | 13 | 0.0529 | 0.2300 | 0.1757 | 0.8637 |
| | **Riverside A** | 13 | -0.4805 | 0.6932 | -1.8172 | 0.0965 |
| | **Riverside B** | 13 | -0.4629 | 0.6804 | -1.7321 | 0.1112 |
| | **Glinkwater Farm A** | 13 | -0.4417 | 0.6646 | -1.6329 | 0.1308 |
| | **Glinkwater Farm B** | 13 | 0.2279 | 0.4774 | 0.7764 | 0.4539 |
| **Precipitation** | **Overall** | **78** | **0.2722** | **0.5217** | **2.4662** | **0.0159** |
| | **Bath Farm A** | 13 | 0.3733 | 0.6110 | 1.3347 | 0.2090 |
| | **Bath Farm B** | 13 | 0.2087 | 0.4568 | 0.7077 | 0.4938 |
| | **Riverside A** | 13 | 0.5029 | 0.7091 | 1.9295 | 0.0799 |
| | **Riverside B** | 13 | 0.4629 | 0.6804 | 1.7321 | 0.1112 |
| | **Glinkwater Farm A** | 13 | 0.4291 | 0.6550 | 1.5755 | 0.1435 |
| | **Glinkwater Farm B** | 13 | -0.2279 | 0.4774 | -0.7764 | 0.4539 |
| **Wind Direction** | **Overall** | 78 | 0.1627 | 0.4034 | 1.4377 | 0.1546 |
| | **Bath Farm A** | 13 | 0.3554 | 0.5962 | 1.2611 | 0.2334 |
| | **Bath Farm B** | 13 | -0.0647 | 0.2543 | -0.2149 | 0.8338 |
| | **Riverside A** | 13 | 0.2682 | 0.5179 | 0.9233 | 0.3757 |
| | **Riverside B** | 13 | 0.3858 | 0.6211 | 1.3868 | 0.1930 |
| | **Glinkwater Farm A** | 13 | 0.1514 | 0.3892 | 0.5081 | 0.6214 |
| | **Glinkwater Farm B** | 13 | 0.1140 | 0.3376 | 0.3804 | 0.7109 |
| **Wind Speed** | **Overall** | **78** | **-0.3778** | **0.6147** | **-3.5574** | **0.0007** |
| | **Bath Farm A** | 13 | -0.3733 | 0.6110 | -1.3347 | 0.2090 |
| | **Bath Farm B** | 13 | -0.3380 | 0.5814 | -1.1912 | 0.2587 |
| | **Riverside A** | **13** | **-0.7264** | **0.8523** | **-3.5050** | **0.0049** |
| | **Riverside B** | 13 | -0.4629 | 0.6804 | -1.7321 | 0.1112 |
| | **Glinkwater Farm A** | **13** | **-0.6720** | **0.8198** | **-3.0097** | **0.0119** |
| | **Glinkwater Farm B** | 13 | 0.1709 | 0.4135 | 0.5754 | 0.5766 |

For 2015 (Fig. 5.21) there was no relationship between trap catches and maximum and minimum temperature (Table 5.8) (Fig. 5.22), precipitation (Fig. 5.23) and wind speed (Table 5.7, 5.8), but there was a relationship for wind direction (Table 5.7) for Riverside B ($p$ = 0.0341, $R^2$ = 0.9193) (Table 5.8), but no other orchards (Table 5.8).

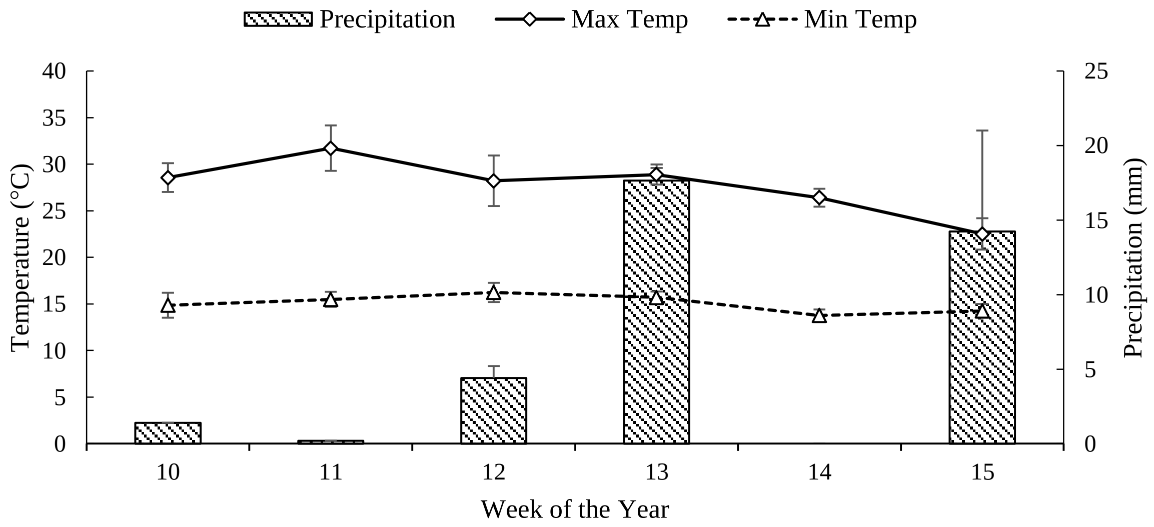


**Figure 5.21**: The weekly mean daily maximum and minimum temperatures (°C) and precipitation (mm), during 2015 at Kat River Valley, during 6 week sampling period.

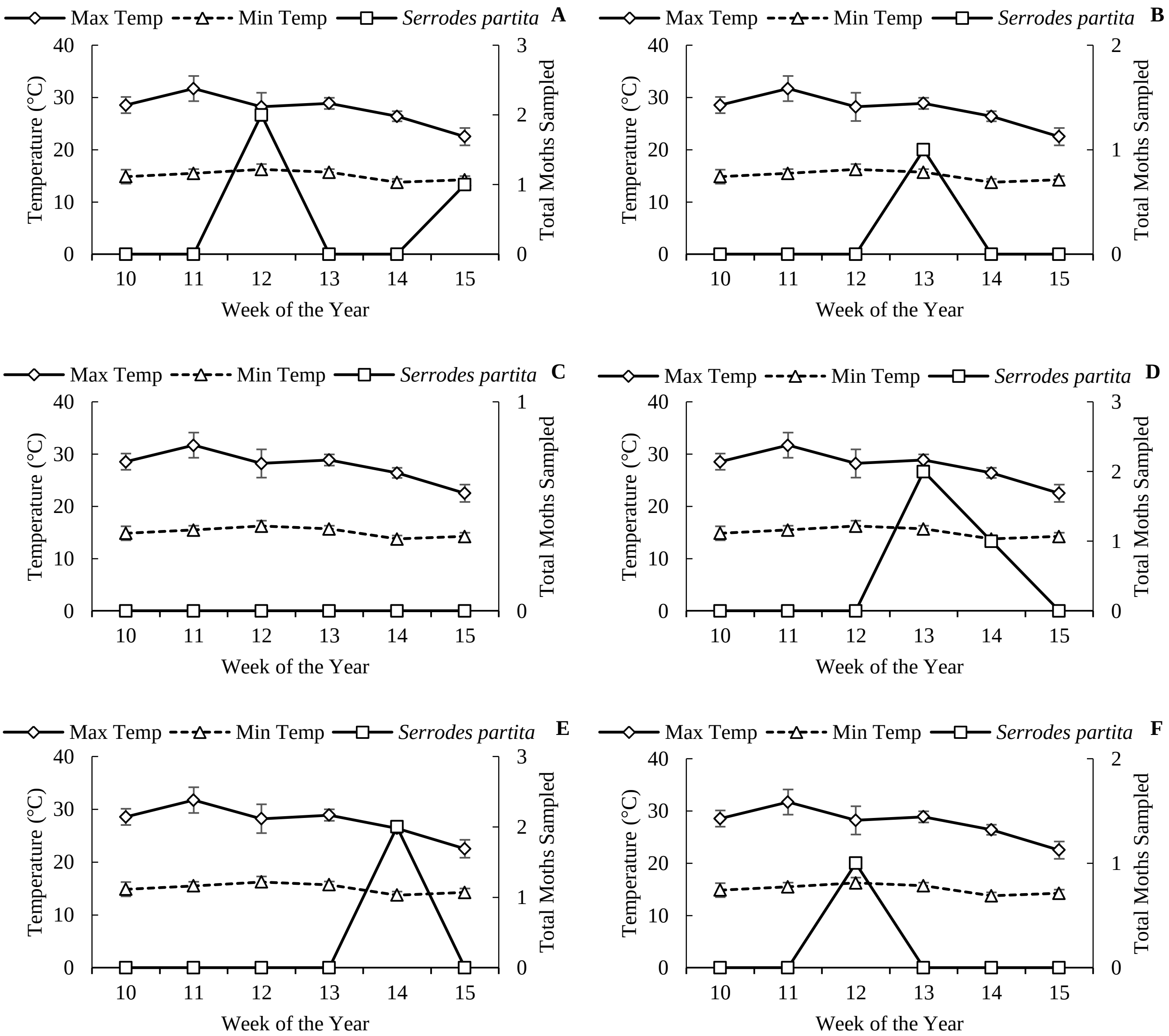


**Figure 5.22**: The weekly *Serrodes partita* activity within the orchards compared with the mean daily maximum and minimum temperatures (°C) per week, during 2015 at Kat River Valley, during 6 week sampling period. **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

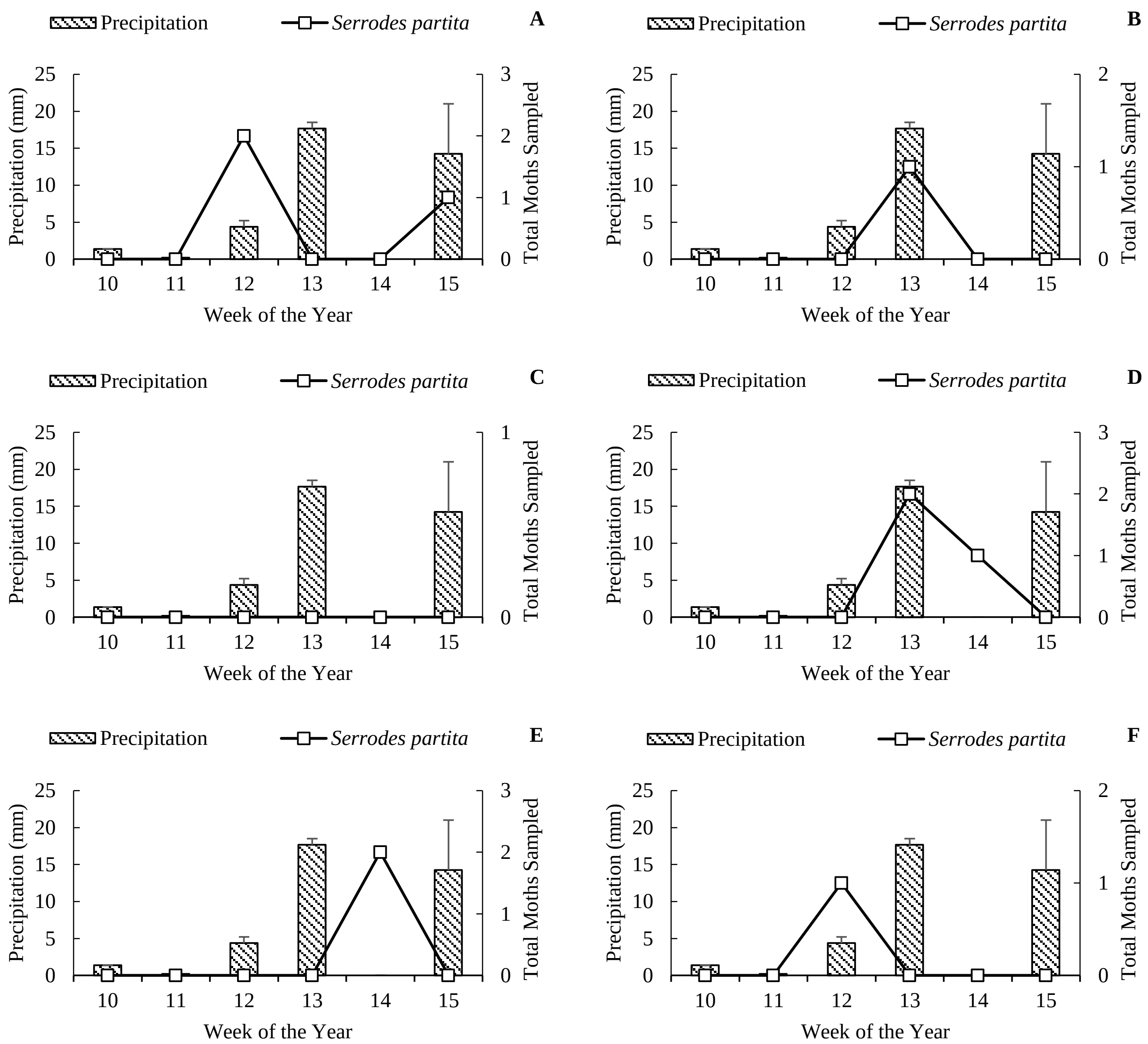


**Figure 5.23**: The weekly *Serrodes partita* activity within the orchards compared with the mean precipitation (mm) per week, during 2015 at Kat River Valley, during 6 week sampling period. **A** – Bath Farm A; **B** – Bath Farm B; **C** – Riverside A; **D** – Riverside B; **E** – Glinkwater Farm A; **F** – Glinkwater Farm B.

**Table 5.7**: The weekly mean wind speed (m/s) and wind direction, during 2015 at Kat River Valley during a 6 week sampling period.

| | Week of the Year | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| | **Wind Direction** | ESE | SE | SE | S | SSE | SE |
| | **Wind speed (m/s) (± SE)** | 10.41 (± 0.75) | 10.11 (± 0.73) | 11.61 (± 1.17) | 12.08 (± 2.34) | 9.01 (± 1.09) | 8.96 (± 0.65) |
| **Total Moths Sampled** | **Bath Farm A** | 0 | 0 | 2 | 0 | 0 | 1 |
| | **Bath Farm B** | 0 | 0 | 0 | 1 | 0 | 0 |
| | **Riverside A** | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Riverside B** | 0 | 0 | 0 | 2 | 1 | 0 |
| | **Glinkwater Farm A** | 0 | 0 | 0 | 0 | 2 | 0 |
| | **Glinkwater Farm B** | 0 | 0 | 1 | 0 | 0 | 0 |

**N** - North; **NNE** - North North East; **NE** - North East; **ENE** - East North East; **E** - East; **ESE** - East South East; **SE** - South East; **SSE** - South South East; **S** - South; **SSW** - South South West; **SW** - South West; **WSW** - West South West; **W** - West; **WNW** - West North West; **NW** - North West; **NNW** - North North West

**Table 5.8**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and climatic conditions within orchards in the Kat River Valley growing region during 2015.

| | | Valid (N) | Spearman (R) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **Max temp** | **Overall** | 36 | -0.1351 | 0.3675 | -0.7949 | 0.4322 |
| | **Bath Farm A** | 6 | -0.5409 | 0.7355 | -1.2862 | 0.2678 |
| | **Bath Farm B** | 6 | 0.3928 | 0.6267 | 0.8542 | 0.4411 |
| | **Riverside A** | 6 | | | | |
| | **Riverside B** | 6 | 0.1014 | 0.3185 | 0.2039 | 0.8484 |
| | **Glinkwater Farm A** | 6 | -0.3928 | 0.6267 | -0.8542 | 0.4411 |
| | **Glinkwater Farm B** | 6 | -0.1309 | 0.3618 | -0.2641 | 0.8047 |
| **Min temp** | **Overall** | 36 | 0.0681 | 0.2610 | 0.3980 | 0.6931 |
| | **Bath Farm A** | 6 | 0.3381 | 0.5814 | 0.7184 | 0.5122 |
| | **Bath Farm B** | 6 | 0.3928 | 0.6267 | 0.8542 | 0.4411 |
| | **Riverside A** | 6 | | | | |
| | **Riverside B** | 6 | -0.0676 | 0.2600 | -0.1355 | 0.8987 |
| | **Glinkwater Farm A** | 6 | -0.6547 | 0.8091 | -1.7321 | 0.1583 |
| | **Glinkwater Farm B** | 6 | 0.6547 | 0.8091 | 1.7321 | 0.1583 |
| **Precipitation** | **Overall** | 36 | 0.0976 | 0.3124 | 0.5719 | 0.5711 |
| | **Bath Farm A** | 6 | 0.3719 | 0.6098 | 0.8012 | 0.4679 |
| | **Bath Farm B** | 6 | 0.6547 | 0.8091 | 1.7321 | 0.1583 |
| | **Riverside A** | 6 | | | | |
| | **Riverside B** | 6 | 0.1690 | 0.4111 | 0.3430 | 0.7489 |
| | **Glinkwater Farm A** | 6 | -0.6547 | 0.8091 | -1.7321 | 0.1583 |
| | **Glinkwater Farm B** | 6 | 0.1309 | 0.3619 | 0.2641 | 0.8047 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Wind Direction** | **Overall** | 36 | 0.3167 | 0.5628 | 1.9468 | 0.0599 |
| | **Bath Farm A** | 6 | -0.1352 | 0.3677 | -0.2730 | 0.7984 |
| | **Bath Farm B** | 6 | 0.6547 | 0.8091 | 1.7321 | 0.1583 |
| | **Riverside A** | 6 | | | | |
| | **Riverside B** | **6** | **0.8452** | **0.9193** | **3.1623** | **0.0341** |
| | **Glinkwater Farm A** | 6 | 0.3928 | 0.6267 | 0.8542 | 0.4411 |
| | **Glinkwater Farm B** | 6 | 0.1309 | 0.3618 | 0.2641 | 0.8047 |
| **Wind Speed** | **Overall** | 36 | 0.1135 | 0.3369 | 0.6662 | 0.5098 |
| | **Bath Farm A** | 6 | -0.0676 | 0.2600 | -0.1355 | 0.8987 |
| | **Bath Farm B** | 6 | 0.6547 | 0.8091 | 1.7321 | 0.1583 |
| | **Riverside A** | 6 | | | | |
| | **Riverside B** | 6 | 0.3381 | 0.5814 | 0.7184 | 0.5122 |
| | **Glinkwater Farm A** | 6 | -0.3928 | 0.6267 | -0.8542 | 0.4411 |
| | **Glinkwater Farm B** | 6 | 0.3928 | 0.6267 | 0.8542 | 0.4411 |

5.3.3.2 Sundays River Valley

For 2014 (Fig. 5.24) there was no relationship between trap catches and maximum and minimum temperature (Table 5.10) (Fig. 5.25), precipitation (Fig. 5.26), wind direction (Table 5.9; 5.10) and wind speed (Table 5.9; 5.10).

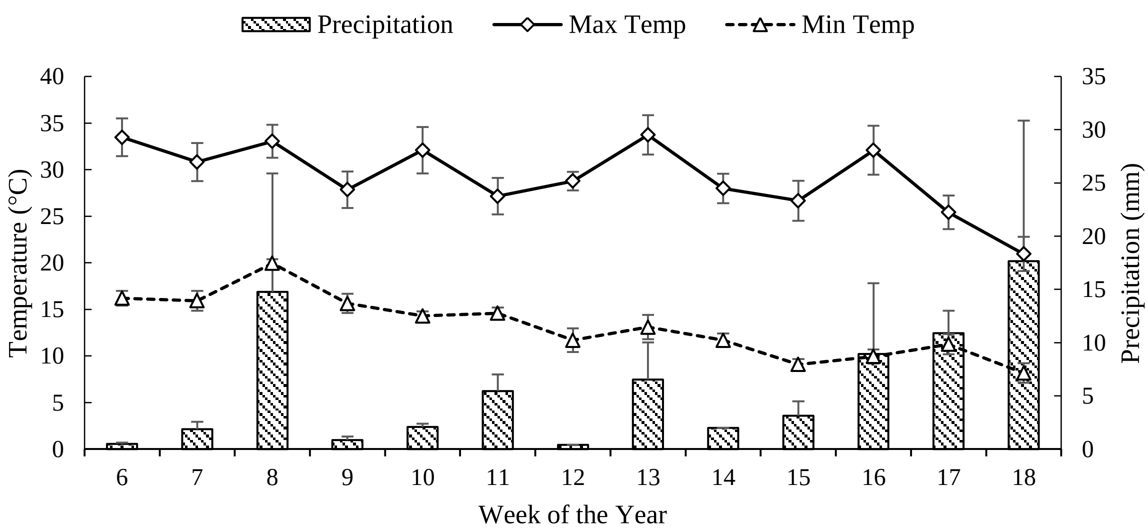


**Figure 5.24**: The weekly mean daily maximum and minimum temperatures (°C) and precipitation (mm), during 2014 at Sundays River Valley, during 13 week sampling period.

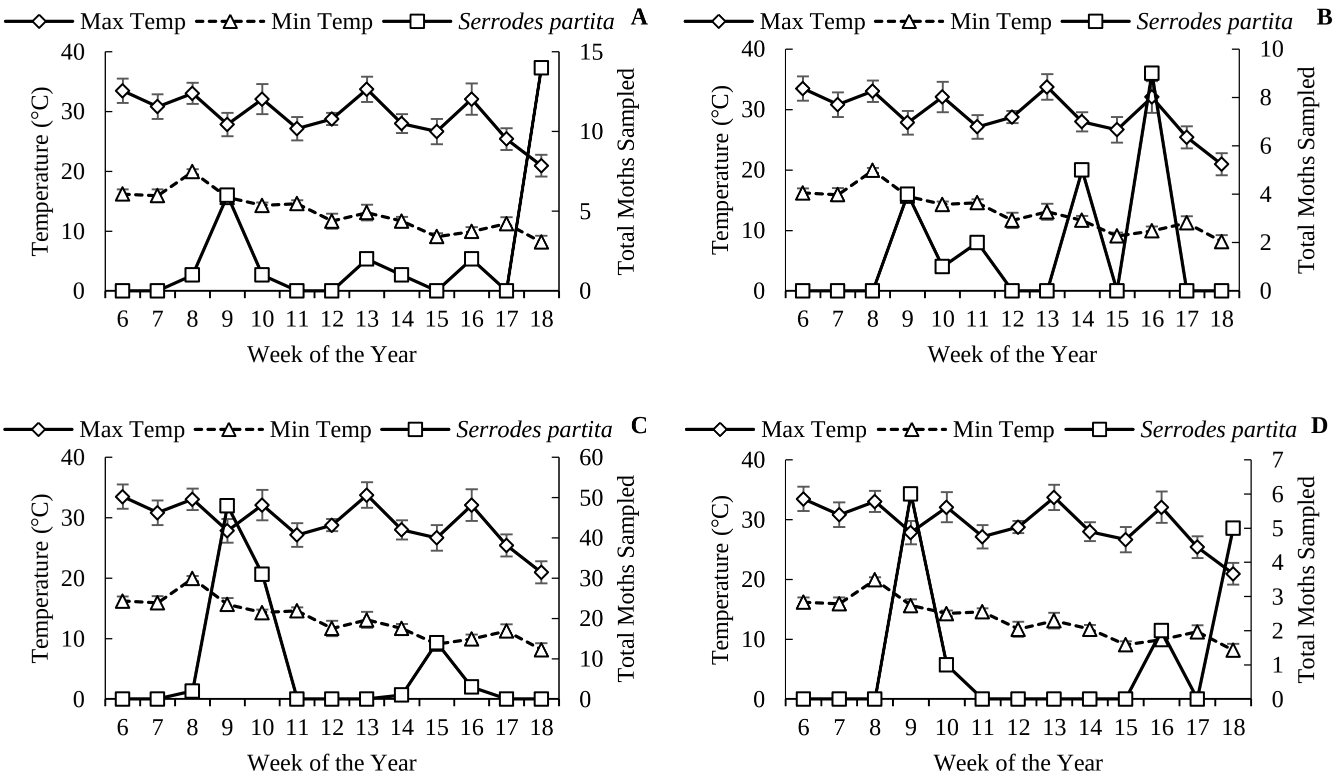


**Figure 5.25**: The weekly *Serrodes partita* activity within the orchards compared with the daily mean maximum and minimum temperatures (°C) per week, during 2014 at Sundays River Valley, during 13 week sampling period. **A** – Hitgeheim; **B** – Halaron Farm; **C** – Dunbrody Estates - Riverside A; **D** – Dunbrody Estates - Riverside B.

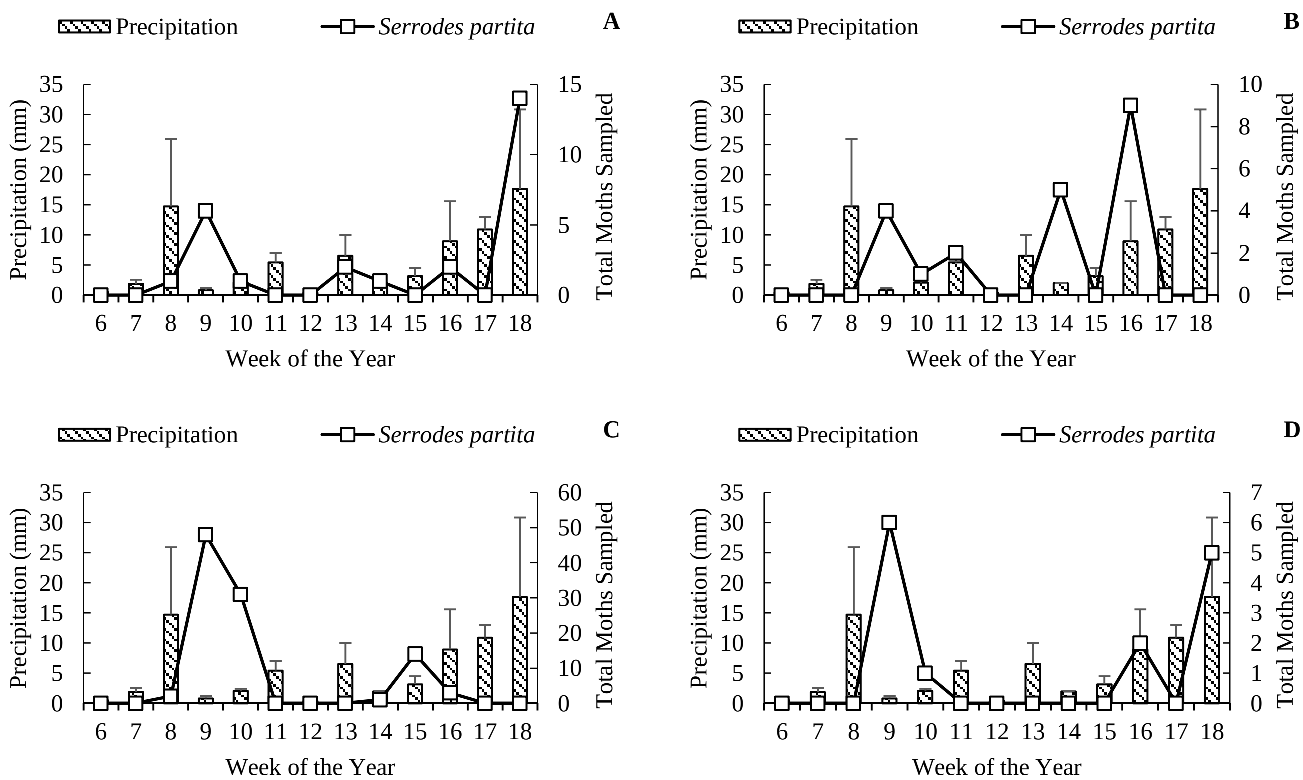


**Figure 5.26**: The weekly *Serrodes partita* activity within the orchards compared with the mean precipitation (mm) per week, during 2014 at Sundays River Valley, during 13 week sampling period. **A** – Hitgeheim; **B** – Halaron Farm; **C** – Dunbrody Estates - Riverside A; **D** – Dunbrody Estates - Riverside B.

**Table 5.9**: The weekly mean wind speed (m/s) and wind direction, during 2014 at Sundays River Valley, during 13 week sampling period.

| **Week of the Year** | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind Direction** | | S | S | S | SSE | S | SSE | S | SW | SSW | S | S | S | WSW |
| **Wind speed (m/s) (± SE)** | | 13.06 (± 1.17) | 11.06 (± 0.4) | 10.34 (± 0.76) | 10.61 (± 0.85) | 12.2 (± 1.18) | 11.84 (± 0.69) | 9.76 (± 1.06) | 11.69 (± 1.24) | 9.42 (± 1.02) | 9.17 (± 1.06) | 8.27 (± 1.14) | 7.86 (± 0.64) | 8.45 (± 0.47) |
| **Total Moths Sampled** | **Dunbrody estates - Riverside A** | 0 | 0 | 2 | 48 | 31 | 0 | 0 | 0 | 1 | 14 | 3 | 0 | 0 |
| | **Dunbrody estates - Riverside B** | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 |
| | **Halaron Farm** | 0 | 0 | 0 | 4 | 1 | 2 | 0 | 0 | 5 | 0 | 9 | 0 | 0 |
| | **Hitgeheim** | 0 | 0 | 1 | 6 | 1 | 0 | 0 | 2 | 1 | 0 | 2 | 0 | 14 |

**N** - North; **NNE** - North North East; **NE** - North East; **ENE** - East North East; **E** - East; **ESE** - East South East; **SE** - South East; **SSE** - South South East; **S** - South; **SSW** - South South West; **SW** - South West; **WSW** - West South West; **W** - West; **WNW** - West North West; **NW** - North West; **NNW** - North North West

**Table 5.10**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and climatic conditions within orchards in the Sundays River Valley growing region during 2014.

| | | Valid (N) | Spearman (R ) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **Max Temp** | **Overall** | 52 | -0.0435 | 0.2086 | -0.3078 | 0.7595 |
| | **Dunbrody estates - Riverside A** | 13 | 0.0358 | 0.1893 | 0.1189 | 0.9075 |
| | **Dunbrody estates - Riverside B** | 13 | -0.2080 | 0.4561 | -0.7054 | 0.4952 |
| | **Halaron Farm** | 13 | -0.0407 | 0.2018 | -0.1352 | 0.8949 |
| | **Hitgeheim** | 13 | 0.0524 | 0.2289 | 0.1741 | 0.8650 |
| **Min Temp** | **Overall** | 52 | -0.1291 | 0.3594 | -0.9209 | 0.3615 |
| | **Dunbrody estates - Riverside A** | 13 | -0.0120 | 0.1093 | -0.0396 | 0.9691 |
| | **Dunbrody estates - Riverside B** | 13 | -0.2483 | 0.4983 | -0.8502 | 0.4134 |
| | **Halaron Farm** | 13 | -0.0877 | 0.2962 | -0.2920 | 0.7757 |
| | **Hitgeheim** | 13 | -0.2155 | 0.4642 | -0.7319 | 0.4796 |
| **Precipitation** | **Overall** | 52 | 0.0956 | 0.3092 | 0.6789 | 0.5003 |
| | **Dunbrody estates - Riverside A** | 13 | -0.0538 | 0.2319 | -0.1786 | 0.8615 |
| | **Dunbrody estates - Riverside B** | 13 | 0.1544 | 0.3929 | 0.5181 | 0.6146 |
| | **Halaron Farm** | 13 | -0.0908 | 0.3014 | -0.3025 | 0.7679 |
| | **Hitgeheim** | 13 | 0.3902 | 0.6247 | 1.4055 | 0.1875 |
| **Wind Direction** | **Overall** | 52 | -0.1053 | 0.3245 | -0.7488 | 0.4575 |
| | **Dunbrody estates - Riverside A** | 13 | -0.0597 | 0.2444 | -0.1985 | 0.8463 |
| | **Dunbrody estates - Riverside B** | 13 | -0.1678 | 0.4096 | -0.5644 | 0.5838 |
| | **Halaron Farm** | 13 | -0.0407 | 0.2018 | -0.1352 | 0.8949 |
| | **Hitgeheim** | 13 | -0.1747 | 0.4180 | -0.5885 | 0.5681 |
| **Wind Speed** | **Overall** | 52 | -0.1053 | 0,.2450 | -0.7488 | 0.4575 |
| | **Dunbrody estates - Riverside A** | 13 | -0.0597 | 0.2444 | -0.1985 | 0.8463 |
| | **Dunbrody estates - Riverside B** | 13 | -0.1678 | 0.4096 | -0.5644 | 0.5838 |
| | **Halaron Farm** | 13 | -0.0407 | 0.2018 | -0.1352 | 0.8949 |
| | **Hitgeheim** | 13 | -0.1747 | 0.4180 | -0.5885 | 0.5681 |

For 2015 (Fig. 5.27) there was no relationship between trap catches and maximum temperature (Table 5.12) (Fig. 5.28). However, there was a relationship between trap catches and minimum temperature (Fig. 5.28) for the overall trap catches of *Serrodes partita* in Kat River Valley ($p = 0.0453$, $R^2 = 0.6725$) (Table 5.12) and Dunbrody Estates - Riverside C ($p = 0.0139$, $R^2 = 0.9740$) (Table 5.12). There was no relationship between trap catches and precipitation (Fig. 5.29) and wind direction (Table 5.11, 5.12). There was a relationship between trap catches and wind speed (Table 5.11) for the overall trap catches of *Serrodes partita* in the Kat River Valley ($p = 0.0233$, $R^2 = 0.7102$) (Table 5.12).

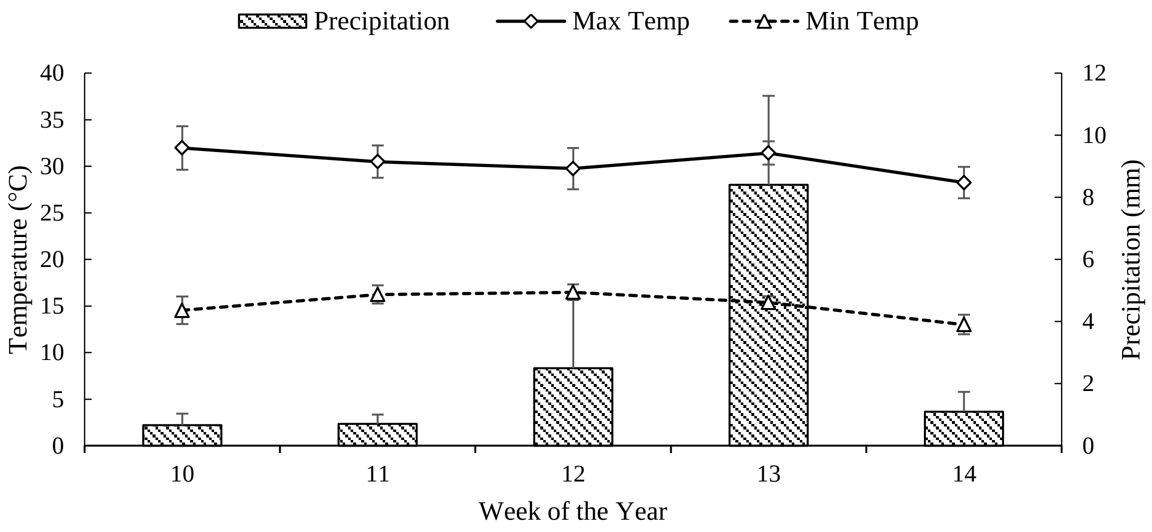


**Figure 5.27**: The weekly mean daily maximum and minimum temperatures (°C) and precipitation (mm), during 2015 at Sundays River Valley, during 5 week sampling period.

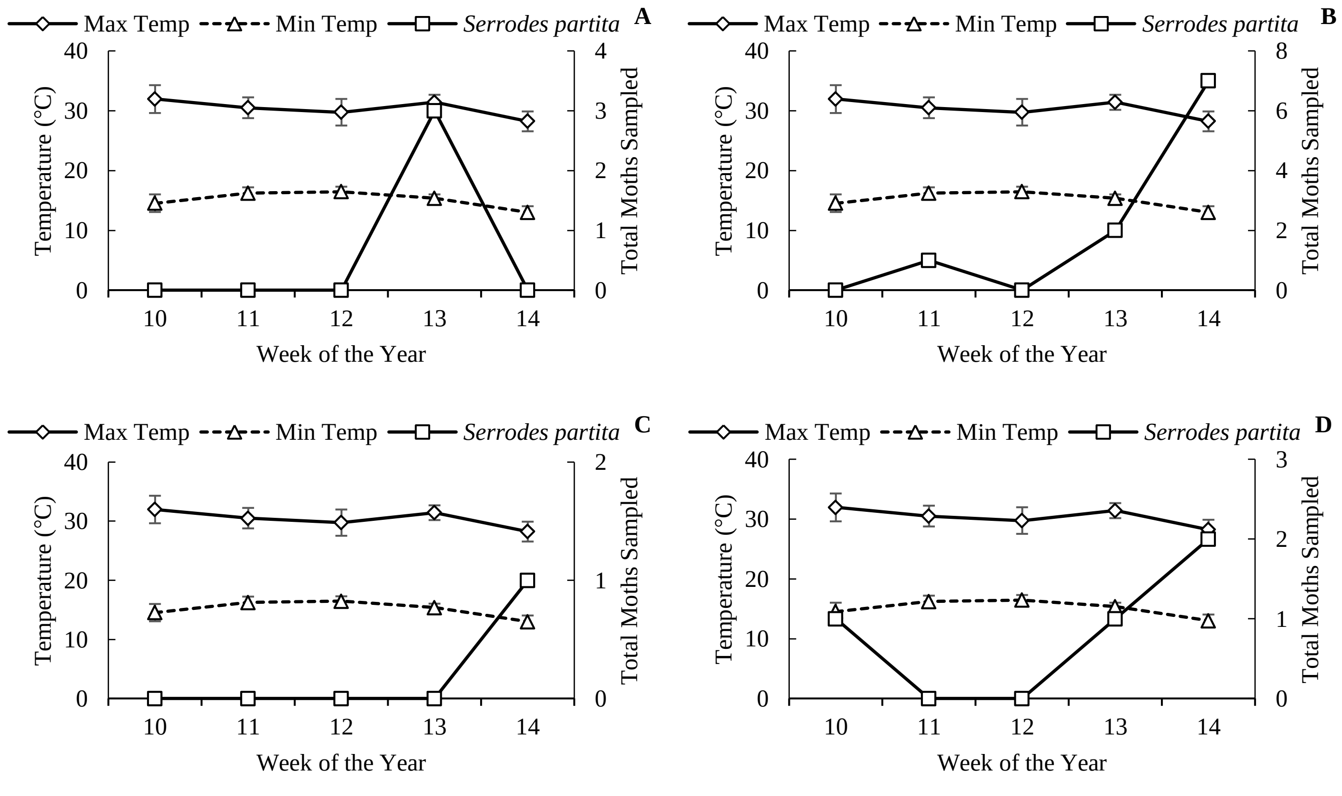


**Figure 5.28**: The weekly *Serrodes partita* activity within the orchards compared with the mean daily maximum and minimum temperatures (°C) per week, during 2015 at Sundays River Valley, during 5 week sampling period. **A** – Halaron Farm; **B** – Dunbrody Estates - Riverside A; **C** – Dunbrody Estates - Riverside B; **D** - Dunbrody Estates - Riverside C.

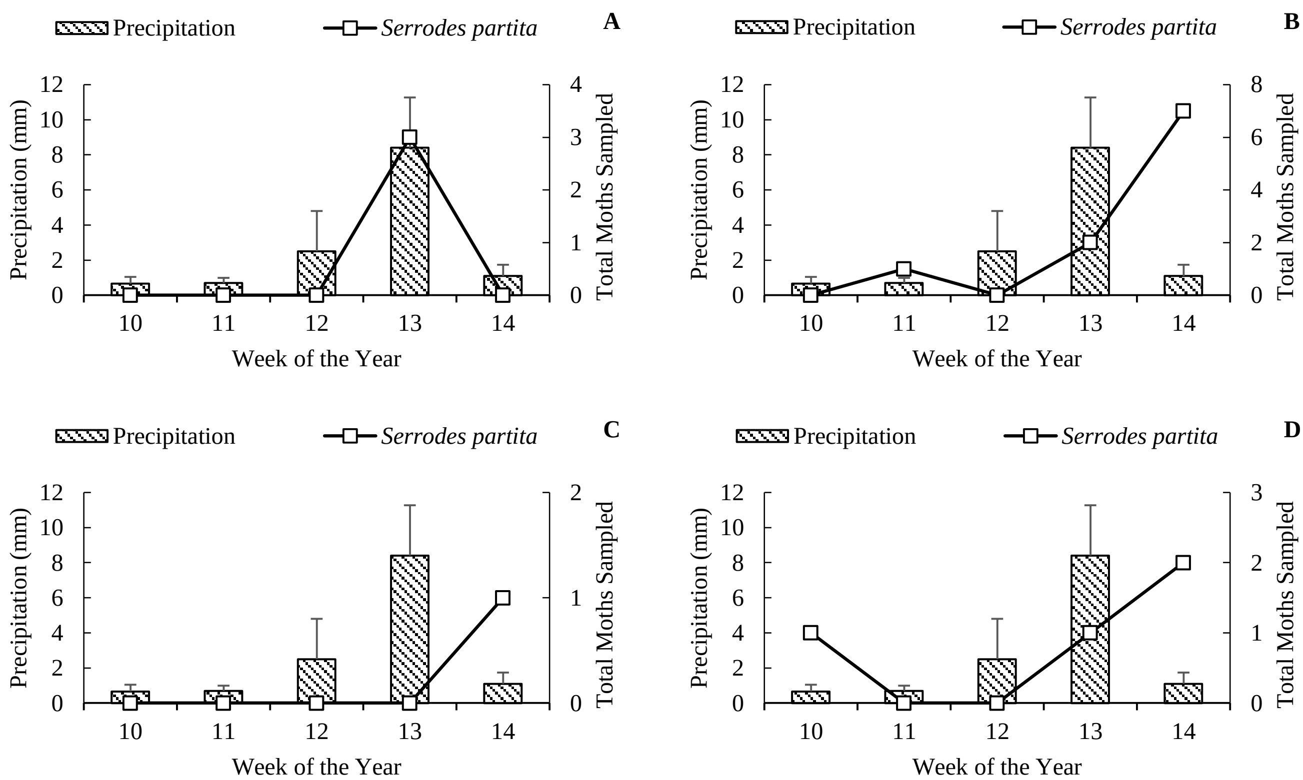


**Figure 5.29**: The weekly *Serrodes partita* activity within the orchards compared with the mean precipitation (mm) per week, during 2015 at Sundays River Valley, during 5 week sampling period. **A** – Halaron Farm; **B** – Dunbrody Estates - Riverside A; **C** – Dunbrody Estates - Riverside B; **D** - Dunbrody Estates - Riverside C.

**Table 5.11**: The weekly mean wind speed (m/s) and wind direction, during 2015 at Sundays River Valley, during 15 week sampling period.

| **Week of the Year** | | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|
| **Wind Direction** | | SSE | S | S | S | SSE |
| **Wind speed (m/s) (± SE)** | | 10.91 (± 0.95) | 10.87 (± 0.88) | 10.34 (± 0.63) | 10.17 (± 0.74) | 9.31 (± 1.05) |
| **Total Moths Sampled** | **Dunbrody estates - Riverside A** | 0 | 1 | 0 | 2 | 7 |
| | **Dunbrody estates - Riverside B** | 0 | 0 | 0 | 0 | 1 |
| | **Dunbrody estates - Riverside C** | 1 | 0 | 0 | 1 | 2 |
| | **Halaron Farm** | 0 | 0 | 0 | 3 | 0 |

**N** - North; **NNE** - North North East; **NE** - North East; **ENE** - East North East; **E** - East; **ESE** - East South East; **SE** - South East; **SSE** - South South East; **S** - South; **SSW** - South South West; **SW** - South West; **WSW** - West South West; **W** - West; **WNW** - West North West; **NW** - North West; **NNW** - North North West

**Table 5.12**: The p-values for the Spearman Rank Order Correlations, comparing the trap catches for *Serrodes partita*, and climatic conditions within orchards in the Sundays River Valley growing region during 2015.

| | | Valid (N) | Spearman (R ) | Spearman ($R^2$) | t(N-2) | p-value |
|---|---|---|---|---|---|---|
| **Max Temp** | **Overall** | 20 | -0.1218 | 0.3489 | -0.5204 | 0.6091 |
| | **Dunbrody estates - Riverside A** | 5 | -0.4617 | 0.6795 | -0.9015 | 0.4338 |
| | **Dunbrody estates - Riverside B** | 5 | -0.7071 | 0.8409 | -1.7321 | 0.1817 |
| | **Dunbrody estates - Riverside C** | 5 | -0.1054 | 0.3247 | -0.1836 | 0.8660 |
| | **Halaron Farm** | 5 | 0.3536 | 0.5946 | 0.6547 | 0.5594 |
| **Min Temp** | **Overall** | **20** | **-0.4522** | **0.6725** | **-2.1511** | **0.0453** |
| | **Dunbrody estates - Riverside A** | 5 | -0.5643 | 0.7512 | -1.1839 | 0.3217 |
| | **Dunbrody estates - Riverside B** | 5 | -0.7071 | 0.8409 | -1.7321 | 0.1817 |
| | **Dunbrody estates - Riverside C** | **5** | **-0.9487** | **0.9740** | **-5.1962** | **0.0139** |
| | **Halaron Farm** | 5 | | | | |
| **Precipitation** | **Overall** | 20 | 0.2713 | 0.5209 | 1.1960 | 0.2472 |
| | **Dunbrody estates - Riverside A** | 5 | 0.3591 | 0.5992 | 0.6664 | 0.5528 |
| | **Dunbrody estates - Riverside B** | 5 | | | | |
| | **Dunbrody estates - Riverside C** | 5 | | | | |
| | **Halaron Farm** | 5 | 0.7071 | 0.8409 | 1.7321 | 0.1817 |
| **Wind Direction** | **Overall** | 20 | -0.0139 | 0.1180 | -0.0590 | 0.9536 |
| | **Dunbrody estates - Riverside A** | 5 | -0.0513 | 0.2265 | -0.0890 | 0.9347 |
| | **Dunbrody estates - Riverside B** | 5 | -0.7071 | 0.8409 | -1.7321 | 0.1817 |
| | **Dunbrody estates - Riverside C** | 5 | -0.5271 | 0.7260 | -1.0741 | 0.3615 |
| | **Halaron Farm** | 5 | 0.7071 | 0.8409 | 1.7321 | 0.1817 |
| **Wind Speed** | **Overall** | **20** | **-0.5044** | **0.7102** | **-2.4783** | **0.0233** |
| | **Dunbrody estates - Riverside A** | 5 | -0.8208 | 0.9060 | -2.4887 | 0.0886 |
| | **Dunbrody estates - Riverside B** | 5 | -0.7071 | 0.8409 | -1.7321 | 0.1817 |
| | **Dunbrody estates - Riverside C** | 5 | -0.5271 | 0.7260 | -1.0741 | 0.3615 |
| | **Halaron Farm** | 5 | -0.3536 | 0.5946 | -0.6547 | 0.5594 |

## 5.4 Discussion

During this study, although not considered an outbreak year, fruit-piercing moth caused notable damage within the orchards. Fruit-piercing moth damage was observed on the fruit six to eight weeks before all the fruit had been harvested. Fay and Halfpapp (2006) observed a similar trend in Australia where most damage occurred eight weeks prior to harvest when the fruit were unripe or just starting to ripen. Fay and Halfpapp (2006), suggest that the damaged fruit caused either by fruit-feeding moths or mechanically could be releasing volatiles, which in turn results in more moths been attracted into the orchard. Orchard sanitation could help reduce the number of fruit-feeding moths within the orchard and respectfully reduce damage to the fruit.

*Serrodes partita* still persists within the orchards during periods when it is not regarded as an outbreak year and has been shown to still be a problem. The moth was present in the orchards for the entire sampling period. It is evident that in these non-outbreak years, the growers are probably oblivious to the level of damage being caused, as levels of damage are relatively low, and as they are not monitoring and thus unaware that the moth is present in the orchards. Furthermore the damaged fruit does not make it to the packhouse, as it is not harvested off the trees. However the growers may only become aware and begin noting the damage during outbreak years when the fruit makes it to the packhouse or the damage and/or moth presence is so noticeable in the orchards, that it cannot be missed.

Even though there was no statistically significant relationship shown for the activity of *S. partita* in the orchards and damage to fruit, two to three weeks after a peak in *S. partita* trap catches, associated damage was recorded on the fruit, indicating that there is a lag phase until damage is visible. Although not significant, this relationship should not be discarded as it could be used as an indicator for the growers to determine when they could expect damage within the orchards. However, if monitoring and scouting is carried out earlier in the same season, a relationship might become more obvious, as damage might be observed earlier. Robinson *et al.* (2012), explains that the reason there is no true correlation, is that the fruit are picked as they ripen and this is when the moths are most active, as all the damaged fruit are removed and cannot be scored. This can be hopefully avoided if communication with the growers is maintained and that scouting of the fruit occurs before the farmers' harvest, so that scores can be counted.

The weeks that had the highest trap catches of *S. partita* for all years were consistently during the 10$^{th}$ week of the year for the Kat River Valley growing region and the 9$^{th}$ and 10$^{th}$ week for the Sundays River Valley growing region and again during harvesting in both regions. Knowing when *S. partita* is the most active, these weeks could allow farmers to know when they should be placing traps in the orchards for best control of *S. partita*.

Of all climatic factors, precipitation appeared to have the most influence on trap catches of *S. partita*. This might be attributable to changes in humidity or moon phases, as humidity and moon phases have been shown to impact the activity and abundance of moths sampled in traps (Jonason *et al.* 2014). However, these relationships were only observed for a few orchards and not for all, indicating that weather could be playing a role in the activity of moths within the orchard and the number of individuals that are sampled in the traps. Using weather to predict trap catches might not be an appropriate method as trends were not consistent for all orchards. However the study was done over three years, which may not have provided sufficient data to show a true relationship and additional years of monitoring data may be needed. Observing daily, nightly or hourly weather conditions and traps catches could allow for a better relationship as daily weather variations can influence the number of moths being sampled in traps (Jonason *et al.* 2014; Holyoak *et al.* 1997). Observing the weather activity within the *S. partita* area of origin of these moths (the larval hosts range) might be a better indicator in order to see if weather plays a role in the activity of the moth.

# Chapter 6

# GENERAL DISCUSSION

## 6.1 Introduction

The fruit-piercing moth, *S. partita*, is now understood to be a sporadic pest, which only becomes a problematic pest every five to 10 years after good rainfall in the Little Karoo (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). During these outbreaks the damage caused to fruit can range from 70 to 90% in an orchard (Johannsmeier 1998; Box 1942; Gunn 1929). This is especially so for soft skinned citrus as it is easily pierced (Robinson *et al.* 2012; Moore 2010). There was no outbreak of *S. partita* during the three growing seasons during this study, as a low abundance of the moths were sampled during the sampling weeks. It was also observed that there was a greater abundance of fruit-sucking moth species in the orchards than there were fruit-piercing moth species. Currently, the only way in which to successfully control fruit-feeding moths within the orchards is the use of repellent lights (Johannsmeier 1998; Whitehead & Rust 1967, 1971, 1972). However, this method is not ideal as there is no way of monitoring what moth species are attacking the fruit in the orchards during the night. Therefore it is important to find an alternative control method, such as using a bait to attract and kill the moths when they are in the orchards, like the synthetic fruit-piercing moth attractant that Fay and Halfpapp (2003) developed to attract and kill fruit-piercing moths in the genus *Eudocima*. A synthetic attractant would be ideal and may be cost effective if growers do not need to replace it weekly, as would be the case with fresh banana bait. Furthermore, it would allow growers to better relate moth presence to damage observed in the orchards.

Initial studies on the use of baits for attracting fruit feeding moths in citrus in South Africa were conducted by Robinson *et al.* (2012). Here he showed that banana was more attractive to *S. partita* in Satsuma orchards. The research done by Robinson *et al.* (2012) was consistent with other literature, showing the attractiveness of banana to fruit-feeding moths (Reddy & Muniappan 2007; Johannsmeier 1998). Therefore this current study has added to the research done by Robinson *et al.* (2012). One of the main focuses of this study was to develop an alternative attractant to that of banana, so that a cost efficient method could be used as an attractant for monitoring fruit-feeding moths in citrus orchards. However, to do this, it was firstly necessary to identify all possible species of fruit-feeding moths in citrus orchards, which was done in the Eastern Cape and Tshipise growing regions (Chapter 2).

General confusion amongst growers of which species are fruit-piercing and which species are fruit-sucking moths led to research within this study to confirm which species are fruit-piercing (i.e. cause primary damage) by looking at the morphology of the proboscis (Chapter 3). Moth species collected within the orchards were thus identified and categorised as either fruit-piercing moths or fruit-sucking moths. It was confirmed that the ability of a fruit-piercing moth to feed on undamaged fruit is a direct result of its proboscis morphology. There were only two fruit-piercing moths identified, namely *S. partita* and *Eudocima* sp. Fresh banana was compared to nine alternative synthetic attractants, frozen banana and a control in the hope of identifying a more suitable attractant for these moths (Chapter 4). Once again, banana was shown to be the most attractive bait. However, there were a few *S. partita* sampled using three alternative baits, which are artificially made, resembling different ripening stages of banana. Future research can look at how attractive the individual volatiles (Thaiphanit & Anprung 2010) from ripe banana are to *S. partita* by attaching the antenna, dissected from recently dead adult moths, to an oscilloscope and monitoring how they respond to each volatile (Fay & Halfpapp 2003). Once the volatile or suite of volatiles is identified, an attractant can be synthesised and compared against banana, to see if the synthetic lure is adequately attractive to fruit-piercing moths.

The different damage types monitored weekly (Chapter 5) in the five orchards, in the 2013 growing season, and the 10 orchards in the 2014 and 2015 growing season, has provided a clearer picture of what level of impact *S. partita* has in citrus orchards during non-outbreak years, particularly relative to other forms of damage. Despite there being no outbreak years, fruit-piercing moth damage was still shown to be one of the most abundant damage types to ripening fruit. By monitoring the damage caused to fruit in citrus orchards during the course of the three growing seasons it was hoped that a correlation would be shown between weekly trap catches of *S. partita* and fruit-piercing moth damage (Chapter 5). The intention was to help farmers better predict the degree of damage they could expect from a certain number of moths, or stated otherwise, to establish a trap-based economic threshold. Unfortunately there was no correlation shown. However, there was a trend observed where two to three weeks after a peak in *S. partita* trap catches, there was a peak in damage to the fruit, indicating that even though there was no correlation shown, there was still a pattern or trend. An example of a similar situation is in the monitoring of false codling moth (FCM), *Thaumatotibia leucotreta*, on citrus, where in all the years of monitoring FCM with pheromone traps, no statistically significant correlation could be shown between trap catches and fruit infestation. However, there still is an observed relationship between the two, in that a peak in trap catches will often lead to a rise in fruit infestation (Moore pers. comm. 2015; May *et al.* 2010). Weather conditions were recorded and compared to weekly trap catches of *S. partita* in order to determine if there was a correlation i.e. if increases in *S. partita* levels could be triggered by certain weather parameters and hence predicted based on the weather (Chapter 5). Weekly precipitation patterns within the growing regions were shown to be the most closely correlated with weekly trap catches of *S. partita*, when compared with temperature (maximum and minimum), wind speed and wind direction. However, this correlation between *S. partita* activity and precipitation was only shown to be true for a few orchards, but not for all.

Thus, to date, what is known about the potential of developing an attractant for monitoring fruit-feeding moths in citrus orchards is that: (1) there is a large diversity of fruit-feeding moths in the orchards, but only 6.9% of trap catches were fruit-piercing moths i.e. predominantly *S. partita*; (2) from the 23 moth species sampled within the orchards, only two were fruit-piercing moths and these two species were *S. partita* and *Eudocima* sp.; (3) fresh banana is still the most attractive bait in attracting fruit-feeding moths in the orchards; (4) there was no correlation observed for weekly activity of *S. partita* and damage, but a trend was observed with a peak in damage two to three weeks after a peak in *S. partita* activity; and (5) precipitation showed a correlation with *S. partita* activity, but only for a few orchards.

### 6.1.1 Abundance of fruit-piercing moth

During the past three growing seasons, there was a large number of different fruit-feeding moths sampled weekly in the orchards, where only two of the moth species were fruit-piercing moths. They comprised a very low percent of the total trap catches. This was confirmed by looking at the morphology of these moths' proboscides. This begs the question as to whether if it is necessary to monitor fruit-sucking moths, such as *A. lienardi* and not just focus on fruit-piercing moths. Fruit-sucking moths don't cause any primary damage to the fruit and only add to the weekly by-catch, which may confuse the growers in determining which species are fruit-piercing and which are fruit-sucking. Therefore, if fruit-piercing moths were trapped without any fruit-sucking moths, it could lead to less confusion for the growers.

The populations of these moth species within the orchards were constant throughout the growing seasons, with peaks in activity often occurring during the 9$^{th}$ and 10$^{th}$ week of the year and again during harvesting in both regions. These low abundances observed may be typical of a non-outbreak year. The high diversity of fruit-feeding moths sampled within orchards raise two issues: growers are most likely under estimating the importance of fruit-piercing moths, as outbreaks only occur every five to 10 years, where growers may forget about the moths in between outbreaks and then are unprepared during outbreak years; and the need for growers to be able to better identify which species are in fact fruit-piercing moths and which are fruit-sucking moths. However, these moth species are difficult to differentiate from one another, once damaged, as they are similar in size and there is therefore a need for an identification guide for growers.

### 6.1.2 Damaged caused by fruit-piercing moths

Previous reports on fruit-piercing moths during outbreaks years, have recorded up to 70% loss in yield in the Eastern Cape (Gunn 1929; Johannsmeier 1998). However, in this study fruit-piercing moth damage was recorded at a low percent in the orchards, rarely going past 4% loss in yield ($ 790 loss in yield per ha, to Satsumas in 2014, if Satsumas in South Africa experienced 4% loss across the country, this would compare to a loss of $ 763 876 (CGA Key Industry Statistics 2015). These values were calculated by using CGA Key Industry Statistics (2015) and calculating the gross worth of Satsumas to the industry in 2014. This value worked out to be $ 19 million and 4% of that worth was $ 763 876, this was divided by the number of hectares grown of Satsumas which worked out to be $ 790/ha). From the weekly surveys, a large variety of different damage types were recorded, besides that of fruit-piercing moth damage, with mechanical (fruit split, damage caused by tractors or by other machinery) and other damage (which was undefined damage, sunburn or other pests, such as red scale or mealybug) being recorded at the same percent as fruit-piercing moth damage. As the fruit-piercing moth damaged fruit was not removed from the trees during weekly orchard sanitation, the conspicuousness of the damaged fruit on the trees may have led to an exaggerated impression of the damage caused by fruit-piercing moths within the orchards. However this is contrary to recommendations for orchard sanitation (Moore 2012; Moore & Kirkman 2008), where it is recommended to the growers, that any fruit-piercing moth damaged fruit be removed from the trees, as this would reduce the volume of volatiles been emitted from damaged fruit and decrease the presence of fruit-piercing moths in the orchards. Furthermore, it would further reduce fungal spore load in the orchards and would reduce the numbers of fruit (damaged) that is susceptible to other pests such as fruit fly and FCM.

### 6.1.3 The influence of climate on fruit-piercing moth populations

This study showed that there was no significant relationship found between fruit-piercing moth activity and climatic conditions in the orchards. However, it may not be surprising that there is no relationship between climatic conditions and *S. partita* adults in orchards, as the moths originate from outside of the orchards, sometimes hundreds of kilometres away, where their larval host plants occur (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). It could therefore be beneficial to understand where these moths are migrating from and to determine the relationship in these areas between climatic conditions (e.g. temperature and rainfall) and *S. partita* biology (e.g. oviposition success and larval and pupal development on the host plant). It has already been reported that rainfall has an effect in the area of origin of these moths (the larval hosts range), as it induces an extra flush of new leaves on host trees, providing newly hatched larvae more food, resulting in a type of population explosion, which then triggers a migratory cue (Robinson *et al.* 2012; Moore 2010; Johannsmeier 1998). Furthermore, considering other climatic conditions (e.g. temperature (night and day)) may reveal other potential predictors of migratory activity. It would also be helpful to determine what proportion of the population migrates from the areas of origin and how this is influenced by various conditions.

This would enable more accurate prediction of pest pressure that could be expected in citrus orchards during any given year. Different climatic conditions during the warmer times of the year have been shown to have an impact on the activity of moths, where the species richness and abundance per night were mainly influenced by night temperatures and humidity (Jonason *et al.* 2014). Jonason *et al.* (2014) conducted a study in Germany, where they sampled over 49 472 individual moths belonging to 372 species. They were able to show that an increase in air humidity decreased the abundance of these moths and that most moth species were most active during the summer. Furthermore, a higher number of species were captured when their sampling was limited to the warmest nights in each month.

The use of climatic conditions within the orchards to provide an early warning of what trap catches and damage potential might be, may not be appropriate, whereas using the climatic conditions within the larval host range could provide a more accurate warning of what trap catches and damage potential might be. This difference could be due to only having the highest recorded values of climatic conditions for each day or week at set locations in the regions. However, having real time weather stations in set locations within the larval host range and in the region of the orchards, would give a real indication of whether and what climatic factors are influencing the moths to migrate. Observing nightly or hourly climatic conditions and then linking them to traps catches could also allow for a better understanding of which climatic conditions may be influencing the number of moths sampled in traps.

### 6.1.4 Development of an appropriate monitoring/scouting protocol

One of the main objectives of this study was to establish a suitable method for attracting fruit-piercing moths to baits in citrus orchards. Fruit-feeding moths have been recorded to be attracted to a wide range of fruit and the volatiles that these fruit emit (Robinson *et al.* 2012; Reddy & Muniappan 2007; Fay & Halfpapp 2003, 2001). In this study, like many other studies (Robinson *et al.* 2012; Reddy & Muniappan 2007; Fay & Halfpapp 2003, 2001), fruit-piercing moths were shown to be attracted to banana. Even though these moths are attracted by the volatiles released by the citrus fruit, they apparently find banana more attractive than citrus fruit (Robinson *et al.* 2012; Reddy & Muniappan 2007; Fay & Halfpapp 2003, 2001). However, this is unusual as fruit-piercing moths have not been recorded as pests on banana. This could be because fruit-piercing moths are only attracted to ripe bananas and the volatiles they emit, whereas bananas are harvested while still very green and are ripened artificially (Grierson 1995; Marriott & Palmer 1980). Several attempts, over three growing seasons, were made to use synthetically produced components of banana volatiles and to compare their attractiveness to that of fresh banana in attracting fruit-piercing moths, but these were not successful in attracting the moths. Therefore, development of a suitable bait is yet to be achieved, as even though banana is the ideal bait from an attractiveness point of view, its use is not practical as it would have to be replaced weekly. This may also become costly over time. Therefore considerable laboratory work is still required to further tests volatiles and possibly volatiles bouquets.

The use of banana in attracting other fruit-feeding moths has also been shown in other studies, such as the study done by Reddy and Muniappan (2007), who showed that banana was the most successful fruit bait in attracting the fruit-piercing moth, *E. phalonia* when comparing it to other fruit baits such as, guava, orange, kiwi, apple, pineapple, pear, papaya, mango, grapefruit, tomato, green grape, star fruit, plum and soursop. Their study indicated the definitive attractiveness of fruit baits to economically important fruit-piercing moths, identifying valuable attractants which may be used as part of a lure and kill strategy for this important pest. Fay and Halfpapp (2001) showed that *Eudocima phalonia* was attracted to sugared-agar baits that contained volatile fruity esters.

Fruit baits have been shown to be attractive to moths due to the carbohydrates found within the fruit (Reddy & Muniappan 2007; Fay & Halfpapp 2001). These carbohydrates help with egg development in fruit-feeding moths and butterflies. It is known that during the larval life stage, the larvae collected the necessary nutrients for survival, adult morphology and possibly egg development for the adult moths (Boggs & Freeman 2005). However, fecundity is also affected by adult dietary restriction (Boggs & Freeman 2005). While the importance of carbohydrates is fairly well understood for egg development, the role of other nutrients for other adult-derived substances is only partially resolved (Bauerfeind & Fischer 2005).

Bananas are high in carbohydrates (Cordenunsi & Lajolo 1995; Marriott *et al.* 1981), making banana an ideal food source for fruit-feeding moths and egg development. However the attraction of these moths to banana could occur during the fermentation of banana, as ethanol is an olfactory cue for the attraction of moths (Bauerfeind *et al*. 2007; Omura & Honda 2003). Ethanol at low concentrations is an energy source, but at high concentrations is deadly. Ethanol increases in banana, over a 48 hour period, as banana pulp starts to ferment (Arumugam & Manikandan 2011; Dudley 2004; Milton 2004; Bokor and Pecsenye 2000), making the fruit more attractive to fruit-feeding moths. However, this does not increase feeding rate or reproductive output (Bauerfeind *et al*. 2007). All of this could explain why fruit-feeding moths, especially the fruit-piercing moth, *S. partita*, find banana more attractive than the Satsuma Mandarin fruit. Furthermore, ethanol could be combined with a synthetic fruit volatile lure to increase its attractiveness or even to a fresh fruit pulp lure, which could also help to preserve it and extend its field life.

Another strategy that has been employed successfully for monitoring and control of various lepidopteran pests, is the use of sex pheromones, which generally attract males apart from monitoring, can be used in mating disruption (Moore pers. comm. 2015; May 2010). If a *S. partita* (or any other fruit-piercing moths species) sex pheromone could be identified, an effective method for monitoring and possibly even controlling the pest might be developed.

### 6.1.5 Development of an appropriate control protocol

The use of different control methods or implementation of an attract and kill system for fruit-piercing moths could be beneficial to growers. Using a range of control methods may help reduce the number of damage caused to fruit within orchards. Other methods that can be looked at for the control of fruit-piercing moths are the use of entomopathogenic fungi, virus or bacteria. Swart *et al.* (1975) reported, without quoting any evidence, that bacterial or viral diseases often kill larvae of the fruit-piercing moth, *S. partita*. Furthermore if these bacterial or viral diseases were identified, they could be applied in an aerial spray to the larval host plants during outbreak years and potentially reduce the number of adults migrating to the orchards. Another possibility is to identify and use parasitoids augmentatively. These should preferably be egg or larval parasitoids, such as an unidentified tachinid fly that parasitizes the larvae of *S. partita*. This would require mass rearing of the parasitoids and releasing them against the larvae during suspected outbreak years. However this would entail mass rearing of the host, which could be problematic as the larvae take a period of 53-61 days to develop from egg to pupa and a further 20-33 days to reach to the adult stage. Neonate larvae are currently known to feed exclusively on newly flushed leaves, which occurs after good rainfall (Johannsmeier 1998). Therefore, if mass rearing was to be practically possible, it would be necessary to develop a synthetic larval diet.

Bats play an important role in arthropod suppression (Kunz *et al.* 2011), where they have been seen feeding on moths or deterring moths within orchards due to their echo-location (Johannsmeier 1998). Lepidopteran pests comprised an extensive part of bat diets, providing valuable natural pest control services within agricultural ecosystems (Kunz *et al.* 2011; Lee & McCracken 2005).Bats have been shown to reduce damage caused to the cotton industry by lepidopteran pest populations in North America by an estimated $741 000 per annum (Cleveland *et al.* 2006). Therefore constructing bat boxes and placing them around orchards might help decrease the number of lepidopteran pest species within the orchards. However, this possibility would need to be tested for fruit-piercing moths (and possibly other lepidopteran pests) in citrus.

## 6.2 Conclusion and future research

Banana was again shown to be the most effective attractant to monitor fruit-feeding moths within Satsuma orchards. However, there were a few *S. partita* sampled with R1 and R3, which were artificially made baits resembling different ripening stages of banana. This indicates potential for finding an alternative synthetic bait to banana. As banana was shown to be a broad attractant, attracting various species of fruit-feeding moths, it isn't ideal, as the majority of fruit-feeding moths present in orchards and thus the majority of moths sampled were fruit-sucking moths, which do not cause primary damage. Even though there was only relatively low activity of *S. partita* within the orchards in this study, there was an average of 4% damage caused to fruit. This could indicate that banana may not be as attractive as initially thought as it might only be catching a small proportion of the actual number of *S. partita* within the orchards, resulting in a poor correlation between weekly trap catches of *S. partita* and damage. However, it doesn't matter how many or how few are sampled in the traps, as long as it is possible to relate catches to fruit damage.

Future research could include: (1) looking at possible alternative attractants to fruit for the control of *S. partita,* such as sex pheromones, as there is a lot of by-catch of fruit-sucking moths; (2) or conducting laboratory tests to determine which volatiles or group of volatiles from banana are the most attractive to *S. partita*; (3) developing of a better volatile or bait dispenser for attracting *S. partita* within the orchards; (4) establishing a laboratory culture of *S. partita,* so to (a) better understand the biology of the moth, to prospect for (i) pathogens, and (ii) rear biocontrol agents (e.g. the tachinid fly), and (b) to conducted laboratory trials to test (i) pathogens, (ii) parasitoids, (iii) chemical pesticides and (b) to achieve a higher level of accuracy in comparing the attractiveness of baits to banana because of the exclusion of the multitude of confounding variables found within the field; (5) placing traps at different heights in trees or positions within orchards to determine optimal trap positioning for maximum possible catches; (6) comparing the activity and movement of *S. partita* between orchards, including host range; (7) recording daily or even hourly (instead of weekly) weather conditions in the orchards and the larval host range; this could aid in better predicting future movements of *S. partita*, particularly outbreaks; (8) monitoring fruit-piercing moth damage on fallen fruit and fruit on the trees, which could assist in determining a correlation between activity of *S. partita* and damage; and (9) monitoring activity of fruit-feeding moths throughout the growing season from blossom to harvest could lead to a better understanding of when *S. partita* is active in the orchards, thus monitoring damage so as to better determine when fruit first becomes susceptible to fruit-piercing moth damage.

# Chapter 7

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# Appendix I

## FRUIT-FEEDING MOTH SPECIES DESCRIPTION

*Serrodes partita* (Fabricius, 1779) refer to Chapter 1 (Fig. 1.2).

*Achaea* spp. was regarded as one of the most abundant species collected in all the growing regions. *Achaea* spp. consisted of *A. lienardi*, *A. echo*, *A, indeterminata* and in the Tshipise growing region it consisted of *A. lienardi* and *A. cattela*. The *Achaea* genus is regarded as a large genus with triangular forewings. The majority of which are attracted to light and fermenting fruit (Pinhey 1975). *Achaea lienardi* (Biosduval, 1833) refer to Chapter 1 (Fig. 1.5). *Achaea echo* (Walker, 1858) (Fig. I.1 A) is distributed through the Eastern Cape, Kwa-Zulu Natal and in Eastern and equatorial Western Africa. The forewing is dark brown at the base, up to a curved whitish-edged medial line and then a pinkish-brown, dark red-brown shade curving from the apex and then running down to the tornus, with two fine brown dots at end of cell; the hindwing is grey-brown, darker outwardly, with a faint whitish medial fascia and an apical white spot (Pinhey 1975). Forewing length 25-30mm. The larvae feed on *Panicum. Achaea indeterminata* (Walker, 1865) (Fig. I.1 B) is distributed through the Ethiopian Africa. It has a forewing length 20-22mm. *Achaea cattela* (Guenee, 1852) (Fig. I.1 C), is distributed through all parts of the Ethiopian region. The moth looks very similar to *A. lienardi*, particularly the hindwing, but the forewing is variegated grey or greyish-brown, with a sinuous inner line, not as straight as in *A. lienardi*; the hindwing is blackish-brown, with a sharp white central band and white marginal spots (Pinhey 1975). Forewing length is 21-31mm. The larva is almost a semi-looper, with the anterior pro-legs poorly developed; it has been recorded feeding on *Bauhinia, Ricinus communis*, *Lonchocarpus, Tamarindus, Eucalyptus* species and recently recorded feeding on citrus.

*Ericeia inangulata* (Guenee, 1852) (Fig. I.1 D) is distributed in the Ethiopian region and also Asia to Australia. The wings are pale grey, brownish-grey, ochreous or ochreous-brown, with wavy dotted lines; there is a thicker wavy band before the outer margin, especially on the forewing (Pinhey 1975). The forewing is often with twin grey dots towards the apex. Forewing length is 15-20mm.

*Sphingomorpha chlorea* (Cramer, 1779) (Fig. I.1 E) is distributed in most parts of Ethiopian Africa as far North as Sudan and also occurs in Southern Asia. The forewing is deep brown with an eye-like mark; the hindwing is darkish brown with a cream median band. There is a characteristic cream stripe down the middle of the brown body. The male has thick yellowish tufts of hair on the legs. It is not, of course, a hawk moth, but its inclination to evening refreshments, such as sherry, beer and also overripe fruit, readily attract this ubiquitous moth (Pinhey 1975). Forewing length is 26-31mm. The larva is a twig-like brown semi-looper with red and yellow dorsal spots, edged with black, near the anterior end; the larvae have been recorded feeding on *Acacia*, *Azanza*, *Burkea* and *Sclerocarya*, often gregariously.

*Anomis flava* (Fabricius, 1755) (Fig. I.1 F) is distributed through most of Africa and also parts of Asia and Australia. The forewing is angled at the outer margin, orange at the basal half, becoming darker in the outer half in female moths, and a deep orange-reddish in males, with a fine irregular transverse line, with a white or yellow dot at the end of the cell; the hindwing is yellowish-orange to brown (Pinhey 1975). Forewing length is 13-15mm. *Anomis flava has* been recorded as a common pest on cotton. The larvae are green, with faint white dorsal lines and some white ringed black dots and feed on *Hibiscus*, *Alcea* and cotton plant foliage, but not the bolls.

*Hypanua xylina* (Distant, 1898) is distributed through the Eastern Cape, Kwa-Zulu Natal and Zimbabwe. The forewing is a typical yellowish-brown with two fine oblique yellow-edged brown lines, one from near the base of the costa to the middle of inner margin, rather narrowly separated here from the outer line which extends to near the outer end of the costa, a sinuous row of dark brown sub-terminal dots starting as a blackish spot near the apex, typically kidney shaped in form and a minute dot for the orbicular stigma; the hindwing is creamy-yellow near the base and broadly brown distally with yellow cilia (Pinhey 1975). Forewing length is 24-27mm. *Hypanua roseitincta* (Hampson, 1918), nothing has been describe on this species.

*Nagia sacerdotis* (Hampson, 1926) (Fig. I.2 A) is distributed through the Eastern Cape up to Mozambique, Zimbabwe, Malawi and Zambia. The forewing is very dark reddish-brown; the hindwing is blackish-brown with a white central crescent (Pinhey 1975). Forewing length is 21-25mm.

*Parallelia algira* (Walker, 1858) (Fig. I.2 B) is distributed through the Eastern Cape, Kwa-Zulu Natal and in Eastern and equatorial Western Africa. Forewing length is 25-30mm (Pinhey 1975). This species has been regarded as a pest on grapes (Mani *et al.* 2014).

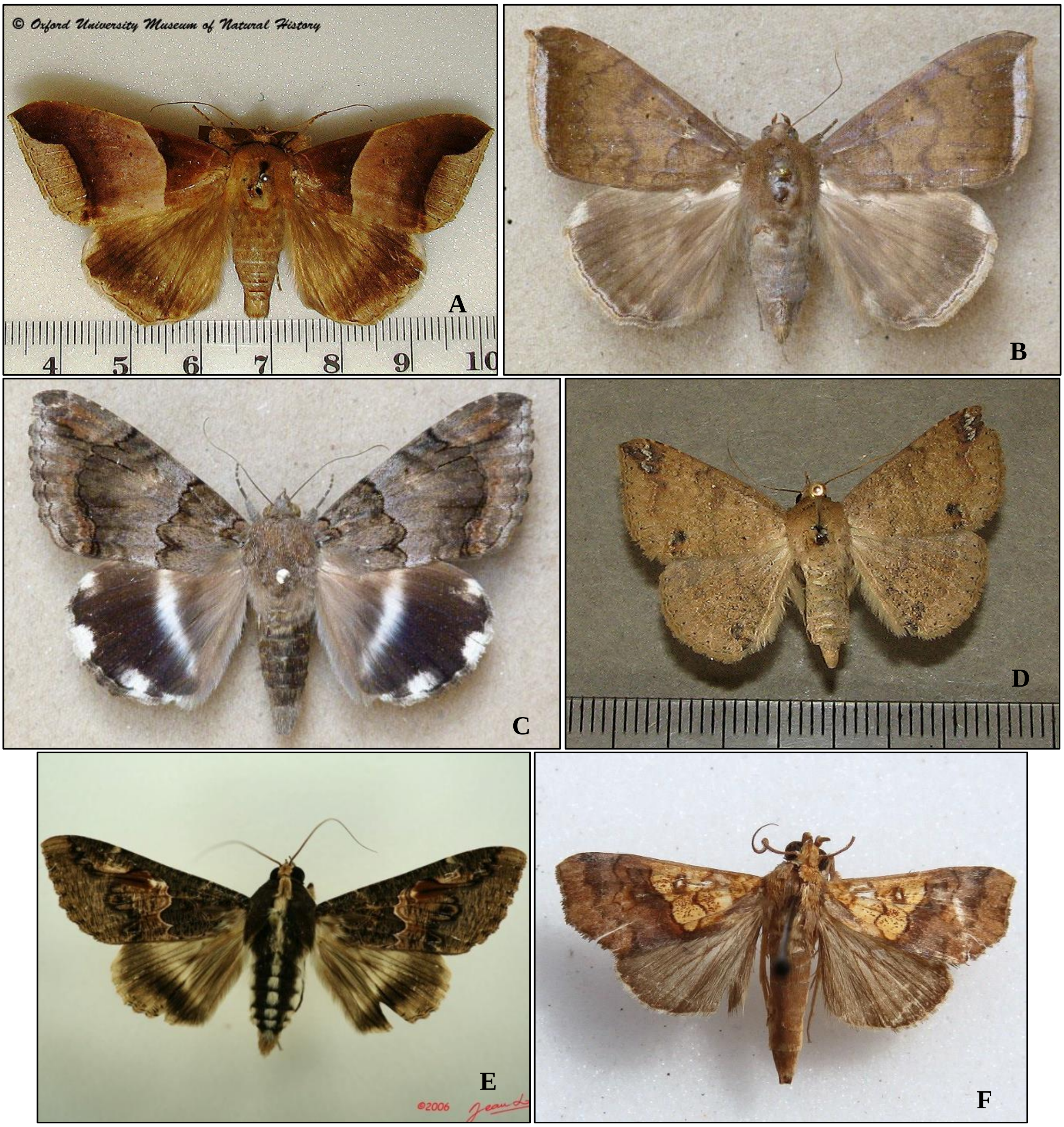


**Figure I.1**: **A** - *Achaea echo* adult; **B** - *Achaea indeterminata* adult; **C** - *Achaea cattela* adult; **D** - *Ericeia inangulata* adult; **E** - *Sphingomorpha chlorea* adult; **F** - *Anomis flava* adult (http://www.africanmoths.com/index.html).

*Ophiusa tirhaca* (Cramer, 1780) (Fig. I.2 C) is distributed throughout the African Continent, Southern Europe, Madagascar and is widespread in Asia. The thorax and forewing are an apple green with some brown spots and a reddish-brown outer margin zone; the hindwing and abdomen are yellow with a black bar on the hindwing (Pinhey 1975). Forewing length is 24-30mm. The larvae are grey, with paler grey strips, feed on *Combretum, Eucalyptus, Rhys* and also apparently on *Cistus, Pistacia, Daphne, Erica, Osyris* and *Viburnum.*

*Ulotrichopus catocala* (Walker, 1858) (Fig. I.2 D) is distributed through the Eastern Cape to Kwa-Zulu Natal. The forewing is variable in tone, pale red-brown, grey, grey-brown, dark grey mixed with red-brown or sometimes suffused with white, with a sharply oblique black line below the costa leading to one or two short longitudinal black strokes below the apical area, with a minute dot at the end of the cell; the hindwing is orange-yellow with a broad but discontinuous dark brown marginal band (Pinhey 1975). Forewing length is 23-26mm.

*Hydrillodes uliginosalis* (Guenee, 1854) (Fig. I.2 E) is distributed through the Eastern Cape up to Kwa-Zulu Natal, Mozambique, Zimbabwe, Malawi, and Zambia to Tropical West Africa. The forewing is narrow, rounded at the terman and apex; blackish-brown with a purplish tinge, the medial area paler brown, with crenulated yellowish-edged brown lines, the fine subterminal wavy line appearing only yellow, with a small black lunule at the end of the cell; the hindwing is grey-brown with a spot at the end of the cell (Pinhey 1975). Forewing length is 11-14mm.

*Cuneisigna obstans* (Walker, 1858) (Fig. I.2 F) is distributed through the Eastern Cape to Kwa-Zulu Natal, Mozambique, Zimbabwe, Tanzania and Zanzibar. The forewing is whitish-brown with an elongated dark brown wedge and a wavy dark brown band followed by an outer fine white line; the hindwing is pale brown in the male with a dark border, and darker altogether in the female (Pinhey 1975). Forewing length 13-16mm.

*Prodotis stolida* (Fabricius, 1775) (Fig. I.3 A) is distributed throughout Africa, parts of Europe and most of Asia. The forewing is brown with two white stripes, the outer one kinked inwardly; the hindwing brown with a white medial stripe, a white submarginal spot and the fringe is mainly white, but partly brown (Pinhey 1975). Forewing length is 12-17mm. The larvae are a greyish-yellow with thin brown lines, feeding on *Quercus* and *Coriaria myrtifolia, Rubus, Paliurus* and *Tribulus.*

*Anua dianiris* (Guenee, 1852) (Fig. I.3 B) is distributed throughout Namibia, Eastern and Western Cape up to Kwa-Zulu Natal, Mozambique, Zimbabwe, northwards to Kenya and Ethiopia. The forewing is pale grey with darker markings; the hindwing yellowish-orange with a broad brown border (Pinhey 1975). Forewing length is 22-25mm.


**Figure I.2**: **A** - *Nagia sacerdotis* adult; **B -** *Parallelia algira* adult; **C** - *Ophiusa tirhaca* adult; **D** - *Ulotrichopus catocala* adult; **E** - *Hydrillodes uliginosalis* adult; **F** - *Cuneisigna obstans* adult (http://www.africanmoths.com/index.html).

*Rhodogastria bauri* (Moschler, 1884) (Fig. I.3 C) is distributed throughout Namibia, Eastern Cape up to Kwa-Zulu Natal. The thorax, base of abdomen and forewing are brownish-yellow, the rest of abdomen and legs pink, the apical area of the forewing darker and with a group of four hyaline spots before this (Pinhey 1975). Forewing length is 27-28mm. The larvae feed on *Eugenia.*

*Aganais speciose* (Drury, 1773) (Fig. I.3 D) is distributed through the Western Cape up to Kwa-Zulu Natal, Mozambique, Zimbabwe, Angola, Zambia, Malawi, Tanzania, Uganda and West Equatorial Africa. The body is orange, usually with black central dots on the abdomen; wings are white or orange, forewings are brown, with fine white veins, the basal area is orange and white with black dots; the hindwing is orange or white with or without a partial black outer border (Pinhey 1975). Forewing length is 22-32mm. The larvae feed on *Ficus, Acokanthera* and *Carissa.*

*Digama culta* (Hubner, 1827-1831) (Fig. I.3 E) is distributed through the Eastern Cape up to Kwa-Zulu Natal and Mozambique. The thorax is pale grey-brown with seven black dots and the forewing broad, pale grey-brown with very irregular brown bands, a medial one branching in the cell to form two arms to the costa and a marginal band, with sub-basal dot and dots through the cell; the hindwing is pale yellow to orange with a dark brown apical band (Pinhey 1975). Forewing length is 15-16mm.

*Cyligramma latona* (Cramer, 1779) (Fig. I.3 F) is distributed throughout the Eastern Cape up to Kwa-Zulu Natal, Mozambique, Zimbabwe, Botswana, Malawi, Zambia to equatorial East and West Africa. The moth is dark brown with a cream stripe across both wings. The forewing has an eyespot at the end of the cell and there is a strongly toothed line on the hindwing (Pinhey 1975). Forewing length is 29-43mm. The larva is a semi-looper feeding on *Acacia.*

*Grammodes congenita* (Walker, 1858) (Fig. I.4 A) is distributed through the Eastern Cape up to Kwa-Zulu Natal, Mozambique, Zimbabwe to Zambia and Malawi. The forewing is purplish-grey, with two cream coloured, parallel straight bands, on the inner side of each band, a broad black bar; the hindwing grey-brown with a faint grey-white sub-central band, with the fringe partly white, partly brown (Pinhey 1975). Forewing length is 15-19mm.

*Spodoptera capicola* (Herrich-Schaffer, 1850) (Fig. I.4 B) is distributed throughout Ethiopian Africa. It is a dull grey brown moth (Pinhey 1975). Forewing length is 11-15mm. The larvae feed on grass roots in the soil and it is a frequent pest. There are a few pest species within the *Spodotera* genus.

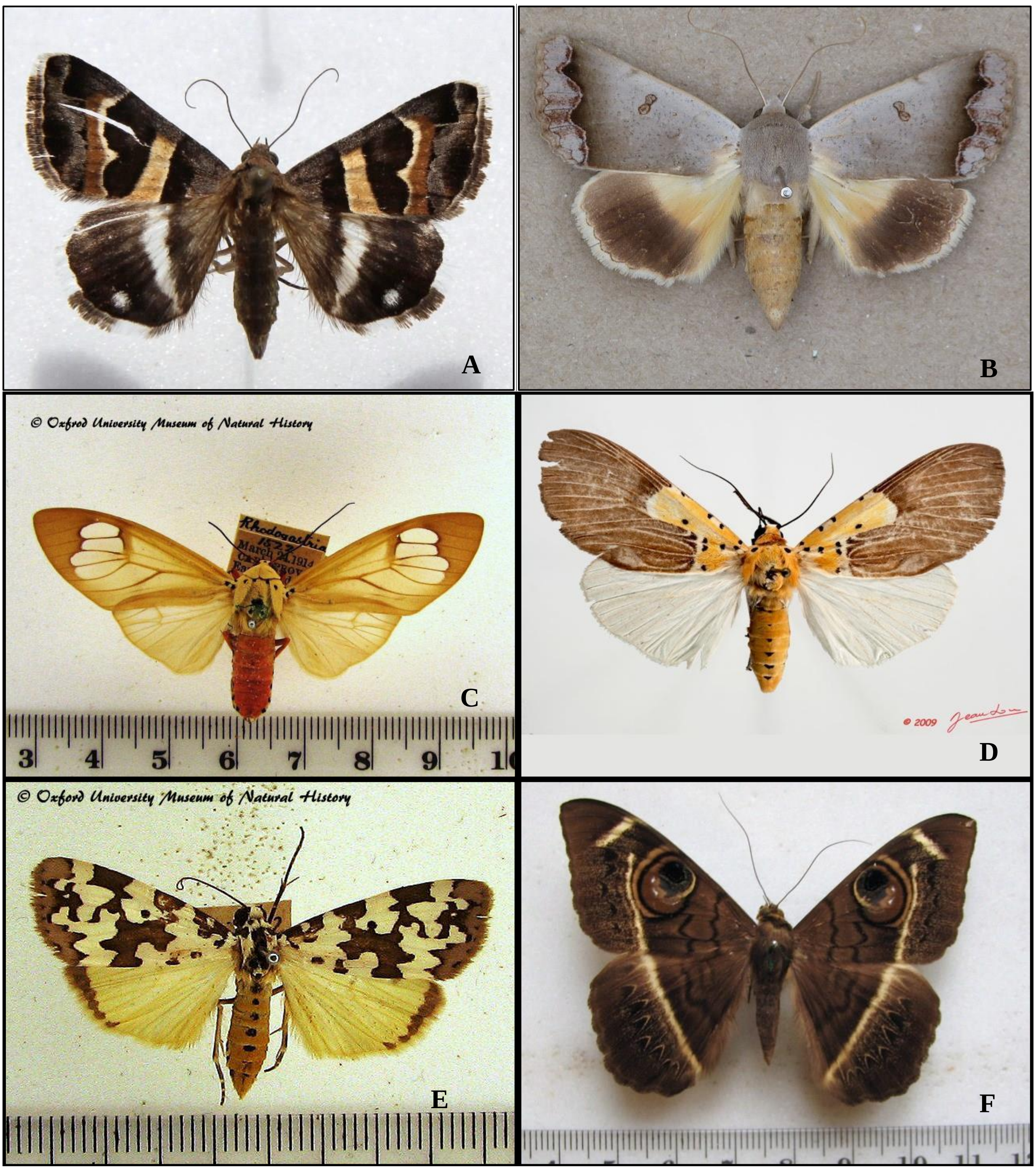


**Figure I.3**: **A** - *Prodotis stolida* adult; **B** - *Anua dianiris* adult; **C** - *Rhodogastria bauri* adult; **D** - *Aganais speciose* adult; **E** - *Digama culta* adult; **F** - *Cyligramma latona* adult (http://www.africanmoths.com/index.html).

*Eudocima* (Hubner, 1823). There are three well known species in Africa: *E. fullonia* (Clerck, 1764) (Fig. I.4 C), *E. materna* (Linnaeus, 1766) (Fig. I.4 D) and *E. divitiosa* (Walker, 1873) (Fig. I.4 E).

They are found from South Africa northwards, and in Asia to Australia. All are large with forewing lengths ranging from 30-47mm, depending on the species. The forewing is lobed on the inner margin and more or less produced at the tornus or anal angle. The orange hindwings are displayed in flight (Pinhey 1975). These moths are renowned fruit-piercing moths. The larvae are semi-loopers.


**Figure I.4**: **A** - *Grammodes congenita* adult; **B -** *Spodoptera capicola* adult; **C** - *Eudocima fullonia* adult; **D** - *Eudocima materna* adult; **E** - *Eudocima divitiosa* adult (http://www.africanmoths.com/index.html).

# Appendix II

## II.1 Abundance and diversity of fruit-feeding moths, within growing regions during three growing seasons

### II.1.1 Kat River Valley and Grahamstown

**Table II.1**: The p-values for the Kruskal-Wallis test (H (14, N= 1564) =547.7077, p = 0.0001) results comparing the trap catches for *Serrodes partita, Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Grahamstown and Kat River Valley growing region during the 2013 growing season.

| | | | ***Serrodes partita*** | | | | | ***Achaea spp.*** | | | | | **All Moths** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **GGR** | | **KRVGR** | | | **GGR** | | **KRVGR** | | | **GGR** | | **KRVGR** | | |
| | | | **M A** | **M B** | **B** | **R A** | **R B** | **M A** | **M B** | **B** | **R A** | **R B** | **M A** | **M B** | **B** | **R A** | **R B** |
| ***Serrodes partita*** | **GGR** | **M A** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.6064 | 0.9999 | **0.0001** | **0.0023** | **0.0004** | **0.0001** | **0.0016** | **0.0001** | **0.0001** | **0.0001** |
| | | **M B** | 0.9999 | | 0.0736 | 0.9999 | 0.9999 | **0.0121** | 0.0752 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **KRVGR** | **B** | 0.9999 | 0.0736 | | 0.9760 | 0.3476 | 0.9999 | 0.9999 | **0.0053** | 0.9999 | 0.9999 | **0.0140** | 0.9999 | **0.0001** | **0.0001** | **0.0001** |
| | | **R A** | 0.9999 | 0.9999 | 0.9760 | | 0.9999 | 0.2147 | 0.9936 | **0.0001** | **0.0003** | **0.0001** | **0.0001** | **0.0002** | **0.0001** | **0.0001** | **0.0001** |
| | | **R B** | 0.9999 | 0.9999 | 0.3476 | 0.9999 | | 0.0639 | 0.3546 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| ***Achaea spp.*** | **GGR** | **M A** | 0.6064 | **0.0121** | 0.9999 | 0.2147 | 0.0639 | | 0.9999 | **0.0350** | 0.9999 | 0.9999 | 0.1081 | 0.9999 | **0.0001** | **0.0001** | **0.0001** |
| | | **M B** | 0.9999 | 0.0752 | 0.9999 | 0.9936 | 0.3546 | 0.9999 | | **0.0052** | 0.9999 | 0.9999 | **0.0136** | 0.9999 | **0.0001** | **0.0001** | **0.0001** |
| | **KRVGR** | **B** | **0.0001** | **0.0001** | **0.0053** | **0.0001** | **0.0001** | **0.0350** | **0.0052** | | 0.9999 | 0.9999 | 0.9999 | 0.2839 | **0.0016** | 0.9999 | 0.9999 |
| | | **R A** | **0.0023** | **0.0001** | 0.9999 | **0.0003** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0003** |
| | | **R B** | **0.0004** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0030** |
| **All Moths** | **GGR** | **M A** | **0.0001** | **0.0001** | **0.0140** | **0.0001** | **0.0001** | 0.1081 | **0.0136** | 0.9999 | 0.9999 | 0.9999 | | 0.9239 | **0.0001** | **0.0045** | 0.2104 |
| | | **M B** | **0.0016** | **0.0001** | 0.9999 | **0.0002** | **0.0001** | 0.9999 | 0.9999 | 0.2839 | 0.9999 | 0.9999 | 0.9239 | | **0.0001** | **0.0001** | **0.0001** |
| | **KRVGR** | **B** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0016** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | | 0.9999 | **0.0332** |
| | | **R A** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | **0.0045** | **0.0001** | 0.9999 | | 0.9999 |
| | | **R B** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.9999 | **0.0003** | **0.0030** | 0.2104 | **0.0001** | **0.0332** | 0.9999 | |

GGR - Grahamstown growing region; KRVGR - Kat River Valley growing region
B - Blinkwater; R A- Riverside A; R B - Riverside B; M A - Mosslands A; M B - Mosslands B

**Table II.2**: The p-values for the Kruskal-Wallis test (H (20, N= 231) =109.4751, p = 0.0001) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) in the Kat River Valley growing region during the 2014 growing season.

| | | ***Serrodes partita*** | | | | | | | ***Achaea spp.*** | | | | | | | **All Moths** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** |
| ***Serrodes partita*** | **B** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1566 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2513 | 0.9999 |
| | **R A** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2569 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0003** | 0.0741 | 0.6686 | **0.0460** | **0.0306** | **0.0005** | **0.0154** |
| | **R B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0538 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0001** | **0.0135** | 0.1566 | **0.0080** | **0.0051** | **0.0001** | **0,0024** |
| | **BF A** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0121** | 0.9999 | 0.9999 | 0.8329 | 0.5996 | **0.0210** | 0.3424 |
| | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0121** | 0.9999 | 0.9999 | 0.8329 | 0.5996 | **0.0210** | 0.3424 |
| | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0035** | 0.4936 | 0.9999 | 0.3259 | 0.2284 | **0.0063** | 0.1247 |
| | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.1026 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0001** | **0.0273** | 0.2856 | **0.0164** | **0.0107** | **0.0002** | **0.0052** |
| ***Achaea spp.*** | **B** | 0.9999 | 0.2569 | 0.0538 | 0.9999 | 0.9999 | 0.9999 | 0.1026 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0481** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0802 | 0.9999 |
| | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2134 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.3387 | 0.9999 |
| | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.1461 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2349 | 0.9999 |
| | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.1789 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2856 | 0.9999 |
| | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.1095 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1778 | 0.9999 |
| **All Moths** | **B** | 0.1566 | **0.0003** | **0.0001** | **0.0121** | **0.0121** | **0.0035** | **0.0001** | 0.9999 | **0.0481** | 0.2134 | 0.1461 | 0.1789 | 0.9999 | 0.1095 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R A** | 0.9999 | 0.0741 | **0.0135** | 0.9999 | 0.9999 | 0.4936 | **0.0273** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R B** | 0.9999 | 0.6686 | 0.1566 | 0.9999 | 0.9999 | 0.9999 | 0.2856 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BF A** | 0.9999 | **0.0460** | **0.0080** | 0.8329 | 0.8329 | 0.3259 | **0.0164** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | **BF B** | 0.9999 | **0.0306** | **0.0051** | 0.5996 | 0.5996 | 0.2284 | **0.0107** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **GF A** | 0.2513 | **0.0005** | **0.0001** | **0.0210** | **0.0210** | **0.0063** | **0.0002** | 0.9999 | 0.0802 | 0.3387 | 0.2349 | 0.2856 | 0.9999 | 0.1778 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **GF B** | 0.9999 | **0.0154** | **0,0024** | 0.3424 | 0.3424 | 0.1247 | **0.0052** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

B - Blinkwater; BF A - Bath Farm A; Bath Farm B; R A- Riverside A; R B - Riverside B; GF A - Glinkwater A; GF B - Glinkwater B

**Table II.3**: The p-values for the Kruskal-Wallis test (H (20, N= 126) =73.07853, p = 0.0001) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) in the Kat River Valley growing region during the 2015 growing season.

| | | ***Serrodes partita*** | | | | | | | ***Achaea spp.*** | | | | | | | **All Moths** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** |
| ***Serrodes partita*** | **B** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R A** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0572 | 0.4478 | 0.9999 | 0.0999 | 0.1209 | 0.5041 | 0.2115 |
| | **R B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4721 | 0.9999 | 0.9999 | 0.7612 | 0.8960 | 0.9999 | 0.9999 |
| | **BF A** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4721 | 0.9999 | 0.9999 | 0.7612 | 0.8960 | 0.9999 | 0.9999 |
| | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1461 | 0.9999 | 0.9999 | 0.2466 | 0.2950 | 0.9999 | 0.4976 |
| | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1999 | 0.9999 | 0.9999 | 0.3335 | 0.3972 | 0.9999 | 0.6618 |
| | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1461 | 0.9999 | 0.9999 | 0.2466 | 0.2950 | 0.9999 | 0.4976 |
| ***Achaea spp.*** | **B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9534 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.2606 | 0.9999 | 0.9999 | 0.4303 | 0.5108 | 0.9999 | 0.8418 |
| | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.6286 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **All Moths** | **B** | 0.9999 | 0.0572 | 0.4721 | 0.4721 | 0.1461 | 0.1999 | 0.1461 | 0.9999 | 0.9999 | 0.9534 | 0.2606 | 0.6286 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R A** | 0.9999 | 0.4478 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BF A** | 0.9999 | 0.0999 | 0.7612 | 0.7612 | 0.2466 | 0.3335 | 0.2466 | 0.9999 | 0.9999 | 0.9999 | 0.4303 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | **BF B** | 0.9999 | 0.1209 | 0.8960 | 0.8960 | 0.2950 | 0.3972 | 0.2950 | 0.9999 | 0.9999 | 0.9999 | 0.5108 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **GF A** | 0.9999 | 0.5041 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **GF B** | 0.9999 | 0.2115 | 0.9999 | 0.9999 | 0.4976 | 0.6618 | 0.4976 | 0.9999 | 0.9999 | 0.9999 | 0.8418 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

B - Blinkwater; BF A - Bath Farm A; Bath Farm B; R A- Riverside A; R B - Riverside B; GF A - Glinkwater A; GF B - Glinkwater B

## II.1.2 Sundays River Valley

**Table II.4**: The p-values for the Kruskal-Wallis test (H (14, N= 150) =48.52935, p = 0.0001) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during the 2014 growing season.

| | | ***Serrodes partita*** | | | | | ***Achaea spp.*** | | | | | **All Moths** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **HF** | **H** | **DE - E** | **DE - R A** | **DE - R B** | **HF** | **H** | **DE - E** | **DE - R A** | **DE - R B** | **HF** | **H** | **DE - E** | **DE - R A** | **DE - R B** |
| | **HF** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0808 | 0.1584 | 0.0779 | 0.9999 |
| | **H** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2577 | 0.4759 | 0.2491 | 0.9999 |
| ***Serrodes partita*** | **DE - E** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4079 | 0.7348 | 0.3947 | 0.9999 |
| | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0200** | **0.0419** | **0.0192** | 0.9999 |
| | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1374 | 0.2621 | 0.1325 | 0.9999 |
| | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.3318 | 0.6045 | 0.3209 | 0.9999 |
| ***Achaea spp.*** | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.2469 | 0.4571 | 0.2386 | 0.9999 |
| | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | **0.0282** | 0.0581 | **0.0271** | 0.9999 |
| | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **H** | 0.0808 | 0.2577 | 0.4079 | 0.9999 | **0.0200** | 0.1374 | 0.3318 | 0.2469 | 0.9999 | **0.0282** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **All Moths** | **DE - E** | 0.1584 | 0.4759 | 0.7348 | 0.9999 | **0.0419** | 0.2621 | 0.6045 | 0.4571 | 0.9999 | 0.0581 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **DE - R A** | 0.0779 | 0.2491 | 0.3947 | 0.9999 | **0.0192** | 0.1325 | 0.3209 | 0.2386 | 0.9999 | **0.0271** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

HF - Halaron Farm; H - Hitgeheim; DE - E - Dunbrody Estates - Enterprise; DE - R A - Dunbrody Estates - Riverside A; DE - R A - Dunbrody Estates - Riverside B

**Table II.5**: The p-values for the Kruskal-Wallis test ($H(14, N = 75) = 32.20747$, $p = 0.0037$) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during the 2015 growing season.

| | | ***Serrodes partita*** | | | | | ***Achaea spp.*** | | | | | **All Moths** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Serrodes partita*** | **HF** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - E** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R A** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2312 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R C** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.3718 | 0.9999 | 0.9999 | 0.9999 |
| ***Achaea spp.*** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4271 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.2312 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R C** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **All Moths** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.2312 | 0.3718 | 0.9999 | 0.4271 | 0.9999 | 0.2312 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **DE - R C** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

DE - E - Dunbrody Estates - Enterprise; DE - R A - Dunbrody Estates - Riverside A; DE - R A - Dunbrody Estates - Riverside B; HF - Halaron Farm; H - Hitgeheim

## II.1.3 Kat River Valley, Grahamstown and Sundays River Valley

**Table II.6**: The p-values for the Kruskal-Wallis test (H (17, N= 1758) =642.0294, p = 0.0001) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) during the three growing regions during the 2013, 2014 and 2015 growing seasons.

| | | | ***Serrodes partita*** | | | | | | ***Achaea spp.*** | | | | | | **All Moths** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **GGR** | **KRVGR** | | | **SRVGR** | | **GGR** | **KRVGR** | | | **SRVGR** | | **GGR** | **KRVGR** | | | **SRVGR** | |
| | | | **2013** | **2013** | **2014** | **2015** | **2014** | **2015** | **2013** | **2013** | **2014** | **2015** | **2014** | **2015** | **2013** | **2013** | **2014** | **2015** | **2014** | **2015** |
| ***Serrodes partita*** | **GGR** | **2013** | | 0.9999 | 0.7506 | 0.9999 | **0.0008** | 0.9999 | **0.0065** | **0.0001** | **0.0001** | **0.0032** | **0.0003** | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **KRVGR** | **2013** | 0.9999 | | 0.9999 | 0.9999 | **0.0203** | 0.9999 | 0.3088 | **0.0001** | **0.0001** | 0.0774 | **0.0078** | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | | **2014** | 0.7506 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0077** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.0676 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | | **2015** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0240** | **0.0007** | 0.9999 | 0.9999 | 0.9999 | 0.0962 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **SRVGR** | **2014** | **0.0008** | **0.0203** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0113** | **0.0001** | **0.0001** | **0.0001** | 0.1765 |
| | | **2015** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.3519 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0004** | **0.0001** | **0.0001** | **0.0001** | **0,0060** |
| ***Achaea spp.*** | **GGR** | **2013** | **0.0065** | 0.3088 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.0702 | **0.0012** | 0.9999 | 0.9999 | 0.9999 | 0.5437 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **KRVGR** | **2013** | **0.0001** | **0.0001** | **0.0077** | **0.0240** | 0.9999 | 0.9999 | 0.0702 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.1761 |
| | | **2014** | **0.0001** | **0.0001** | **0.0001** | **0.0007** | 0.9999 | 0.3519 | **0.0012** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0001** | **0.0002** | **0.0179** | 0.9999 |
| | | **2015** | **0.0032** | 0.0774 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0008** | **0.0001** | **0.0001** | **0.0001** | 0.0520 |
| | **SRVGR** | **2014** | **0.0003** | **0.0078** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | **0.0283** | **0.0001** | **0.0001** | **0.0003** | 0.2897 |
| | | **2015** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0017** |
| **All Moths** | **GGR** | **2013** | **0.0001** | **0.0001** | 0.0676 | 0.0962 | 0.9999 | 0.9999 | 0.5437 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.1359 |
| | **KRVGR** | **2013** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0113** | **0.0004** | **0.0001** | **0.0001** | 0.9999 | **0.0008** | **0.0283** | **0.0001** | **0.0001** | | **0.0001** | 0.1275 | 0.9999 | 0.9999 |
| | | **2014** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 |
| | | **2015** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0002** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.1275 | 0.9999 | | 0.9999 | 0.9999 |
| | **SRVGR** | **2014** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0179** | **0.0001** | **0.0003** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | | **2015** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.1765 | **0,0060** | **0.0001** | 0.1761 | 0.9999 | 0.0520 | 0.2897 | **0.0017** | 0.1359 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

GGR - Grahamstown growing region; KRVGR - Kat River Valley growing region; SRVGR - Sundays River Valley growing region

**Table II.7**: The p-values for the Kruskal-Wallis test (H (86, N= 1758) =729.95574, p = 0.0001) results comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) during the three growing regions during the 2013, 2014 and 2015 growing seasons at each orchard.

| | | | | ***Serrodes partita*** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | | **SRVGR** | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Serrodes partita*** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | *Achaea spp.* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | **SRVGR** | | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Serrodes partita*** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.9999 | 0.9999 | **0.0240** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | All Moths | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2013 | | | | | 2015 | | | | | | | | | | | |
| | | | | GGR | | KRVGR | | | | | | | | | | | SRVGR | | | |
| | | | | M A | M B | B | R A | R B | B | R A | R B | BF A | BF B | GF A | GF B | HF | DE - E | DE - R A | DE - R B | DE - R C |
| | 2013 | GGR | M A | | | | | | **0.0305** | **0.0001** | **0.0003** | **0.0273** | **0.0444** | 0.9192 | 0.2496 | 0.9999 | **0.0476** | 0.9999 | 0.9999 | 0.9999 |
| | | | M B | | | | | | **0.0039** | **0.0001** | **0.0001** | **0.0035** | **0.0059** | 0.1620 | **0.0386** | 0.9999 | **0.0075** | 0.2377 | 0.9999 | 0.3468 |
| | | KRVGR | B | | | | | | 0.9999 | **0.0024** | 0.0893 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | R A | | | | | | **0.0164** | **0.0001** | **0.0001** | **0.0146** | **0.0241** | 0.5452 | 0.1422 | 0.9999 | **0.0272** | 0.7108 | 0.9999 | 0.9999 |
| | | | R B | | | | | | **0.0072** | **0.0001** | **0.0001** | **0.0064** | **0.0107** | 0.2709 | 0.0671 | 0.9999 | **0.0129** | 0.3779 | 0.9999 | 0.5460 |
| *Serrodes partita* | 2014 | KRVGR | B | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | R A | 0.9999 | 0.9999 | **0.0001** | 0.1417 | 0.9999 | 0.8169 | **0.0058** | 0.1231 | 0.7486 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.8548 | 0.9999 | 0.9999 | 0.9999 |
| | | | R B | 0.1910 | 0.9999 | **0.0001** | **0.0004** | **0.0055** | 0.0549 | **0.0001** | **0.0025** | **0.0497** | 0.0770 | 0.9999 | 0.3646 | 0.9999 | 0.0708 | 0.9999 | 0.9999 | 0.9999 |
| | | | BF A | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | BF B | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | GF A | 0.9999 | 0.9999 | 0.7954 | 0.9999 | 0.9999 | 0.9999 | 0.8492 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | GF B | 0.9999 | 0.9999 | **0.0023** | 0.5092 | 0.9999 | 0.5185 | **0.0105** | 0.1391 | 0.4780 | 0.6810 | 0.9999 | 0.9999 | 0.9999 | 0.5113 | 0.9999 | 0.9999 | 0.9999 |
| | | SRVGR | HF | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | H | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - E | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - R A | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - R B | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | ***Serrodes partita*** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | **SRVGR** | | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Achaea spp.*** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | **0.0035** | **0.0002** | 0.6004 | **0.0014** | **0.0004** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | 0.9999 | 0.2154 | 0.9999 | 0.9999 | 0.5164 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.0634 | **0.0018** | 0.9999 | **0.0220** | **0.0052** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.9999 | 0.3342 | 0.9999 | 0.9999 | 0.6376 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | ***Achaea spp.*** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | | **SRVGR** | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Achaea spp.*** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | 0.9999 | 0.5192 | 0.9999 | 0.999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | All Moths | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2013 | | | | | 2015 | | | | | | | | | | | |
| | | | | GGR | | KRVGR | | | | | | | | | | SRVGR | | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| ***Achaea spp.*** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | **0.0070** | 0.2230 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | **0.0020** | 0.0755 | 0.9738 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.1928 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.1930 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | *Serrodes partita* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | | **SRVGR** | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| **All Moths** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.0862 | 0.1213 | 0.9999 | 0.4633 | 0.7738 | 0.4633 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | **0.0001** | **0.0001** | **0.0006** | **0.0001** | **0.0001** | 0.9999 | **0.0257** | 0.0754 | 0.7182 | 0.1155 | 0.1836 | 0.1155 | 0.9232 | 0.9999 | 0.9999 | 0.4263 | 0.9999 |
| | | | **R A** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.9999 | **0.0036** | **0.0039** | 0.1912 | **0.0218** | **0.0378** | **0.0218** | 0.3104 | 0.9999 | 0.9999 | 0.1266 | 0.9999 |
| | | | **R B** | **0.0001** | **0.0001** | **0.0003** | **0.0001** | **0.0001** | 0.9999 | 0.1428 | 0.3847 | 0.9999 | 0.6509 | 0.9999 | 0.6509 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | **0.0005** | **0.0001** | 0.1249 | **0.0002** | **0.0001** | 0.9999 | 0.5341 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | **0.0001** | **0.0001** | **0.0248** | **0.0001** | **0.0001** | 0.9999 | 0.2080 | 0.8202 | 0.9999 | 0.8061 | 0.9999 | 0.8061 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | **0.0001** | **0.0001** | **0.0003** | **0.0001** | **0.0001** | 0.9999 | **0.0186** | 0.0519 | 0.5473 | 0.0855 | 0.1370 | 0.0855 | 0.7178 | 0.9999 | 0.9999 | 0.3276 | 0.9999 |
| | | | **GF B** | **0.0001** | **0.0001** | **0.0151** | **0.0001** | **0.0001** | 0.9999 | 0.1565 | 0.5953 | 0.9999 | 0.6194 | 0.9456 | 0.6194 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.1461 | 0.9999 | 0.6704 | 0.2795 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | **0.0001** | **0.0001** | **0,0078** | **0.0001** | **0.0001** | 0.9999 | 0.0847 | 0.3108 | 0.9999 | 0.3422 | 0.5264 | 0.3422 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | **0.0002** | **0.0001** | **0,0426** | **0.0001** | **0.0001** | 0.9999 | 0.2317 | 0.9590 | 0.9999 | 0.8712 | 0.9999 | 0.8712 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | **0.0001** | **0.0001** | **0,0196** | **0.0001** | **0.0001** | 0.9999 | 0.1457 | 0.5716 | 0.9999 | 0.5665 | 0.8606 | 0.5665 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.4615 | **0.0462** | 0.9999 | 0.2320 | 0.0918 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | *Achaea spp.* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2013 | | | | | 2015 | | | | | | | | | | | |
| | | | | GGR | | KRVGR | | | | | | | | | | SRVGR | | | | |
| | | | | M A | M B | B | R A | R B | B | R A | R B | BF A | BF B | GF A | GF B | HF | DE - E | DE - R A | DE - R B | DE - R C |
| All Moths | 2013 | GGR | M A | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | M B | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | KRVGR | B | | | | | | 0.9999 | 0.9999 | 0.6551 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | R A | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | R B | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | 2014 | KRVGR | B | **0.0018** | **0.0005** | 0.9999 | 0.0525 | 0.0525 | 0.9999 | 0.4218 | 0.2780 | 0.2411 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4263 | 0.9999 |
| | | | R A | **0.0001** | **0.0001** | 0.0803 | **0.0001** | **0.0001** | 0.9999 | **0.0377** | **0.0218** | 0.0523 | 0.3145 | 0.9999 | 0.9999 | 0.9999 | 0.4038 | 0.9999 | 0.1266 | 0.9999 |
| | | | R B | **0.0012** | **0.0002** | 0.9999 | 0.1052 | 0.1053 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | BF A | 0.2975 | 0.1066 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | BF B | 0.0632 | **0.0209** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | GF A | **0.0010** | **0.0003** | 0.9999 | **0.0321** | **0.0322** | 0.9999 | 0.2998 | 0.1960 | 0.1806 | 0.8382 | 0.9999 | 0.9999 | 0.9999 | 0.9037 | 0.9999 | 0.3276 | 0.9999 |
| | | | GF B | **0.0393** | **0.0127** | 0.9999 | 0.7583 | 0.7588 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | SRVGR | HF | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | H | **0.0202** | **0.0066** | 0.9999 | 0.3809 | 0.3812 | 0.9999 | 0.9999 | 0.9999 | 0.6776 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - E | 0.1025 | **0.0363** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - R A | **0.0487** | **0.0166** | 0.9999 | 0.8149 | 0.8154 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | DE - R B | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | | | All Moths | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | | | | | **2015** | | | | | | | | | | | |
| | | | | **GGR** | | **KRVGR** | | | | | | | | | | **SRVGR** | | | | |
| | | | | **M A** | **M B** | **B** | **R A** | **R B** | **B** | **R A** | **R B** | **BF A** | **BF B** | **GF A** | **GF B** | **HF** | **DE - E** | **DE - R A** | **DE - R B** | **DE - R C** |
| **All Moths** | **2013** | **GGR** | **M A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **M B** | | | | | | 0.9999 | 0.0732 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **KRVGR** | **B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | | | | | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2014** | **KRVGR** | **B** | 0.9999 | **0.0195** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R A** | **0.0093** | **0.0001** | 0.9999 | 0.9999 | 0.2985 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **R B** | 0.9999 | **0.0291** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **BF B** | 0.9999 | 0.4899 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF A** | 0.7020 | **0.0117** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **GF B** | 0.9999 | 0.3196 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **SRVGR** | **HF** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **H** | 0.9999 | 0.1610 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - E** | 0.9999 | 0.6996 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R A** | 0.9999 | 0.3573 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | | **DE - R B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

KRVGR - Kat River Valley growing region; SRVGR - Sundays River Valley growing region
B - Blinkwater; R A - Riverside A; R B - Riverside B; BF A - Bath Farm A; BF B - Bath Farm B; GF A - Glinkwater A; GF B - Glinkwater B; HF - Halaron Farm; H - Hitgeheim; DE - E - Dunbrody Estates - Enterprise; DE - R A - Dunbrody Estates - Riverside A; DE - R B - Dunbrody Estates - Riverside B; DE - R C - Dunbrody Estates - Riverside C

## II.1.4 Tshipise

**Table II.8**: The p-values for the Kruskal-Wallis test (H (39, N= 240) =120.9127, p = 0.0001) results comparing the trap catches for *Eudocima* sp., *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) during the 2014 growing season at Alicedale Farm in the Tshipise growing region.

| | | ***Achaea spp.*** | | ***Eudocima sp.*** | | **All Moths** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **B2** | **M9** | **B3** | **F8** | **B2** | **B3** | **M2** | **M9** | **M14** | **F2** | **F8** | **E5** | **E11** |
| ***Achaea spp.*** | **B2** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M9** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| ***Eudocima sp.*** | **B3** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **F8** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **All Moths** | **B2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **B3** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M9** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M14** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **F2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | **F8** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **E5** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **E11** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

**Table II.9**: The p-values for the Kruskal-Wallis test (H (47, N= 336) =113.0719, p = 0.0001) results comparing the trap catches for *Eudocima* sp., *Achaea* spp. and the overall trap catches of fruit-feeding moths (All Moths) during the 2015 growing season at Alicedale Farm in the Tshipise growing region.

| | | ***Achaea spp.*** | | | | ***Eudocima sp.*** | **All Moths** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **M7** | **M14** | **E5** | **E11** | **F1** | **M2** | **M7** | **M9** | **M14** | **F1** | **F2** | **F8** | **E2** | **E5** | **E11** |
| ***Achaea spp.*** | **M7** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M14** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **E5** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **E11** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| ***Eudocima sp.*** | **F1** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **All Moths** | **M2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M7** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M9** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **M14** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **F1** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **F2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **F8** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | **E2** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | **E5** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | **E11** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

# Appendix III

**Table III.1**: The p-values for the Kruskal-Wallis test (H (15, n = 250) = 176.104, p =0.0001) results comparing male and female mean dorsal galeal linkages of proboscides from male and female species of *Achaea echo, Achaea indeterminata*, *Achaea lienardi, Anua dianiris*, *Ericeia inangulata*, *Serrodes partita*, *Eudocima* sp., *Ophiusa tirhaca* and *Sphingomorpha chlorea*.

| | | Male | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *A. indeterminata* | *A. echo* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* |
| **Male** | *A. indeterminata* | | **0.0001** | **0.0004** | 0.9999 | 0.9999 | **0.0001** | 0.9999 |
| | *A. echo* | **0.0001** | | 0.9999 | 0.8248 | **0.0001** | 0.9999 | **0.0010** |
| | *A. lienardi* | **0.0004** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0242** |
| | *A. dianiris* | 0.9999 | 0.8248 | 0.9999 | | 0.6221 | 0.0804 | 0.9999 |
| | *E. inangulata* | 0.9999 | **0.0001** | 0.9999 | 0.6221 | | **0.0001** | 0.7900 |
| | *S. partita* | **0.0001** | 0.9999 | 0.9999 | 0.0804 | **0.0001** | | **0.0011** |
| | *S. chlorea* | 0.9999 | **0.0010** | **0.0242** | 0.9999 | 0.7900 | **0.0011** | |
| **Female** | *A. indeterminata* | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | **0.0001** | 0.9999 |
| | *A. echo* | **0.0055** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.2036 |
| | *A. lienardi* | 0.0780 | 0.9999 | 0.9999 | 0.9999 | **0.0003** | 0.9999 | 0.9999 |
| | *A. dianiris* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0113** | 0.9999 | 0.9999 |
| | *E. inangulata* | 0.9999 | **0.0001** | **0.0001** | 0.6103 | 0.9999 | **0.0001** | 0.7731 |
| | *S. partita* | **0.0002** | 0.9999 | 0.9999 | 0.2916 | **0.0001** | 0.9999 | **0.0072** |
| | *S. chlorea* | 0.9999 | **0.0051** | **0.0128** | 0.9999 | 0.9999 | **0.0001** | 0.9999 |
| | *O. tirhaca* | **0.0201** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.5635 |
| | *Eudocima* sp. | **0.0001** | 0.9999 | 0.9999 | **0.0012** | **0.0001** | 0.9999 | **0.0001** |

| | | Female | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *A. indeterminata* | *A. echo* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* | *O. tirhaca* | *Eudocima* sp. |
| **Male** | *A. indeterminata* | 0.9999 | **0.0055** | 0.0780 | 0.9999 | 0.9999 | **0.0002** | 0.9999 | **0.0201** | **0.0001** |
| | *A. echo* | **0.0001** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | **0.0051** | 0.9999 | 0.9999 |
| | *A. lienardi* | **0.0001** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | **0.0128** | 0.9999 | 0.9999 |
| | *A. dianiris* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.6103 | 0.2916 | 0.9999 | 0.9999 | **0.0012** |
| | *E. inangulata* | 0.9999 | **0.0001** | **0.0003** | **0.0113** | 0.9999 | **0.0001** | 0.9999 | **0.0001** | **0.0001** |
| | *S. partita* | **0.0001** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | **0.0001** | 0.9999 | 0.9999 |
| | *S. chlorea* | 0.9999 | 0.2036 | 0.9999 | 0.9999 | 0.7731 | **0.0072** | 0.9999 | 0.5635 | **0.0001** |
| **Female** | *A. indeterminata* | | **0.0004** | **0.0082** | 0.2991 | 0.9999 | **0.0001** | 0.9999 | **0.0017** | **0.0001** |
| | *A. echo* | **0.0004** | | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.1172 | 0.9999 | 0.2844 |
| | *A. lienardi* | **0.0082** | 0.9999 | | 0.9999 | **0.0003** | 0.9999 | 0.9999 | 0.9999 | **0.0408** |
| | *A. dianiris* | 0.2991 | 0.9999 | 0.9999 | | **0.0110** | 0.9999 | 0.9999 | 0.9999 | 0.1163 |
| | *E. inangulata* | 0.9999 | **0.0001** | **0.0003** | **0.0110** | | **0.0001** | 0.9999 | **0.0001** | **0.0001** |
| | *S. partita* | **0.0001** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | | **0.0042** | 0.9999 | 0.9999 |
| | *S. chlorea* | 0.9999 | 0.1172 | 0.9999 | 0.9999 | 0.9999 | **0.0042** | | 0.3395 | **0.0001** |
| | *O. tirhaca* | **0.0017** | 0.9999 | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.3395 | | 0.1186 |
| | *Eudocima* sp. | **0.0001** | 0.2844 | **0.0408** | 0.1163 | **0.0001** | 0.9999 | **0.0001** | 0.1186 | |

**Table III.2**: The p-values for the Kruskal-Wallis test (H (15, n = 250) = 176.104, p =0.0001) results comparing the mean dorsal galeal linkages of proboscides from male and female species of *Achaea echo*, *Achaea indeterminata*, *Achaea lienardi*, *Anua dianiris*, *Ericeia inangulata*, *Serrodes partita*, *Eudocima* sp., *Ophiusa tirhaca* and *Sphingomorpha chlorea*.

| | *A. echo* | *A. indeterminata* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* | *O. tirhaca* | *Eudocima* sp. |
|---|---|---|---|---|---|---|---|---|---|
| *A. echo* | | **0.0001** | 0.9999 | 0.5058 | **0.0001** | 0.9999 | **0.0001** | 0.9999 | 0.1061 |
| *A. indeterminata* | **0.0001** | | **0.0001** | 0.0850 | 0.5350 | **0.0001** | 0.9999 | **0.0001** | **0.0001** |
| *A. lienardi* | 0.9999 | **0.0001** | | 0.9999 | **0.0001** | 0.5885 | **0.0003** | 0.9999 | **0.0272** |
| *A. dianiris* | 0.5058 | 0.0850 | 0.9999 | | **0.0001** | **0.0060** | 0.9999 | 0.9999 | **0.0003** |
| *E. inangulata* | **0.0001** | 0.5350 | **0.0001** | **0.0001** | | **0.0001** | **0.0062** | **0.0001** | **0.0001** |
| *S. partita* | 0.9999 | **0.0001** | 0.5885 | **0.0060** | **0.0001** | | **0.0001** | 0.6809 | 0.9999 |
| *S. chlorea* | **0.0001** | 0.9999 | **0.0003** | 0.9999 | **0.0062** | **0.0001** | | **0.0285** | **0.0001** |
| *O. tirhaca* | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0001** | 0.6809 | **0.0285** | | **0.0356** |
| *Eudocima* sp. | 0.1061 | **0.0001** | **0.0272** | **0.0003** | **0.0001** | 0.9999 | **0.0001** | **0.0356** | |

**Table III.3**: The p-values for the Kruskal-Wallis test (H (8, N= 250) =172.1968 p =0.0001) comparing the mean distal length of the male and female proboscides in µm of both sexes of noctuid species of *Achaea echo*, *Achaea indeterminata*, *Achaea lienardi*, *Anua dianiris*, *Ericeia inangulata*, *Serrodes partita*, *Eudocima* sp., *Ophiusa tirhaca* and *Sphingomorpha chlorea*.

| | | Male | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *A. echo* | *A. indeterminata* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* |
| **Male** | *A. echo* | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0053** | 0.9999 |
| | *A. indeterminata* | 0.9999 | | 0.9999 | 0.5846 | 0.9999 | **0.0001** | 0.1078 |
| | *A. lienardi* | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | **0.0153** | 0.9999 |
| | *A. dianiris* | 0.9999 | 0.5846 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| | *E. inangulata* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | **0.0014** | 0.9999 |
| | *S. partita* | **0.0053** | **0.0001** | **0.0153** | 0.9999 | **0.0014** | | 0.9999 |
| | *S. chlorea* | 0.9999 | 0.1078 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |
| **Female** | *A. echo* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0009** | 0.9999 |
| | *A. indeterminata* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.2612 | 0.9999 |
| | *A. lienardi* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0002** | 0.8784 |
| | *A. dianiris* | 0.9999 | 0.0695 | 0.9999 | 0.9999 | 0.4627 | 0.9999 | 0.9999 |
| | *E. inangulata* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0005** | 0.5846 |
| | *S. partita* | **0.0153** | **0.0001** | **0.0419** | 0.9999 | **0.0036** | 0.9999 | 0.9999 |
| | *S. chlorea* | 0.9999 | **0.0419** | 0.9999 | 0.9999 | 0.5846 | 0.9999 | 0.9999 |
| | *O. tirhaca* | 0.1691 | **0.0005** | 0.3973 | 0.9999 | **0.0315** | 0.9999 | 0.9999 |
| | *Eudocima* sp. | **0.0209** | **0.0001** | **0.0471** | 0.9999 | **0.0039** | 0.9999 | 0.9999 |

| | | Female | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *A. echo* | *A. indeterminata* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* | *O. tirhaca* | *Eudocima* sp. |
| **Male** | *A. echo* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0153** | 0.9999 | 0.1691 | **0.0209** |
| | *A. indeterminata* | 0.9999 | 0.9999 | 0.9999 | 0.0695 | 0.9999 | **0.0001** | **0.0419** | **0.0005** | **0.0001** |
| | *A. lienardi* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0419** | 0.9999 | 0.3973 | **0.0471** |
| | *A. dianiris* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *E. inangulata* | 0.9999 | 0.9999 | 0.9999 | 0.4627 | 0.9999 | **0.0036** | 0.5846 | **0.0315** | **0.0039** |
| | *S. partita* | **0.0009** | 0.2612 | **0.0002** | 0.9999 | **0.0005** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *S. chlorea* | 0.9999 | 0.9999 | 0.8784 | 0.9999 | 0.5846 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **Female** | *A. echo* | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0030** | 0.9999 | **0.0419** | **0.0057** |
| | *A. indeterminata* | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.5952 | 0.9999 | 0.9999 | 0.4205 |
| | *A. lienardi* | 0.9999 | 0.9999 | | 0.4205 | 0.9999 | **0.0005** | 0.3973 | **0.0090** | **0.0014** |
| | *A. dianiris* | 0.9999 | 0.9999 | 0.4205 | | 0.2566 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *E. inangulata* | 0.9999 | 0.9999 | 0.9999 | 0.2566 | | **0.0014** | 0.2994 | **0.0137** | **0.0018** |
| | *S. partita* | **0.0030** | 0.5952 | **0.0005** | 0.9999 | **0.0014** | | 0.9999 | 0.9999 | 0.9999 |
| | *S. chlorea* | 0.9999 | 0.9999 | 0.3973 | 0.9999 | 0.2994 | 0.9999 | | 0.9999 | 0.9999 |
| | *O. tirhaca* | **0.0419** | 0.9999 | **0.0090** | 0.9999 | **0.0137** | 0.9999 | 0.9999 | | 0.9999 |
| | *Eudocima* sp. | **0.0057** | 0.4205 | **0.0014** | 0.9999 | **0.0018** | 0.9999 | 0.9999 | 0.9999 | |

**Table III.4**: The p-values for the Kruskal-Wallis test (H (8, n = 108) = 98.507, p =0.0001) comparing the mean distal length of proboscides in µm of both sexes of noctuid species of *Achaea echo*, *Achaea indeterminata*, *Achaea lienardi*, *Anua dianiris*, *Ericeia inangulata*, *Serrodes partita*, *Eudocima* sp., *Ophiusa tirhaca* and *Sphingomorpha chlorea*.

| | *A. echo* | *A. indeterminata* | *A. lienardi* | *A. dianiris* | *E. inangulata* | *S. partita* | *S. chlorea* | *O. tirhaca* | *Eudocima* sp. |
|---|---|---|---|---|---|---|---|---|---|
| *A. echo* | | 0.8629 | 0.9999 | 0.9708 | 0.9708 | **0.0001** | 0.9999 | 0.0704 | **0.0093** |
| *A. indeterminata* | 0.8629 | | 0.9999 | **0.0018** | 0.9999 | **0.0001** | **0.0004** | **0.0001** | **0.0001** |
| *A. lienardi* | 0.9999 | 0.9999 | | 0.1452 | 0.9999 | **0.0001** | 0.1038 | **0.0061** | **0.0011** |
| *A. dianiris* | 0.9708 | **0.0018** | 0.1452 | | **0.0046** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| *E. inangulata* | 0.9708 | 0.9999 | 0.9999 | **0.0046** | | **0.0001** | **0.0025** | **0.0002** | **0.0001** |
| *S. partita* | **0.0001** | **0.0001** | **0.0001** | 0.9999 | **0.0001** | | 0.2429 | 0.9999 | 0.9999 |
| *S. chlorea* | 0.9999 | **0.0004** | 0.1038 | 0.9999 | **0.0025** | 0.2429 | | 0.9999 | 0.8042 |
| *O. tirhaca* | 0.0704 | **0.0001** | **0.0061** | 0.9999 | **0.0002** | 0.9999 | 0.9999 | | 0.9999 |
| *Eudocima* sp. | **0.0093** | **0.0001** | **0.0011** | 0.9999 | **0.0001** | 0.9999 | 0.8042 | 0.9999 | |

# Appendix IV

## IV.1 Comparing fresh banana to a variety of artificial banana baits

### IV.1.1 Kat River Valley and Grahamstown

**Table IV.1**: The p-values for the Mann-Whitney U Test ($p < 0.05$) comparing attractiveness of fresh banana to isopentyl acetate to the overall trap catch of fruit-feeding moths (All Moths) in the Grahamstown and Kat River Valley growing region during 2013.

| | Rank Sum | Rank Sum | U | Z | p-value | Z | p-value | Valid N | Valid N |
|---|---|---|---|---|---|---|---|---|---|
| **Total sampled** | 3261.5 | 7178.5 | 633.5 | **-7.8232** | **0.0001** | **-8.1295** | **0.0001** | 72 | 72 |

**Table IV.2**: The p-values for the Kruskal-Wallis test (H (5, N= 432) =244.9994, p =0.0001) comparing trap catches for *Serrodes partita, Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Grahamstown and Kat River Valley growing region during 2013.

| | | **Fresh Banana** | | | **Isopentyl Acetate** | | |
|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | | **0.0001** | **0.0001** | **0.0109** | **0.0109** | 0.9999 |
| | *Achaea* spp. | **0.0001** | | **0.0149** | **0.0001** | **0.0001** | **0.0001** |
| | All Moths | **0.0001** | **0.0149** | | **0.0001** | **0.0001** | **0.0001** |
| **Isopentyl Acetate** | *Serrodes partita* | **0.0109** | **0.0001** | **0.0001** | | 0.9999 | 0.2677 |
| | *Achaea* spp. | **0.0109** | **0.0001** | **0.0001** | 0.9999 | | 0.2677 |
| | All Moths | 0.9999 | **0.0001** | **0.0001** | 0.2677 | 0.2677 | |

**Table IV.3**: The p-values for the Kruskal-Wallis test (H (7, N= 1584) =762.6224, p =0.0001) comparing trap catches for the different bait types in the Kat River Valley growing region during 2014.

| | **Fresh Banana** | **Frozen Banana** | **Control** | **BW Lure** | **BC** | **BS** | **BD** | **BB** |
|---|---|---|---|---|---|---|---|---|
| **Fresh Banana** | | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | 0.9999 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BW Lure** | **0.0001** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.7875 |
| **BC** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BS** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **BD** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **BB** | **0.0001** | **0.0001** | 0.9999 | 0.7875 | 0.9999 | 0.9999 | 0.9999 | |

**Table IV.4**: The p-values for the Kruskal-Wallis test (H (23, N= 1584) =989.4006, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley growing region during 2014.

| | | **Fresh Banana** | | | **Frozen Banana** | | | **Control** | | | **BW Lure** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0111** | **0.0001** | **0.0001** | 0.9999 |
| | *Achaea* spp. | 0.9999 | | 0.3112 | **0.0447** | 0.9999 | 0.7843 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.1048 |
| | All Moths | **0.0001** | 0.3112 | | **0.0001** | 0.0506 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | *Serrodes partita* | 0.9999 | **0.0447** | **0.0001** | | 0.2790 | **0.0001** | **0.0116** | **0.0116** | 0.7998 | **0.0116** | **0.0194** | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.0506 | 0.2790 | | 0.1442 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.5925 |
| | All Moths | **0.0001** | 0.7843 | 0.9999 | **0.0001** | 0.1442 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | All Moths | **0.0111** | **0.0001** | **0.0001** | 0.7998 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.3836 |
| **BW Lure** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0194** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | **0.0076** |
| | All Moths | 0.9999 | 0.1048 | **0.0001** | 0.9999 | 0.5925 | **0.0001** | **0.0044** | **0.0044** | 0.3836 | **0.0044** | **0.0076** | |
| **BC** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | All Moths | 0.0626 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BS** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0524 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0215** |
| | All Moths | 0.9999 | **0.0037** | **0.0001** | 0.9999 | **0.0230** | **0.0001** | 0.1223 | 0.1223 | 0.9999 | 0.1223 | 0.1917 | 0.9999 |
| **BD** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0194** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0076** |
| | All Moths | 0.9999 | **0.0001** | **0.0001** | 0.9999 | **0.0002** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BB** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0116** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0044** |
| | All Moths | **0.0012** | **0.0001** | **0.0001** | 0.1473 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0640 |

| | | BC | | | BS | | | BD | | | BB | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | **0.0001** | **0.0001** | 0.0626 | **0.0001** | **0.0003** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | **0.0012** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0037** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | *Serrodes partita* | **0.0116** | **0.0116** | 0.9999 | **0.0116** | 0.0524 | 0.9999 | **0.0116** | **0.0194** | 0.9999 | **0.0116** | **0.0116** | 0.1473 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0230** | **0.0001** | **0.0001** | **0.0002** | **0.0001** | **0.0001** | **0.0001** |
| | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BW Lure** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1917 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0044** | **0.0044** | 0.9999 | **0.0044** | **0.0215** | 0.9999 | **0.0044** | **0.0076** | 0.9999 | **0.0044** | **0.0044** | 0.0640 |
| **BC** | *Serrodes partita* | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BS** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.4516 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.1223 | 0.1223 | 0.9999 | 0.1223 | 0.4516 | | 0.1223 | 0.1917 | 0.9999 | 0.1223 | 0.1223 | 0.9999 |
| **BD** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1917 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BB** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1223 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

**Table IV.5**: The p-values for the Kruskal-Wallis test (H (4, N= 180) =73.9918, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley growing region during 2015.

| | **Fresh Banana** | **Control** | **R 1** | **R 2** | **R 3** |
|---|---|---|---|---|---|
| **Fresh Banana** | | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | | **0.0016** | **0.0070** | **0.0042** |
| **R 1** | **0.0001** | **0.0016** | | 0.9999 | 0.9999 |
| **R 2** | **0.0001** | **0.0070** | 0.9999 | | 0.9999 |
| **R 3** | **0.0001** | **0.0042** | 0.9999 | 0.9999 | |

**Table IV.6**: The p-values for the Kruskal-Wallis test (H (14, N= 540) =283.2292, p =0.0001) comparing the trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley growing region during 2015.

| | | **Fresh Banana** | | | **Control** | | | **R 1** | | | **R 2** | | | **R 3** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Achaea* spp. | *Serrodes partita* | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | | 0.9999 | **0.0025** | **0.0127** | **0.0127** | 0.1578 | **0.0236** | 0.5292 | 0.9999 | **0.0127** | 0.0826 | 0.9999 | **0.0429** | **0.0429** | 0.9999 |
| | *Achaea* spp. | 0.9999 | | 0.3221 | **0.0001** | **0.0001** | **0.0010** | **0.0001** | **0.0050** | 0.9999 | **0.0001** | **0.0004** | 0.9999 | **0.0002** | **0.0002** | 0.9999 |
| | All Moths | **0.0025** | 0.3221 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.0668 | **0.0001** | **0.0001** | **0.0152** | **0.0001** | **0.0001** | **0.0430** |
| **Control** | *Serrodes partita* | **0.0127** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0003** | 0.9999 | 0.9999 | **0.0021** | 0.9999 | 0.9999 | **0.0006** |
| | *Achaea* spp. | **0.0127** | **0.0001** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | **0.0003** | 0.9999 | 0.9999 | **0.0021** | 0.9999 | 0.9999 | **0.0006** |
| | All Moths | 0.1578 | **0.0010** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | **0.0072** | 0.9999 | 0.9999 | **0.0338** | 0.9999 | 0.9999 | **0.0118** |
| **R 1** | *Serrodes partita* | **0.0236** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | **0.0072** | 0.9999 | 0.9999 | **0.0041** | 0.9999 | 0.9999 | **0.0013** |
| | *Achaea* spp. | 0.5292 | **0.0050** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | **0.0321** | 0.9999 | 0.9999 | 0.1313 | 0.9999 | 0.9999 | 0.0502 |
| | All Moths | 0.9999 | 0.9999 | 0.0668 | **0.0003** | **0.0003** | **0.0072** | **0.0072** | **0.0321** | | **0.0003** | **0.0033** | 0.9999 | **0.0015** | **0.0015** | 0.9999 |
| **R 2** | *Serrodes partita* | **0.0127** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0003** | | 0.9999 | **0.0021** | 0.9999 | 0.9999 | **0.0006** |
| | *Achaea* spp. | 0.0826 | **0.0004** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0033** | 0.9999 | | **0.0165** | 0.9999 | 0.9999 | **0.0055** |
| | All Moths | 0.9999 | 0.9999 | **0.0152** | **0.0021** | **0.0021** | **0.0338** | **0.0041** | 0.1313 | 0.9999 | **0.0021** | **0.0165** | | **0.0080** | **0.0080** | 0.9999 |
| **R 3** | *Serrodes partita* | **0.0429** | **0.0002** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0015** | 0.9999 | 0.9999 | **0.0080** | | 0.9999 | **0.0025** |
| | *Achaea* spp. | **0.0429** | **0.0002** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0015** | 0.9999 | 0.9999 | **0.0080** | 0.9999 | | **0.0025** |
| | All Moths | 0.9999 | 0.9999 | **0.0430** | **0.0006** | **0.0006** | **0.0118** | **0.0013** | 0.0502 | 0.9999 | **0.0006** | **0.0055** | 0.9999 | **0.0025** | **0.0025** | |

## IV.1.2 Sundays River Valley

**Table IV.7**: The p-values for the Kruskal-Wallis test (H (4, N= 180) =73.9918, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during 2014.

| | Fresh Banana | Frozen Banana | Control | BW Lure | BC | BS | BD | BB |
|---|---|---|---|---|---|---|---|---|
| **Fresh Banana** | | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | 0.9999 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BW Lure** | **0.0001** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BC** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BS** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **BD** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **BB** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | |

**Table IV.8**: The p-values for the Kruskal-Wallis test (H (23, N= 1440) =884.4094, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during 2015.

| | | **Fresh Banana** | | | **Frozen Banana** | | | **Control** | | | **BW Lure** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | | 0.9999 | **0.0010** | 0.9999 | 0.9999 | **0.0042** | **0.0001** | **0.0001** | **0.0003** | **0.0001** | **0.0001** | **0.0285** |
| | *Achaea* spp. | 0.9999 | | 0.0734 | 0.9999 | 0.9999 | 0.2388 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0003** |
| | All Moths | **0.0010** | 0.0734 | | **0.0001** | **0.0009** | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | *Serrodes partita* | 0.9999 | 0.9999 | **0.0001** | | 0.9999 | **0.0001** | **0.0015** | **0.0015** | **0.0097** | **0.0015** | **0.0015** | 0.4954 |
| | *Achaea* spp. | 0.9999 | 0.9999 | **0.0009** | 0.9999 | | **0.0039** | **0.0001** | **0.0001** | **0.0003** | **0.0001** | **0.0001** | **0.0307** |
| | All Moths | **0.0042** | 0.2388 | 0.9999 | **0.0001** | **0.0039** | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0003** | **0.0001** | **0.0001** | **0.0097** | **0.0003** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BW Lure** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | All Moths | **0.0285** | **0.0003** | **0.0001** | 0.4954 | **0.0307** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |
| **BC** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0198** | **0.0002** | **0.0001** | 0.3662 | **0.0213** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BS** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0377** | **0.0004** | **0.0001** | 0.6231 | **0.0405** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BD** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0189** | **0.0002** | **0.0001** | 0.3515 | **0.0203** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BB** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0001** | **0.0015** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0003** | **0.0001** | **0.0001** | **0.0092** | **0.0003** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

| | | BC | | | BS | | | BD | | | BB | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | **0.0001** | **0.0001** | **0.0198** | **0.0001** | **0.0001** | **0.0377** | **0.0001** | **0.0001** | **0.0189** | **0.0001** | **0.0001** | **0.0003** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0002** | **0.0001** | **0.0001** | **0.0004** | **0.0001** | **0.0001** | **0.0002** | **0.0001** | **0.0001** | **0.0001** |
| | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | *Serrodes partita* | **0.0015** | **0.0015** | 0.3662 | **0.0015** | **0.0015** | 0.6231 | **0.0015** | **0.0015** | 0.3515 | **0.0015** | **0.0015** | **0.0092** |
| | *Achaea* spp. | **0.0001** | **0.0001** | **0.0213** | **0.0001** | **0.0001** | **0.0405** | **0.0001** | **0.0001** | **0.0203** | **0.0001** | **0.0001** | **0.0003** |
| | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BW Lure** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BC** | *Serrodes partita* | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BS** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **BD** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BB** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

**Table IV.9**: The p-values for the Kruskal-Wallis test (H (4, N= 150) =85.9845, p =0.0001) comparing trap catches for the overall trap catch of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during 2015.

| | Fresh Banana | Control | R 1 | R 2 | R 3 |
|---|---|---|---|---|---|
| **Fresh Banana** | | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | | 0.9999 | 0.9999 | 0.9999 |
| **R 1** | **0.0001** | 0.9999 | | 0.9999 | 0.9999 |
| **R 2** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 |
| **R 3** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | |

**Table IV.10**: The p-values for the Kruskal-Wallis test (H (4, N= 150) =85.9845, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Sundays River Valley growing region during 2015.

| | | **Fresh Banana** | | | **Control** | | | **R 1** | | | **R 2** | | | **R 3** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **Fresh Banana** | *Serrodes partita* | | 0.9999 | **0.0021** | 0.3623 | 0.3623 | 0.9999 | 0.6773 | 0.6773 | 0.9999 | 0.3623 | 0.3623 | 0.9999 | 0.6773 | 0.6773 | 0.9999 |
| | *Achaea* spp. | 0.9999 | | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | **0.0021** | **0.0001** | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | *Serrodes partita* | 0.3623 | 0.9999 | **0.0001** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.3623 | 0.9999 | **0.0001** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **R 1** | *Serrodes partita* | 0.6773 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.6773 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **R 2** | *Serrodes partita* | 0.3623 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.3623 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **R 3** | *Serrodes partita* | 0.6773 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| | *Achaea* spp. | 0.6773 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| | All Moths | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

### IV.1.3 Kat River Valley and Sundays River Valley

**Table IV.11**: The p-values for the Kruskal-Wallis test (H (7, N= 1008) =663.8593, p =0.0001) comparing trap catches for the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley and Sundays River Valley growing region during 2014.

| | Fresh Banana | Frozen Banana | Control | BW Lure | BC | BS | BD | BB |
|---|---|---|---|---|---|---|---|---|
| **Fresh Banana** | | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Frozen Banana** | 0.9999 | | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | **0.0001** | | 0.1091 | 0.9999 | 0.7189 | 0.9999 | 0.9999 |
| **BW Lure** | **0.0001** | **0.0001** | 0.1091 | | 0.9999 | 0.9999 | 0.9999 | **0.0377** |
| **BC** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **BS** | **0.0001** | **0.0001** | 0.7189 | 0.9999 | 0.9999 | | 0.9999 | 0.3009 |
| **BD** | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **BB** | **0.0001** | **0.0001** | 0.9999 | **0.0377** | 0.9999 | 0.3009 | 0.9999 | |

**Table IV.12**: The p-values for the Kruskal-Wallis test (H (47, N= 3024) =1877.127, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley and Sundays River Valley growing region during 2014.

| | | | KRV | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Fresh Banana** | | | **Frozen Banana** | | | **Control** | | | **BW Lure** | | |
| | | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **SRV** | **Fresh Banana** | *Serrodes partita* | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0002** | **0.0001** | **0.0001** | **0.0214** | **0.0001** | **0.0002** | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | **0.0106** | 0.9999 | 0.9999 | **0.0279** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.9999 |
| | | All Moths | **0.0007** | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **Frozen Banana** | *Serrodes partita* | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0001** | **0.0043** | **0.0043** | 0.5009 | **0.0043** | **0.0076** | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0002** | **0.0001** | **0.0001** | **0.0229** | **0.0001** | **0.0001** | 0.9999 |
| | | All Moths | **0.0034** | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **Control** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | **0.0024** | **0.0001** | **0.0001** | 0.3053 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1442 |
| | **BW Lure** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | 0.2325 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BC** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | 0.1560 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BS** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | 0.2937 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BD** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | 0.1478 | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BB** | *Serrodes partita* | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | *Achaea* spp. | **0.0003** | **0.0001** | **0.0001** | 0.0569 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0250** |
| | | All Moths | **0.0022** | **0.0001** | **0.0001** | 0.2900 | **0.0001** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1366 |

| | | | KRV | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BC | | | BS | | | BD | | | BB | | |
| | | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **SRV** | **Fresh Banana** | *Serrodes partita* | **0.0001** | **0.0001** | 0.1198 | **0.0001** | **0.0006** | 0.9999 | **0.0001** | **0.0002** | 0.9999 | **0.0001** | **0.0001** | **0.0022** |
| | | *Achaea* spp. | **0.0001** | **0.0001** | **0.0012** | **0.0001** | **0.0001** | 0.9999 | **0.0001** | **0.0001** | 0.0873 | **0.0001** | **0.0001** | **0.0001** |
| | | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **Frozen Banana** | *Serrodes partita* | **0.0043** | **0.0043** | 0.9999 | **0.0043** | **0.0229** | 0.9999 | **0.0043** | **0.0076** | 0.9999 | **0.0043** | **0.0043** | 0.0728 |
| | | *Achaea* spp. | **0.0001** | **0.0001** | 0.1275 | **0.0001** | **0.0006** | 0.9999 | **0.0001** | **0.0002** | 0.9999 | **0.0001** | **0.0001** | **0.0024** |
| | | All Moths | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| | **Control** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BW Lure** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BC** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BS** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BD** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **BB** | *Serrodes partita* | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.5746 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

SRV - Sundays River Valley; KRV - Kat River Valley

**Table IV.13**: The p-values for the Kruskal-Wallis test (H (4, N= 330) =145.5863, p =0.0001) comparing trap catches for the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley and Sundays River Valley growing region during 2015.

| | Fresh Banana | Control | R 1 | R 2 | R 3 |
|---|---|---|---|---|---|
| **Fresh Banana** | | **0.0001** | **0.0001** | **0.0001** | **0.0001** |
| **Control** | **0.0001** | | **0.0105** | **0.0363** | **0.0429** |
| **R 1** | **0.0001** | **0.0105** | | 0.9999 | 0.9999 |
| **R 2** | **0.0001** | **0.0363** | 0.9999 | | 0.9999 |
| **R 3** | **0.0001** | **0.0429** | 0.9999 | 0.9999 | |

**Table IV.14**: The p-values for the Kruskal-Wallis test (H (29, N= 990) =524.9349, p =0.0001) comparing trap catches for *Serrodes partita*, *Achaea* spp. and the overall trap catch of fruit-feeding moths (All Moths) in the Kat River Valley and Sundays River Valley growing region during 2015.

| | | | **KRV** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Fresh Banana** | | | **Control** | | | **R 1** | | | **R 2** | | | **R 3** | | |
| | | | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths | *Serrodes partita* | *Achaea* spp. | All Moths |
| **SRV** | **Fresh Banana** | *Serrodes partita* | 0.9999 | 0.9999 | **0.0010** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | *Achaea* spp. | 0.9999 | 0.2305 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.7750 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | All Moths | 0.0739 | 0.9999 | 0.9999 | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | 0.7804 | **0.0001** | **0.0001** | 0.2170 | **0.0001** | **0.0001** | 0.5861 |
| | **Control** | *Serrodes partita* | **0.0456** | **0.0005** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0027** | 0.9999 | 0.9999 | **0.0140** | 0.9999 | 0.9999 | **0.0040** |
| | | *Achaea* spp. | **0.0456** | **0.0005** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0027** | 0.9999 | 0.9999 | **0.0140** | 0.9999 | 0.9999 | **0.0040** |
| | | All Moths | 0.9999 | **0.0320** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1264 | 0.9999 | 0.9999 | 0.4769 | 0.9999 | 0.9999 | 0.1739 |
| | **R 1** | *Serrodes partita* | 0.0988 | **0.0013** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0067** | 0.9999 | 0.9999 | **0.0319** | 0.9999 | 0.9999 | **0.0097** |
| | | *Achaea* spp. | 0.0988 | **0.0013** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0067** | 0.9999 | 0.9999 | **0.0319** | 0.9999 | 0.9999 | **0.0097** |
| | | All Moths | 0.9999 | 0.9999 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R 2** | *Serrodes partita* | **0.0456** | **0.0005** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0027** | 0.9999 | 0.9999 | **0.0140** | 0.9999 | 0.9999 | **0.0040** |
| | | *Achaea* spp. | **0.0456** | **0.0005** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0027** | 0.9999 | 0.9999 | **0.0140** | 0.9999 | 0.9999 | **0.0040** |
| | | All Moths | 0.9999 | 0.5703 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **R 3** | *Serrodes partita* | 0.0988 | **0.0013** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0067** | 0.9999 | 0.9999 | **0.0319** | 0.9999 | 0.9999 | **0.0097** |
| | | *Achaea* spp. | 0.0988 | **0.0013** | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | **0.0067** | 0.9999 | 0.9999 | **0.0319** | 0.9999 | 0.9999 | **0.0097** |
| | | All Moths | 0.9999 | 0.1341 | **0.0001** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4719 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.6314 |

SRV - Sundays River Valley; KRV - Kat River Valley

# Appendix V

## V.1 Damage observed within the orchards

### V.1.1 Grahamstown and Kat River Valley

**Table V.1**: The p-values for the Kruskal-Wallis test (H (4, N= 30) =19.0522, p =0.0008) results comparing the percent damage of fruit-piercing moth found within the orchards in the Grahamstown and Kat River Valley growing region during the 2013 growing season.

| | Blinkwater | Riverside A | Riverside B | Mosslands A | Mosslands B |
|---|---|---|---|---|---|
| **Blinkwater** | | 0.9999 | 0.9999 | 0.9999 | 0.3305 |
| **Riverside A** | 0.9999 | | 0.9999 | 0.4042 | **0.0242** |
| **Riverside B** | 0.9999 | 0.9999 | | 0.0532 | **0.0016** |
| **Mosslands A** | 0.9999 | 0.4042 | 0.0532 | | 0.9999 |
| **Mosslands B** | 0.3305 | **0.0242** | **0.0016** | 0.9999 | |

**Table V.2**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =6.6284, p =0.2498) results comparing the percent damage within the Blinkwater in the Kat River Valley growing region during the 2013 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.8010 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.8010 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.3**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =14.7829, p =0.0113) results comparing the percent damage within the Riverside A in the Kat River Valley growing region during the 2013 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.0552 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.0552 | | 0.1001 | 0.1180 | 0.9999 | 0.1562 |
| **B** | 0.9999 | 0.1001 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.1180 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.1562 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.4**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =17.6657, p =0.0034) results comparing the percent damage within the Riverside B in the Kat River Valley growing region during the 2013 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0222** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | **0.0222** | | 0.5411 | **0.0367** | 0.1690 | **0.0193** |
| **B** | 0.9999 | 0.5411 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | **0.0367** | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.1690 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | **0.0193** | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.5**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =12.5389, p =0.0281) results comparing the percent damage within the Mosslands A in the Grahamstown growing region during the 2013 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | **0.0281** | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.4563 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.3832 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.1001 | 0.9999 |
| **D** | **0.0281** | 0.4563 | 0.3832 | 0.1001 | | 0.9365 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9365 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.6**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =8.7517, p =0.1194) results comparing the percent damage within the Mosslands B in the Grahamstown growing region during the 2013 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.4563 | 0.9999 | 0.9658 | 0.9999 | 0.9999 |
| **FPM** | 0.4563 | | 0.9999 | 0.9999 | 0.6603 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9658 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.6603 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.7**: The p-values for the Kruskal-Wallis test (H (5, N= 180) =23.7947, p =0.0002) results for the overall percent damage in the Grahamstown and Kat River Valley growing region during the 2013 growing season.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | **0.0226** | 0.9999 | 0.9999 | 0.0904 | 0.9999 |
| **FPM** | **0.0226** | | 0.2705 | **0.0051** | 0.9999 | 0.3647 |
| **B** | 0.9999 | 0.2705 | | 0.9999 | 0.7902 | 0.9999 |
| **M** | 0.9999 | **0.0051** | 0.9999 | | **0.0239** | 0.9999 |
| **D** | 0.0904 | 0.9999 | 0.7902 | **0.0239** | | 0.9999 |
| **O** | 0.9999 | 0.3647 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.8**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =18.7520, p =0.0021) results comparing the percent damage of fruit-piercing moth found between the orchards in the Kat River Valley growing region during the 2014 growing season.

| | **Glinkwater Farm A** | **Glinkwater Farm B** | **Riverside A** | **Riverside B** | **Bath Farm A** | **Bath Farm B** |
|---|---|---|---|---|---|---|
| **Glinkwater Farm A** | | 0.9999 | 0.9999 | 0.3839 | 0.9999 | 0.9641 |
| **Glinkwater Farm B** | 0.9999 | | 0.3283 | **0.0083** | 0.9999 | **0.0320** |
| **Riverside A** | 0.9999 | 0.3283 | | 0.9999 | 0.9999 | 0.9999 |
| **Riverside B** | 0.3839 | **0.0083** | 0.9999 | | 0.2530 | 0.9999 |
| **Bath Farm A** | 0.9999 | 0.9999 | 0.9999 | 0.2530 | | 0.6703 |
| **Bath Farm B** | 0.9641 | **0.0320** | 0.9999 | 0.9999 | 0.6703 | |

**Table V.9**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =10.4094, p =0.0644) results comparing the percent damage types found within Glinkwater Farm A in the Kat River Valley growing region during the 2014 growing season.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.4559 | 0.5197 | 0.2744 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.4559 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.5197 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.2744 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.10**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =3.9040, p =0.5633) results comparing the percent damage types found within Glinkwater Farm B in the Kat River Valley growing region during the 2014 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.11**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =8.2505, p =0.1430) results comparing the percent damage types found within Riverside A in the Kat River Valley growing region during the 2014 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.4307 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.4307 | | 0.7070 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.7070 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.12**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =12.2795, p =0.0312) results comparing the percent damage types found within Riverside B in the Kat River Valley growing region during the 2014 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.1701 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.1701 | | 0.9999 | 0.6584 | 0.2190 | 0.1027 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.6584 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.2190 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.1027 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.13**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =15.3295, p =0.0090) results comparing the percent damage types found within Bath Farm A in the Kat River Valley growing region during the 2014 growing season.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.1495 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.7323 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.7323 | | **0.0474** |
| **O** | 0.9999 | 0.9999 | 0.1495 | 0.9999 | **0.0474** | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.14**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =29.6217, p =0.0001) results comparing the percent damage types found within Bath Farm B in the Kat River Valley growing region during the 2014 growing season.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | **0.0066** | 0.9999 | **0.0213** | 0.9999 | 0.0647 |
| **FPM** | **0.0066** | | **0.0362** | 0.9999 | **0.0362** | 0.9999 |
| **B** | 0.9999 | **0.0362** | | 0.1004 | 0.9999 | 0.2635 |
| **M** | **0.0213** | 0.9999 | 0.1004 | | 0.1004 | 0.9999 |
| **D** | 0.9999 | **0.0362** | 0.9999 | 0.1004 | | 0.2635 |
| **O** | 0.0647 | 0.9999 | 0.2635 | 0.9999 | 0.2635 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.15**: The p-values for the Kruskal-Wallis test (H (5, N= 324) =29.6933, p =0.0001) results comparing the overall percent damage found within the orchards in the Kat River Valley growing region during the 2014 growing season.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | **0.0060** | 0.9999 | 0.0547 | 0.9999 | **0.0341** |
| **FPM** | **0.0060** | | **0.0192** | 0.9999 | 0.1013 | 0.9999 |
| **B** | 0.9999 | **0.0192** | | 0.1448 | 0.9999 | 0.0940 |
| **M** | 0.0547 | 0.9999 | 0.1448 | | 0.5670 | 0.9999 |
| **D** | 0.9999 | 0.1013 | 0.9999 | 0.5670 | | 0.3939 |
| **O** | **0.0341** | 0.9999 | 0.0940 | 0.9999 | 0.3939 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.16**: The p-values for the Kruskal-Wallis test (H (5, N= 30) =18.0402, p =0.0029) results comparing the percent damage of fruit-piercing moth found between the orchards in the Kat River Valley growing region during the 2015 growing season.

| | Glinkwater Farm A | Glinkwater Farm B | Riverside A | Riverside B | Bath Farm A | Bath Farm B |
|---|---|---|---|---|---|---|
| **Glinkwater Farm A** | | 0.9999 | 0.9999 | 0.4886 | 0.2415 | 0.9999 |
| **Glinkwater Farm B** | 0.9999 | | 0.9999 | **0.0251** | **0.0097** | 0.9999 |
| **Riverside A** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **Riverside B** | 0.4886 | **0.0251** | 0.9999 | | 0.9999 | 0.4886 |
| **Bath Farm A** | 0.2415 | **0.0097** | 0.9999 | 0.9999 | | 0.2415 |
| **Bath Farm B** | 0.9999 | 0.9999 | 0.9999 | 0.4886 | 0.2415 | |

**Table V.17**: The p-values for the Kruskal-Wallis test (H (5, N= 30) =17.9091, p =0.0031) results comparing the percent damage types found within Glinkwater Farm A in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0097** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | **0.0097** | | **0.0320** | 0.1381 | 0.6640 | 0.2663 |
| **B** | 0.9999 | **0.0320** | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.1381 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.6640 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.2663 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.18**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =19.3813, p =0.0016) results comparing the percent damage types found within Glinkwater Farm B in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0049** | 0.3545 | 0.9999 | 0.9999 | 0.4671 |
| **FPM** | **0.0049** | | 0.9999 | 0.4266 | **0.0143** | 0.9999 |
| **B** | 0.3545 | 0.9999 | | 0.9999 | 0.7229 | 0.9999 |
| **M** | 0.9999 | 0.4266 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | **0.0143** | 0.7229 | 0.9999 | | 0.9267 |
| **O** | 0.4671 | 0.9999 | 0.9999 | 0.9999 | 0.9267 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.19**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =18.6333, p =0.0022) results comparing the percent damage types found within Riverside A in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0236** | 0.9999 | 0.8195 | 0.9999 | 0.3715 |
| **FPM** | **0.0236** | | 0.0682 | 0.9999 | 0.0950 | 0.9999 |
| **B** | 0.9999 | 0.0682 | | 0.9999 | 0.9999 | 0.8195 |
| **M** | 0.8195 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.0950 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.3715 | 0.9999 | 0.8195 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.20**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =16.9767, p =0.0045) results comparing the percent damage types found within Riverside B in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.5582 | 0.9999 | 0.8195 | 0.9999 | **0.0283** |
| **FPM** | 0.5582 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.2298 |
| **M** | 0.8195 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.0721 |
| **O** | **0.0283** | 0.9999 | 0.2298 | 0.9999 | 0.0721 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.21**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =11.6028, p =0.0407) results comparing the percent damage types found within Bath Farm A in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.1310 | 0.9999 | 0.1788 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.1310 | 0.9999 | 0.9999 | | 0.7867 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.7867 | | 0.9999 |
| **O** | 0.1788 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.22**: The p-values for the Kruskal-Wallis test (H (5, N= 54) =18.8103, p =0.0021) results comparing the percent damage types found within Bath Farm B in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0208** | 0.9999 | 0.9999 | 0.9999 | 0.0851 |
| **FPM** | **0.0208** | | 0.1788 | 0.9999 | 0.1003 | 0.9999 |
| **B** | 0.9999 | 0.1788 | | 0.9999 | 0.9999 | 0.5582 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.1003 | 0.9999 | 0.9999 | | 0.3382 |
| **O** | 0.0851 | 0.9999 | 0.5582 | 0.9999 | 0.3382 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.23**: The p-values for the Kruskal-Wallis test (H (5, N= 180) =80.6576, p = 0.0001) results comparing the overall percent damage found within the orchards in the Kat River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0001** | 0.2090 | **0.0004** | 0.9999 | **0.0001** |
| **FPM** | **0.0001** | | **0.0001** | 0.0536 | **0.0001** | 0.9999 |
| **B** | 0.2090 | **0.0001** | | 0.9999 | 0.9999 | **0.0175** |
| **M** | **0.0004** | 0.0536 | 0.9999 | | 0.1001 | 0.9999 |
| **D** | 0.9999 | **0.0001** | 0.9999 | 0.1001 | | **0.0004** |
| **O** | **0.0001** | 0.9999 | **0.0175** | 0.9999 | **0.0004** | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.24**: The p-values for the Kruskal-Wallis test (H (2, N= 114) =9.1248, p =0.0104) results comparing the percent damage of fruit-piercing moth damage between the years in the Grahamstown and Kat River Valley growing region.

| | 2013 | 2014 | 2015 |
|---|---|---|---|
| **2013** | | 0.9999 | 0.1890 |
| **2014** | 0.9999 | | **0.0089** |
| **2015** | 0.1890 | **0.0089** | |

**Table V.25**: The p-values for the Kruskal-Wallis test (H (17, N= 720) =134.5607, p = 0.0001 results comparing the percent damage found within the orchards in the Grahamstown and Kat River Valley growing region during the 2013, 2014 and 2015 growing season.

| | | 2013 | | 2014 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Riverside A | Riverside B | Riverside A | Riverside B | Glinkwater Farm A | Glinkwater Farm B | Bath Farm A | Bath Farm B |
| **2013** | **Riverside A** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.1973 | 0.9999 | 0.9999 |
| | **Riverside B** | 0.9999 | | 0.9999 | 0.9999 | 0.2389 | **0.0062** | 0.2389 | 0.9999 |
| **2015** | **Riverside A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.6949 | 0.9999 | 0.9999 |
| | **Riverside B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **Glinkwater Farm A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0760 | 0.9999 | 0.9999 |
| | **Glinkwater Farm B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0938 | **0.0024** | 0.0938 | 0.9999 |
| | **Bath Farm A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **Bath Farm B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.0584 | 0.9999 | 0.9999 |

### V.1.2 Sundays River Valley

**Table V.26**: The p-values for the Kruskal-Wallis test (H (3, N= 24) =10.5582, p =0.0144) results comparing the percent damage of fruit-piercing moth damage between orchards in the Sundays River Valley growing region during 2014.

| | Hitgeheim | Halaron Farm | Dunbrody estate - Riverside A | Dunbrody estate - Riverside B |
|---|---|---|---|---|
| **Hitgeheim** | | 0.9999 | 0.4545 | **0.0173** |
| **Halaron Farm** | 0.9999 | | 0.9999 | 0.1134 |
| **Dunbrody estate - Riverside A** | 0.4545 | 0.9999 | | 0.9999 |
| **Dunbrody estate - Riverside B** | **0.0173** | 0.1134 | 0.9999 | |

**Table V.27**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =20.2616, p =0.0011) results comparing the percent damage of fruit-piercing moth damage within Hitgeheim in the Sundays River Valley growing region during 2014.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0124** | 0.9999 | 0.9999 | 0.9999 | 0.8010 |
| **FPM** | **0.0124** | | **0.0423** | 0.8802 | **0.0370** | 0.9999 |
| **B** | 0.9999 | **0.0423** | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.8802 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | **0.0370** | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.8010 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.28**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =17.9151, p =0.0031) results comparing the percent damage of fruit-piercing moth damage within Halaron Farm in the Sundays River Valley growing region during 2014.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0052** | 0.8010 | 0.9999 | 0.9999 | 0.5596 |
| **FPM** | **0.0052** | | 0.9999 | **0.0443** | 0.2476 | 0.9999 |
| **B** | 0.8010 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | **0.0443** | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.2476 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.5596 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.29**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =10.9602, p =0.0522) results comparing the percent damage of fruit-piercing moth damage within Dunbrody estate - Riverside A in the Sundays River Valley growing region during 2014.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.3322 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.3322 | | 0.9999 | 0.9999 | 0.9658 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9658 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.30**: The p-values for the Kruskal-Wallis test (H (5, N= 36) =7.2031, p =0.2060) results comparing the percent damage of fruit-piercing moth damage within Dunbrody estate - Riverside B in the Sundays River Valley growing region during 2014.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.31**: The p-values for the Kruskal-Wallis test (H (5, N= 144) =46.9141, p = 0.0001) results comparing the overall percent damage found within the orchards in the Sundays River Valley growing region during the 2014 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0001** | 0.9999 | 0.9999 | 0.9999 | **0.0027** |
| **FPM** | **0.0001** | | **0.0077** | **0.0154** | **0.0006** | 0.9999 |
| **B** | 0.9999 | **0.0077** | | 0.9999 | 0.9999 | 0.4830 |
| **M** | 0.9999 | **0.0154** | 0.9999 | | 0.9999 | 0.7648 |
| **D** | 0.9999 | **0.0006** | 0.9999 | 0.9999 | | 0.0859 |
| **O** | **0.0027** | 0.9999 | 0.4830 | 0.7648 | 0.0859 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.32**: The p-values for the Kruskal-Wallis test (H (3, N= 24) =10.5582, p =0.0144) results comparing the percent damage of fruit-piercing moth damage between orchards in the Sundays River Valley growing region during 2015.

| | Halaron Farm | Dunbrody estate - Riverside A | Dunbrody estate - Riverside B | Dunbrody estate - Riverside C |
|---|---|---|---|---|
| **Halaron Farm** | | 0.9999 | 0.9999 | 0.9999 |
| **Dunbrody estate - Riverside A** | 0.9999 | | 0.9999 | 0.9999 |
| **Dunbrody estate - Riverside B** | 0.9999 | 0.9999 | | 0.9999 |
| **Dunbrody estate - Riverside C** | 0.9999 | 0.9999 | 0.9999 | |

**Table V.33**: The p-values for the Kruskal-Wallis test (H (5, N= 24) =6.1483, p =0.2921) results comparing the percent damage of fruit-piercing moth damage within Halaron Farm in the Sundays River Valley growing region during 2015.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.34**: The p-values for the Kruskal-Wallis test (H (5, N= 24) =6.9006, p =0.2281) results comparing the percent damage of fruit-piercing moth damage within Dunbrody estate - Riverside A in the Sundays River Valley growing region during 2015.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | 0.5038 | 0.9999 | 0.9999 | 0.9999 | 0.7676 |
| **FPM** | 0.5038 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.7676 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.35**: The p-values for the Kruskal-Wallis test (H (5, N= 24) =10.1431, p =0.0713) results comparing the percent damage of fruit-piercing moth damage within Dunbrody estate - Riverside B in the Sundays River Valley growing region during 2015.

| | **S** | **FPM** | **B** | **M** | **D** | **O** |
|---|---|---|---|---|---|---|
| **S** | | 0.4445 | 0.9999 | 0.9999 | 0.9999 | 0.6430 |
| **FPM** | 0.4445 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.6430 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.36**: The p-values for the Kruskal-Wallis test (H (5, N= 24) =6.0221, p =0.3041) results comparing the percent damage of fruit-piercing moth damage within Dunbrody estate - Riverside C in the Sundays River Valley growing region during 2015.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **B** | 0.9999 | 0.9999 | | 0.9999 | 0.9999 | 0.9999 |
| **M** | 0.9999 | 0.9999 | 0.9999 | | 0.9999 | 0.9999 |
| **D** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | | 0.9999 |
| **O** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.37**: The p-values for the Kruskal-Wallis test (H (5, N= 96) =22.4860, p =0.0004) results comparing the overall percent damage found within the orchards in the Sundays River Valley growing region during the 2015 growing season.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| **FPM** | 0.9999 | | 0.0799 | 0.2606 | 0.1013 | 0.9999 |
| **B** | 0.9999 | 0.0799 | | 0.9999 | 0.9999 | 0.3406 |
| **M** | 0.9999 | 0.2606 | 0.9999 | | 0.9999 | 0.7639 |
| **D** | 0.9999 | 0.1013 | 0.9999 | 0.9999 | | 0.2932 |
| **O** | 0.9999 | 0.9999 | 0.3406 | 0.7639 | 0.2932 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

**Table V.38**: The p-values for the Mann-Whitney U Test ($p < 0.05$) comparing the percent damage of fruit-piercing moth between the 2014 vs 2015 growing season in the Sundays River Valley growing region.

| | Rank Sum | Rank Sum | U | Z | p-value | Z | p-value | Valid N | Valid N |
|---|---|---|---|---|---|---|---|---|---|
| **FPM** | 520.5000 | 299.5000 | 163.5000 | 0.77302 | 0.4395 | 0.7823 | 0.4340 | 24 | 16 |

**Table V.39**: The p-values for the Kruskal-Wallis test (H (7, N= 40) =12.4777, p =0.0859) results comparing the percent damage of fruit-piercing moth damage between the orchards in the Sundays River Valley growing region during the 2014 vs 2015 growing season.

| | | 2014 | | | |
|---|---|---|---|---|---|
| | | **Hitgeheim** | **Halaron Farm** | **Dunbrody estate - Riverside A** | **Dunbrody estate - Riverside B** |
| **2015** | **Halaron Farm** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **Dunbrody estate - Riverside A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **Dunbrody estate - Riverside B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **Dunbrody estate - Riverside C** | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

### V.1.3 Kat River Valley and Sundays River Valley

**Table V.40**: The p-values for the Kruskal-Wallis test (H (11, N= 744) =164.3241, p = 0.0001) results comparing the overall percent damage found within the orchards in the Kat River Valley and Sundays River Valley growing region during 2014 and 2015.

| | | | SRVGR | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2014 | | | | 2015 | | | |
| | | | **Hitgeheim** | **Halaron Farm** | **Dunbrody estate - Riverside A** | **Dunbrody estate - Riverside B** | **Halaron Farm** | **Dunbrody estate - Riverside A** | **Dunbrody estate - Riverside B** | **Dunbrody estate - Riverside C** |
| **KRVGR** | **2014** | **Glinkwater A** | 0.2891 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Glinkwater B** | **0.0100** | 0.1918 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Riverside A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Riverside B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Bath Farm A** | 0.3134 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Bath Farm B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | **2015** | **Glinkwater A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Glinkwater B** | 0.9999 | 0.9999 | 0.9999 | 0.1334 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Riverside A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Riverside B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Bath Farm A** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | | **Bath Farm B** | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |

KRVGR - Kat River Valley growing region; SRVGR - Sundays River Valley growing region

**Table V.41**: The p-values for the Kruskal-Wallis test (H (5, N= 744) =151.6946, p = 0.0001) results comparing the percent damage found within the orchards in the Kat River Valley and Sundays River Valley growing regions.

| | S | FPM | B | M | D | O |
|---|---|---|---|---|---|---|
| **S** | | **0.0001** | 0.0630 | **0.0001** | 0.7451 | **0.0001** |
| **FPM** | **0.0001** | | **0.0001** | **0.0005** | **0.0001** | 0.8189 |
| **B** | 0.0630 | **0.0001** | | 0.2649 | 0.9999 | **0.0001** |
| **M** | **0.0001** | **0.0005** | 0.2649 | | **0.0160** | 0.3890 |
| **D** | 0.7451 | **0.0001** | 0.9999 | **0.0160** | | **0.0001** |
| **O** | **0.0001** | 0.8189 | **0.0001** | 0.3890 | **0.0001** | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other

## V.1.4 Tshipise

**Table V.42**: The p-values for the Kruskal-Wallis test (H (11, N= 120) =97.8201, p = 0.0001) results comparing the percent damage found within the orchards in the Tshipise growing region during 2014 and 2015.

| | | **2014** | | | | | | **2015** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **S** | **FPM** | **B** | **M** | **D** | **O** | **S** | **FPM** | **B** | **M** | **D** | **O** |
| **2014** | **S** | | 0.9999 | 0.9999 | **0.0062** | **0.0097** | **0.0003** | 0.9999 | 0.9999 | 0.9999 | **0.0002** | 0.4534 | **0.0013** |
| | **FPM** | 0.9999 | | 0.9999 | **0.0314** | **0.0471** | **0.0019** | 0.9999 | 0.9999 | 0.9999 | **0.0016** | 0.9999 | **0.0074** |
| | **B** | 0.9999 | 0.9999 | | **0.0372** | 0.0554 | **0.0024** | 0.9999 | 0.9999 | 0.9999 | **0.0020** | 0.9999 | **0.0089** |
| | **M** | **0.0062** | **0.0314** | **0.0372** | | 0.9999 | 0.9999 | **0.0062** | **0.0143** | **0.0409** | 0.9999 | 0.9999 | 0.9999 |
| | **D** | **0.0097** | **0.0471** | 0.0554 | 0.9999 | | 0.9999 | **0.0097** | **0.0218** | 0.0608 | 0.9999 | 0.9999 | 0.9999 |
| | **O** | **0.0003** | **0.0019** | **0.0024** | 0.9999 | 0.9999 | | **0.0003** | **0.0008** | **0.0026** | 0.9999 | 0.9999 | 0.9999 |
| **2015** | **S** | 0.9999 | 0.9999 | 0.9999 | **0.0062** | **0.0097** | **0.0003** | | 0.9999 | 0.9999 | **0.0002** | 0.4534 | **0.0013** |
| | **FPM** | 0.9999 | 0.9999 | 0.9999 | **0.0143** | **0.0218** | **0.0008** | 0.9999 | | 0.9999 | **0.0006** | 0.8258 | **0.0031** |
| | **B** | 0.9999 | 0.9999 | 0.9999 | **0.0409** | 0.0608 | **0.0026** | 0.9999 | 0.9999 | | **0.0022** | 0.9999 | **0.0098** |
| | **M** | **0.0002** | **0.0016** | **0.0020** | 0.9999 | 0.9999 | 0.9999 | **0.0002** | **0.0006** | **0.0022** | | 0.9999 | 0.9999 |
| | **D** | 0.4534 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0.4534 | 0.8258 | 0.9999 | 0.9999 | | 0.9999 |
| | **O** | **0.0013** | **0.0074** | **0.0089** | 0.9999 | 0.9999 | 0.9999 | **0.0013** | **0.0031** | **0.0098** | 0.9999 | 0.9999 | |

S - Snail; FPM – Fruit-piercing moth; B – Bird; M – Mechanical; D – Diseased; O – Other