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Developmental biology of *Amblypelta lutescens lutescens* Distant (Heteroptera: Coreidae) on a choice of tropical crops in Australia with regard to environmentally sound control methodology

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In memory of my late parents

and

to Rachel and Ross for professional guidance

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1 INTRODUCTION

1.1 Nature and history of the *Amblypelta lutescens lutescens* (Distant) (Heteroptera: Coreidae) pest problem in Australia

Fruitspotting bugs were first mentioned as a pest in Australia in 1926 (VEITCH, 1926). VEITCH & SIMMONDS (1929) reported *Amblypelta lutescens lutescens* (as *Pendulinus lutescens* Distant) and *Amblypelta nitida* Stål (as *Pendulinus fuscescens* Distant) (Heteroptera: Coreidae) being a serious problem on papaya (commonly called papaw in Australia) (*Carica papaya* Linnaeus) in the Rockhampton district. They have subsequently been recorded from more than 26 crop hosts in this country, with many ornamental plants attacked as well.

The banana-spotting bug *Amblypelta lutescens lutescens* (Distant) (Heteroptera: Coreidae) is one of the most important pests of tree fruit and nut crops in tropical and near tropical Australia. The common name banana-spotting bug arose possibly because it had caused extensive damage in bananas (VEITCH, 1926). Because of the control measures for other pests in bananas, the banana-spotting bug is rarely a problem pest in cultivated bananas these days.

Amblypelta spp. damage their hosts by piercing the plant tissue and injecting salivary enzymes which facilitate feeding. The parenchymal cells are drained (FAY, 1991).

There seem to be four major reasons behind the fruitspotting bug pest problem.

1) *A.l. lutescens* has an enormous host range, being recorded on 104 different plant species in 47 plant families. There is a variety of alternate hosts available to fruitspotting bugs most of the year. The various host plants include commercially grown crops (including a large variety of tropical tree fruit and nuts), a number of ornamental plants such as *Murraya paniculata* (L.) Jack. (mock orange or orange jessamine), *Delonix regia* (Hook.) Raf. (*Poinciana regia*) (poinciana or flamboyant) and roses as well as native hosts such as for example *Ficus* spp. and *Eucalyptus* spp. (see host list, Appendix I). Damage to commercial and ornamental plants results in significant monetary losses. The fact that a broad range of native plants are also attacked, and that these are distributed through the insects range

provides an enormous undisturbed feeding and breeding ground for the bugs and makes control very difficult.

Very little has been recorded about the relationship of the bugs and its various host plants. Vegetation containing native host plants and the introduction of exotic tropical fruit trees into the backyards and orchards have increased the availability of hosts for fruitspotting bugs in recent years (WAITE et al., 1993). The part of the host plant attacked by *A.l. lutescens* depends on the specific host, but the fruit, stem and petioles are commonly fed on (BROWN, 1958a).

2) A small population of bugs can cause a large amount of damage and any feeding damage makes fruits or nuts unmarketable. The economic threshold therefore is very low.

The numbers of bugs found in the field at any one time appears very low, and belies the amount of damage caused by the insect. Individuals, both adults as well as nymphs, appear to frequently change feeding sites.

3) The only current control methods used is insecticidal control. Endosulfan is mostly applied repetitively, and sprays are usually prophylactic as there are no means of adequately monitoring the insect (FAY, 1990). This one-sided chemical control can be environmentally hazardous and causes disruption to other control measures for other pests employed in affected crops. Fully Integrated Pest Management (IPM) in crops like papayas, for example, is prevented by the requirement for repetitive endosulfan sprays, despite this product's moderate toxicity to beneficial insects.

4) Breeding is thought to occur largely outside the crop environment limiting the effectiveness of existing control measures. This assumption is confirmed by the fact that under prophylactic sprays both adults and nymphs are killed preventing maintenance of breeding within the crop or at least significantly suppressing it. The damage level can increase as the crop develops, which suggests that adults keep flying into the crop to feed and breed between sprays. Feeding behaviour and control of transient adults is therefore a major concern in containing fruitspotting bug damage.

Studying the insects feeding biology in greater detail and examining alternative control methods, as accomplished by the author, are obvious responses to these difficulties.

1.2 Affects and costs to horticultural industries

A.l. lutescens occurs along the east coast of Australia, north from Brisbane to the Torres Strait (DONALDSON, 1983), in parts of the Northern Territory and northern Western Australia (SMITH, 1985). As banana-spotting bugs attack such a wide range of fruit and nut crops, there is a high level of awareness and concern by fruit growers about this pest in subtropical and tropical Australia. At the same time, the demand for cultivation of exotic tropical tree crops is increasing. Crops presently valued at about $ 85 million p.a., are heavily affected by fruitspotting bug in Queensland. Further, crops valued at $ 140 million p.a. suffer minor bug damage (FAY, 1992). Probably more than 2500 farmers use chemical control measures against fruitspotting bugs, which may result in product and application costs as high as $10 million p.a. (FAY, 1992). Endosulfan is approved for use in 26 crops against fruitspotting bugs in Queensland (WAITE et al., 1993). The current recommendations in various crops, by the Queensland Department of Primary Industries are shown in Appendix II. Insecticide applications are suggested as full cover sprays of the trees, at 10 to 14 day intervals if necessary - between September and May under north Queensland conditions. Even though endosulfan is an effective control agent against *Amblypelta* spp., there are considerable environmental concerns over its use. It is one of the few remaining organochlorines in agricultural use, and although it is not of a persistent type, concerns over its role as an agricultural chemical have been expressed. Future use of endosulfan in Australia is therefore under scrutiny and it is under threat of deregistration. Banning endosulfan would leave many crops exposed to fruitspotting bug damage and alternative control strategies would be keenly wanted (FAY, 1995).

At present the most affected industries are the papaya, lychee (*Litchi chinensis* Sonn.), macadamia (*Macadamia integrifolia* Maiden & Betche), custard apple (*Annona reticulata* L.) and avocado (*Persea americana* Mill.) industries in Australia. The cashew (*Anacardium occidentale* L.) industry at the moment is only small, but with potential for expansion. Should it do so this industry will become one of the most affected ones. In the context of a specific crop, *A. nitida* and *A.l. lutescens* can each cause the drop of more than 90% green fruit in lychees (WAITE, 1990). In avocado which is also attacked by both fruitspotting bug species, one fruit can receive as many as 20 feeding marks. A single feeding mark makes the fruit unmarketable (SAROOSHI et al., 1979). In avocado grown without insecticide protection, a crop loss of 21 % has been recorded (WAITE et al., 1993). In organically produced

macadamias, up to 50 % of a crop has been lost due to fruitspotting bug damage (WAITE et al., 1993).

1.3 Goal of the research project

The principal goal of this project is a better understanding of the relationships between *A.l. lutescens* and some of its host plants and exploration of alternative control methods with the potential to alleviate prophylactic use of endosulfan. This project included studies on feeding preference in the bugs, their nutritional requirements for breeding and their seasonal associations with host plants. The project will provide an insight into the biology of the insect which could lead to improved control opportunities. Reduced spray frequency, strategically timed application, trap cropping, biological control windows and less disruptive insecticidal options are all areas which can draw on an improved understanding of insects and their hosts.

2 LITERATURE REVIEW

2.1 The bug family Coreidae

The hemipteran family of Coreidae is represented world-wide by a total of about 2000 species. Most species are found in India, Africa and South America (IMMS, 1960). Fifty-seven species of this family occur in Australia. Coreids are medium to large-sized insects. One of their characteristics is the production of a strong odour (IMMS, 1960; CARVER et al., 1991). Several genera of Coreidae exhibit unusual enlargements of antennae and tibiae with unknown function (IMMS, 1960).

2.2 The genus *Amblypelta* Stål

In 1873 STÅL first described the genus *Amblypelta*, which was then based on two species from New Caledonia and Vanuatu (LEVER, 1981). BROWN (1958) revised the genus and recognised a total of 12 *Amblypelta* species and five subspecies. BROWN and GHAURI (1961) described *Amblypelta madangana*, GHAURI (1984) described a further two species, *Amblypelta bukharii* and *Amblypelta danishi*, which brings the total of *Amblypelta* spp. up to 15 species and five subspecies. The distribution of this genus "is confined to Australia north of Sydney, the islands between Australia and New Guinea, New Guinea and to the west, the Kai Is., Timor and Java; the Bismarck Archipelago (New Britain and New Ireland); the Solomon Islands including Bougainville, Rennell and Bellona; the New Hebrides and New Caledonia" (BROWN, 1958; p.538).
A very important diagnostic character of the genus *Amblypelta* is a truncate tip to the scutellum (BROWN, 1958). The same author divided the genus *Amblypelta* into the three following groups, based on zoogeographical and taxonomic evidence.

1) *A. bilineata* Stål, *A. nitida* Stål and *A. brevicornis* Brown
(New Hebrides, New Caledonia and Australia)

2) *A. lutescens* Distant and *A. manihotis* Blöte
(Northern Australia, Torres Strait Islands, southern New Guinea, as far west as Java).

3) *A. costalis* Van Duzee, *A. theobromae* Brown, *A. ardleyi* Brown, *A. blötei* Brown, *A. gallegonis* Lever, *A. christobalensis* Brown and *A. cocophaga* China
(New Guinea, Bismarck and Solomon Islands (BROWN, 1958).
The three last described species *A. madangana* Brown & Ghauri (New Guinea), *A. bukharii* Ghauri (Papua New Guinea) and *A. danishi* Ghauri (Irian Jaya) can probably be included in this group (BROWN & GHAURI, 1961; GHAURI, 1984).

All species of this genus are strong fliers but do not cover vast distances (BROWN, 1958). This is an important fact in terms of quarantine measures, especially in island situations (BROWN, 1958).

The genus *Amblypelta* is very closely related to the genera *Pseudotheraptus*, which has a distribution limited to Africa, and *Dasynus*, with a distribution in the oriental region (CHINA, 1934). All three genera belong to the tribe Dasinini (BROWN, 1955-1956). Even though the genera *Amblypelta* and *Pseudotheraptus* are very similar, because of geographical isolation, they have developed individual characteristics justifying generic separation. *Dasynus fuscescens* is the only Australian species of this genus and has been recorded in several locations in Queensland (DONALDSON, 1993). The clear division of the genus *Amblypelta* and the genus *Dasynus* seems to be the cause of confusion. BROWN (1958) as well as CHINA (1934) mention in their papers the difficulty in differentiating between the two genera. BROWN (1955-1956 and 1958) remarks that the position of the genus *Amblypelta* is very vague, and recommends a complete new revision of all related genera.

2.3 *Amblypelta* spp. in Australia

The three *Amblypelta* species occurring in Australia are *A. lutescens lutescens*, *A. nitida* and *A. brevicornis*. Records of *A. lutescens papuensis* in the Torres Strait are unconfirmed. At the present, in terms of pest status, *A.l. lutescens* is the most important of the three species and its range appears to be expanding. Even at the southern end of its distribution, more damage is caused by the banana-spotting bug than by *A. nitida* (WAITE, 1993), although they appear to have slightly different host preferences.

2.3.1 Feeding ecology

Fruitspotting bugs are active in Queensland right through the year. During the cooler months between June and September, the activity of the insects is diminished. This period is slightly extended in the southern areas of Queensland. The *Amblypelta* populations appear to reach their peak around February. Researchers studying fruit-spotting bugs in Australia currently agree that a significant portion of the crop invading bugs breed in the native bushland and forest. It is extremely difficult to study these

populations and their movements without adequate tools, like pheromone traps, which are not yet available. The presence of *Amblypelta* in the different commercial crops is dependent on the phenology of the crop and the availability of alternative food sources in the vicinity of the orchard. In coastal and subcoastal Queensland it appears that crops which are surrounded by natural bushland are most susceptible to fruitspotting bug attack (IRONSIDE, 1981; RYAN, 1994). In the case of avocados and carambolas (*Averrhoa carambola* L.), *A.l. lutescens* prefers these fruits when they are immature. When not available the bugs must look for an alternative in the surrounding environment. It appears unlikely that they will fly great distances to find another food source.

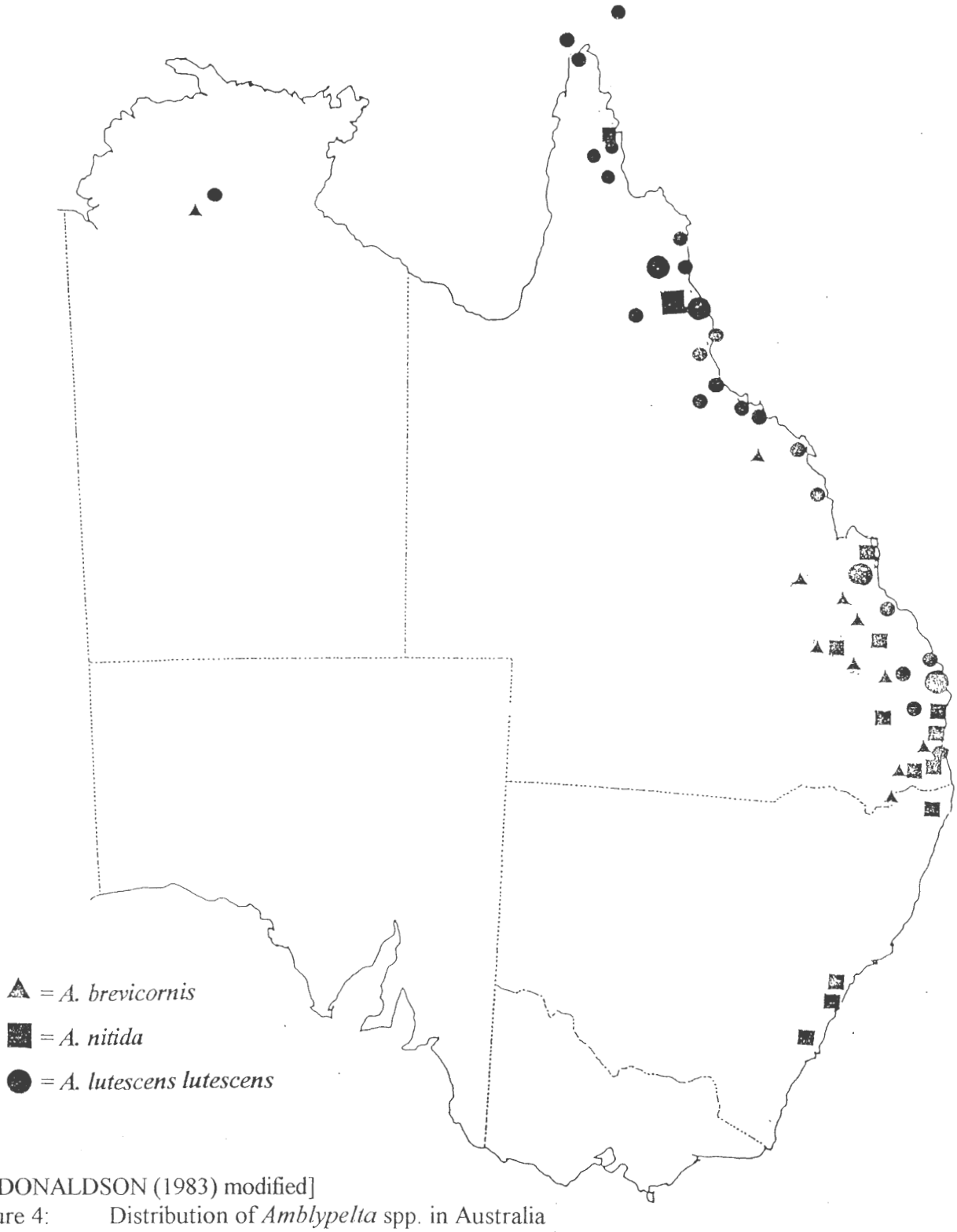
In the case of cashew, *A.l. lutescens* feeds on several parts of the host plant, young shoots, stalks of leaves and flowers, small cashew nuts and cashew apples (Figs. 1-3). A mature cashew tree therefore provides nearly continuous nourishment and it could provide a permanent breeding ground.

Papayas are mostly attacked when they are very young, from planting until about three to four months old.

Figure 1: Damage on flower panicles

Figure 2: Damage on cashew shoots

Figure 3: Damage on cashew nuts



[ex DONALDSON (1983) modified]
Figure 4: Distribution of *Amblypelta* spp. in Australia

2.3.2 Distribution

A.l. lutescens has been recorded in all coastal areas from Brisbane to the tip of Cape York Peninsula and the Torres Strait Islands, and in the Northern Territory around Katherine and Darwin (DONALDSON, 1983). The banana-spotting bug has also been found in several localities in northern Western Australia, including Kununurra and the Ord River area (SMITH, 1985).

A.l. papuensis has been described by SZENT-IVANY & CATLEY (1960) as an exclusively Papua New Guinean subspecies. There is one record from Murray Island in Torres Strait about 120 kilometres south of the PNG mainland, but this needs confirmation (FAY, 1993). So far it has not been recorded in the surveys of the North Australian Quarantine Strategy (NAQS), either in Torres Strait or on Cape York (GRIMSHAW, 1993). Because of the relatively small distances between Papua New Guinea (PNG) and the Torres Strait Islands, frequent travel and trade between Papua New Guinea, the Torres Strait Islands and the mainland of Australia, a southward movement of *A.l. papuensis* cannot be completely excluded.

A. nitida mainly occurs along subtropical east coast, from Wollongong (NSW) in the south to as far north as Iron Range. In southern Queensland it occurs as far west as the Carnarvon Range (DONALDSON, 1983).

A. brevicornis seems to have very limited but disjunct distribution. Records have been taken in the southern half of Queensland and northern New South Wales as far west as the Great Dividing Range. It has also been recorded from Katherine in the Northern Territory (DONALDSON, 1983).

The distribution areas for *A.l. lutescens*, *A. nitida* and *A. brevicornis* are shown in Figure 4.

2.4 Host range of some *Amblypelta* spp.

The host range of *Amblypelta* spp. is large and their polyphagy is a factor in their significant pest status. The natural hosts of *A.l. lutescens* and *A. nitida* in Australia are considered mainly to be fruits of rainforest and young growth of open forest trees

(PINESE & PIPER, 1994), but they have adapted to utilise numerous commercial crops as host plants. The number of recorded host species varies between bug species and even with subspecies, as indicated in Table 1 for a range of the *Amblypelta* spp. Host record deficiencies can be attributed to bugs being difficult to find as they are cryptic and always in low numbers. Many fruit growers have never actually seen the insect and their awareness depends upon recognising the characteristic damage. The individual host plant records of *A.l. lutescens*, *A.l. papuensis*, *A. nitida*, *A. brevicornis*, *A. cocophaga* and *A. theobromae* are listed in Appendix I. These *Amblypelta* species were chosen because they are present in Australia or its neighbours, Papua New Guinea and Irian Jaya (West New Guinea), and are the most studied species with the most comprehensive host records. The individual host plant species are arranged into families in alphabetical order. The plant list provides scientific names as well as common names, where possible. The host list includes 33 breeding and 41 feeding records for *A. nitida* as well as 83 feeding and 46 breeding records for *A.l. lutescens*. The extent of damage caused by the insect is mentioned, if known. Table 1 also summarises the plant families containing the most records for an individual *Amblypelta* species. SCHAEFFER & MITCHELL (1983) remarked that members of the subfamily Coreinae generally have a wide host range, even though some tribes and genera have a distinct host preference.

This subfamily of bugs also seems to show a preference for dicots, rather than monocots. In the Coreinae, 219 species are recorded to have hosts in 26 orders of dicots (in all subclasses) and on two of the four monocot subclasses. Coreid bugs seem to have a preference for the subclasses Rosidae or Asteridae. According to the study by SCHAEFFER & MITCHELL (1983), most host plants for *Amblypelta lutescens* are in the plant subclass Rosidae, which is supported by the records of *Amblypelta* spp. in Table 1 and the host record list in Appendix I. Coreidae and members of other families of Heteroptera preferably feed on buds, fruits, shoot-tips and immature seeds, where nutrients are concentrated (DOLLING, 1991). The tribe Gnocerini, in which the authors include *Amblypelta*, shows a preference for developing fruit (SCHAEFFER & MITCHELL, 1983).

Table 1: Records of host species and host families for six *Amblypelta* spp. and subspecies (for more details see Appendix I)

Amblypelta sp.	Total number of host plant species	Total number of host plant families	Most important hosts		
			Host plant family (*)	**No of host species**	**No and % of records of host families with most records (Total No of host records)**
Amblypelta l. lutescens	104	47	Caesalpiniaceae (I) Rutaceae (I) Rosaceae (I)	7 7 6	(20) 19.2 %
Amblypelta nitida	51	27	Rosaceae (I) Rutaceae (I) Myrtaceae (I)	6 6 5	(17) 33.3 %
Amblypelta cocophaga	41	28	Euphorbiaceae (I) Moraceae (II) Convolvulaceae (IV) Curcubitaceae (III) Fabaceae (I) Meliaceae (I)	8 3 2 2 2 2	(19) 46.3 %
Amblypelta l. papuensis	18	13	Fabaceae (I) Euphorbiaceae (I) Malvaceae (III) Sterculiaceae (III)	3 2 2 2	(9) 50 %
Amblypelta brevicornis	4	4	Musaceae (VI) Myrtaceae (I) Oleaceae (IV) Rutaceae (I)	1 1 1 1	
Amblypelta theobromae	6	5	Euphorbiaceae (I) Arecaceae (V) Fabaceae (I) Myrtaceae (I) Sterculiaceae (III)	2 1 1 1 1	

(*) = (*) = (plant) subclass: (I) = Rosidae; (II) = Hammamelidae; (III) = Dilleniidae; (IV) = Asteridae; (V) = Areiadae; (VI) = Zingiberidae

2.4.1 Feeding mechanism of *Amblypelta*

MILES (1986) undertook a detailed study on the feeding mechanism of an *Amblypelta* sp. and *Helopeltis clavifer* (Walker) (Heteroptera: Miridae). While feeding, a number of parenchymal cells can be drained despite physical penetration of a single cell only. Feeding marks caused by *Amblypelta* spp. in sweet potato stems [*Ipomoea batatas* (L.) Lam.] and cassava (*Manihot esculenta* Crantz) resulted in the lesion extending by up to 3.5 mm from the actual puncture (MILES, 1987). At the beginning of the feeding process, the bug 'saws' into the plant tissue with a stylet bundle containing four stylets. A stylet sheath is formed by solidified saliva. One constituent of the salivary glands of *Amblypelta* spp. is invertase, the feeding enzyme component. MILES (1987) suggested that a hydrolytic enzyme is contained in bug saliva, which releases an osmotically active substance into the intercellular space. Consequently, liquid containing nutrients flows out of the nearby cells and is sucked up by the insect. Therefore they have access to the cell contents more than 3 mm away from stylet bundle opening, without actual penetration (MILES, 1987).

In further studies, MILES & TAYLOR (1994) describe the feeding mechanism of coreids as an osmotic pump. They discovered that the sucrose-hydrolysing enzyme of coreids is a sucrose α-D-glucohydrolase, which operates similar to invertase. The authors noted that the osmotic pressure of intra- and extracellular contents are very much alike. They suggest that with the injection of an enzyme by insects into extracellular space, which changes sucrose into glucose and fructose, the extracellular osmotic pressure increases causing an osmotically forced outflow of water including molecules like amino acids, which would confirm the theory of phloem unloading (MILES & TAYLOR, 1994).

2.4.2 Symptoms of damage on fruit and young growth terminals

Fruit:

In fruit, very distinct circular black spots develop, often with a depression in the centre and with the piercing mark frequently noticeable (VEITCH, 1938; BROWN, 1958a; GEORGE & NISSEN, 1985; FAY, 1991) (Fig. 5). Fruitspotting bug damage often causes some premature drop of the immature crop in various hosts, such as macadamia nut (BRIMBLECOMBE, 1948; BROWN, 1958a; IRONSIDE, 1981), custard apples (VEITCH et al., 1951; BROWN, 1958a) and lychees (WAITE, 1990). Fruit which has been attacked at an early stage, but continues to develop shows irregular growth later, causing for example distorted fruit in cocoa (BROWN, 1958a; WAITE & PINESE, 1991) and avocados or splits and cracks in bananas (*Musa paradisiaca* L.) (VEITCH & SIMMONDS, 1929; BROWN, 1958a; PINESE & PIPER, 1994).

A latexy exudate is produced by papayas and in fruit such as peaches [*Prunus persica vulgaris* (L.) Batsch] or in cocoa, a gummy exudate is released at the feeding site (BROWN, 1958a). In avocados, the feeding sites develop into deep star-shaped scars as the fruit matures, which can be 5 mm across and 3 mm deep. A white powdery exudate is released from the injured tissue and can be seen around the feeding site (Fig. 6) (SAROOSHI et al., 1979). Beneath the feeding site the plant tissue hardens and forms a callus. In avocados, bug damage can look superficially similar to fruit fly damage. However the scars fruit flies cause are not as deep and usually their eggs can be found (SAROOSHI et al., 1979). In bananas, the symptom of fruitspotting bug damage are the typical black spots of up to 5 mm diameter on the outward curve of the fruit (PINESE & PIPER, 1994). In macadamia nuts, apart from the externally visible feeding marks, cells of the inner husk and soft shell break down and change colour around the feeding punctures. The kernels become distorted and opaque coloured, not the typical white. Sometimes the kernel can be affected by the injury, but not the shell (IRONSIDE, 1981; BRIMBLECOMBE, 1948).

Growth terminals and stems:

When minor damage on vegetative parts of the host occurs, such as the young shoots of papaya, cashew, mango, cassava, *Eucalyptus* spp., longitudinal grooves appear

Figure 5: Damage on carambola (dark spots)

Figure 6: Damage on avocado (white spots)

Figure 7: Damage on mango

Figure 8: Damage on papaya stem (growth)

Figure 9: 'Bunchy top' in young papaya plant

near the feeding puncture. When major damage on growth terminals of host plants occurs, like papaya, beans or macadamia, the growth tip above the feeding site wilts rapidly (BROWN, 1958a) (Fig. 7).

If the damaged part survives the tissue develops into cankerous swellings and cracks (BROWN, 1958a). In papaya, white latex is released where the plant is injured. This often becomes covered with sooty mould fungus. The cracks can be up to 10 cm long in leaf stalks and they can be up to 6.4 mm deep in the main stem.

If the terminal growth tip is heavily attacked, it results in stunted or distorted growth and short stalked leaves. New side shoots are induced to replace the growth tip, causing a 'bunchy top' or dichotomy (SLOAN, 1946; BROWN, 1958a) (Figs. 8 and 9).

Flowers/flower petioles:

Flowers and petioles of flowers can also be attacked by fruitspotting bugs. The petioles are drained like the growth terminals and flower buds wilt before they are fully developed and fall off. Crops were *Amblypelta* damage on petioles has been recorded are

custard apples and relatives such as *Rollinia* sp. (WAITE et al., 1994), mangosteen (*Garcinia mangostana* L.) (ZAPPALA, 1994) and cashew (own observation).

2.4.3 Feeding habits

WAITE (1986) observed in his study on avocados that third instar nymphs of *A. nitida* fed less frequently than adults and late instar nymphs and caused less damage.

LEACH (1948) studied the feeding behaviour of *A. cocophaga* in the Solomon Islands. He remarked, that the bugs are capable of utilising coconuts (*Cocos nucifera* L.) of all sizes. He recorded that one adult in captivity fed on a nut for 40 minutes, without removing its proboscis. The extent of the feeding mark is dependent on the feeding time as well as the maturity level of the attacked plant tissue. One single puncture can kill the ovary of an unopened female flower, and the damage to nuts at 8 to 12 weeks of age can cause their fall.

FENEMORE (1958) in the Solomon Islands investigated the frequency of scar production by *A. cocophaga*. Fourth and fifth instar nymphs and adults were caged with young inflorescences (2 nymphs or adults with 5 inflorescences) for eight to ten days. Nymphs produced 1.7 scars per individual per day and adults produced 3.9 scars per individual per day. Fenemore used the average of these numbers to calculate the size of a mixed population which was estimated to produce the number of scars recorded in the field.

2.5 Seasonal relationships between *Amblypelta l. lutescens* and its crop host plants

There appears to be a strong seasonal relationship between *A.l. lutescens* and its hosts which is relevant to the timing and extent of control measures.

Two periods of major damage in cashews seem to occur in north Queensland, between mid November and mid December when the nuts mature and a new flush of foliage is developing, and between mid March and mid April during the time of the second growth flush (WAITE et al., 1993). STRICKLAND & WILLIAMS (unpublished) studied the

effect of feeding by *A.l. lutescens* on the cashew yield. Fruitspotting bug damage starts to occur in cashews when flower panicles start to emerge. The damage increased greatly until the nuts reached ten days development and then decreased. The population dynamics of the bugs in cashews needs to be studied in more detail to confirm these observations.

Lychees in south Queensland are most susceptible to fruitspotting bugs, mainly *A. nitida*, during fruit development (between October and November) (WAITE et al., 1993).

In macadamia nuts there are two peaks in damage during the year. The first peak occurs between late September and early January in north Queensland (between flowering and maturity of the nuts), the second peak appears between April and May, during the autumn growth flush (WAITE et al., 1993).

Peak damage in avocados occurs in north Queensland between late September and March, again from flowering until fruit maturity (WAITE et al., 1993). The main attack on young papayas in north Queensland happens between February and mid May (WAITE et al., 1993). Carambolas are mostly attacked between mid December and mid March, when the majority of fruit mature (WAITE et al., 1993).

In general, in north Queensland *Amblypelta* causes most damage between December and March (WAITE et al., 1993).

2.6 Approaches to alternative control

2.6.1 Varietal resistance in different host plants

WAITE (1990) suggested that in lychees late maturity would be an advantage to reducing fruitspotting bug damage, since in southern Queensland the early cultivar Tai So was more affected by fruitspotting bugs than later varieties. Late maturity in this case is obviously a potential avoidance factor which should be considered in plant selection. The most common, thick skinned avocado variety Hass suffers less from *Amblypelta* attack than the thin skinned varieties Fuerte and Wurtz (WAITE et al., 1993). This is evidence of physical resistance in a fruit.

LEACH (1948) investigated the potential resistance suspected in some coconut varieties to *A. cocophaga* used in plantations, but he could not confirm this in his experiments.

OSWALD (1989) studied the related coreid bug *Pseudotheraptus wayi* in Zanzibar. *P. wayi* did not show preference for any particular coconut variety tested (East African Tall, Malayan Yellow Dwarf, Malayan Green Dwarf, Cameroon Red Dwarf, Port Bouet Hybrid 121) and there was no significant difference in the damage level (OSWALD, 1989).

2.6.2 Natural enemies

Predators

Solomon Islands:

PHILLIPS (1940) reported a reduviid bug *Euagora dorycus* Boisduval (Heteroptera: Reduviidae) as an occasional predator of nymphs and adults of *Amblypelta cocophaga*. Unfortunately, their life-cycle is twice as long as that of *A. cocophaga*, and the predator had little long term impact on the pest population (COTTRELL-DORMER & PHILLIPS, 1938; PHILLIPS, 1940).

Ants appear to be the most effective predators of *A. cocophaga*. *Oecophylla smaragdina* (F.) asserted the best control over *A. cocophaga* of a number of ant species investigated (PHILLIPS, 1940; MacFARLANE et al., 1976; LÖHR & OSWALD, 1989).

BROWN (1959-1960a+b) and PHILLIPS (1940) did extensive studies in the Solomon Islands on populations of the four ant species *Oecophylla smaragdina*, *Pheidole megacephala* (Fabricius), *Iridomyrmex myrmecodiae* Emery and *Anoplolepis longipes* (Jerd.). These studies included the possible association of the ant species with certain vegetation types, and their impact on the *Amblypelta* population and damage (BROWN, 1959-1960a+b). *O. smaragdina* actively destroys *Amblypelta* (PHILLIPS, 1940; 1956; BROWN, 1959-1960a). In the areas where *O. smaragdina* and *A. longipes* are present, nutfall, and therefore *Amblypelta* damage is not important (PHILLIPS, 1940). *A. longipes* decimates the *Amblypelta* population at a similar rate to *O. smaragdina*, but they only offer such protection if they are well established in almost all palms (BROWN, 1959-1960a).

The author also undertook an experiment to determine the effectiveness of the ant *A. longipes* against *A. cocophaga*, by keeping adult bugs and nymphs in a cage which could be entered by the ants. During five days, 26 out of 28 adults and 18 out of 24

nymphs were killed by the ants (BROWN, 1956). The ants were observed to disturb *A. cocophaga* continuously and therefore stop the bugs from feeding. High numbers of *A. longipes* were needed to be effective (BROWN, 1956). This author did not regard *Anoplolepsis* as efficient against *A. cocophaga* as *Oecophylla* (BROWN, 1956). The two smaller ants, *P. megacephala* and *I. myrmecodiae*, appear to attack *O. smaragdina* (STAPELY, 1973), but PHILLIPS (1940) suggested these two species are also predators of *Amblypelta* if they get a chance to catch them.

Studies on the effect of the vegetation reached the conclusion that the distribution of ant species cannot be controlled by certain vegetation types (BROWN, 1959-1960b).

Papuan New Guinea:

In Papua New Guinea a spider of the genus *Oxiopus* was recorded as a predator of *A.l. papuensis* and again the ant *O. smaragdina* as a predator of *A. theobromae* (WAITE et al., 1993).

Australia:

IRONSIDE (1981) has listed the assassin bug *Pristhesancus papuensis* Stål, a spider of the genus *Ocrisiona* and the ant *Pheidole megacephala*, as local predators of *A. nitida* and *A.l. lutescens* in Australia.

The relationship between the green tree ant *Oecophylla smaragdina* and major pests in cashews have been observed during a six month survey (PENG et al., 1994). The cashew farms chosen were surrounded by native bush. The presence of *O. smaragdina* commonly reduced the damage of fruitspotting bugs and the other major pests studied. The study showed that the brown ant *Pheidole megacephala* and the meat ant *Iridomyrmex* sp. also have a small impact on fruitspotting bug and the tea mosquito bug *Helopeltis* sp. (PENG, 1994).

Parasitoids

Solomon Islands:

Three species of endemic egg parasitoids of *Amblypelta cocophaga* were found in the Solomon Islands, one thought to be *Anastatus axiagasti* Ferr. (PHILLIPS, 1940; 1956;

BROWN, 1959-1960c). The average rate of parasitism of *A. cocophaga* eggs in the Solomon Islands by parasitoids was 33.3 % and 31.3 % successful hatching of eggs (BROWN, 1959-1960c). *Anastatus axiagasti* was therefore considered not to be very effective (PHILLIPS, 1936).

Ooencyrtus sp. n. (Hymenoptera: Encyrtidae), *Ooencyrtus malayensis* Ferrière, *Hadronotus homoeoceri* Nixon (Hymenoptera: Scelionidae) and *Anastatus ?dasyni*, which are egg parasitoids of dasinine bugs in Indonesia, have been reared on eggs of *Amblypelta cocophaga* (PHILLIPS, 1941). They were introduced to the Solomon Islands for the controls of the bugs (PHILLIPS, 1941; BROWN, 1959-1960c). Although some of these parasitoids became established their control of *A. cocophaga* was without much success (PHILLIPS, 1956).

Papua New Guinea:

SZENT-IVANY & CATLEY (1960) reported that eggs of *Amblypelta lutescens papuensis* were parasitised by a *Hadronotus* sp., an *Anastatus* sp. and an *Ooencyrtus* sp. (Hymenoptera: Encyrtidae). However, none of these egg parasitoids were thought to have any impact in controlling the Papuan tip-wilt bug (SZENT-IVANY & CATLEY, 1960). DORI later reported on proportional parasitism of fruitspotting bug eggs (*A.l. papuensis*) by *Anastatus* sp. (60 %), *Gryon* sp. (Hymenoptera: Scelionidae) (14 %), *Ooencyrtus malayensis* (8 - 25%) and a further *Ooencyrtus* sp. (WAITE et al., 1993).

Australia:

COTTRELL-DORMER (1938) studied two tachinid flies, one identified as *Pentatomophaga bicincta* de Meijere. They parasitised the fourth and fifth instar nymphs and adults of *A. lutescens*. Their potential as biological control agents against *A. cocophaga* was also investigated in the Solomon islands (COTTRELL-DORMER, 1938; 1939; IRONSIDE, 1981).

IRONSIDE (1981) mentioned an unidentified wasp parasitising *Amblypelta* eggs in north Queensland. In October and November 1992 in north Queensland three egg parasitoids, *Anastatus* sp., *Ooencyrtus caurus* Huang & Noyes (HUANG & NOYES, 1994) and *Gryon* sp., were first recorded for *A.l. lutescens* in Australia (FAY & HUWER, 1993). This group of parasitoids is analogous to the ones found on the related coreids, (*Amblypelta* spp. and *Dasynus* spp.) in Indonesia and Papua New Guinea as well as *Pseudotheraptus wayi* in Africa (FAY & HUWER, 1993). WAITE (1995) later found

two parasitoids on *Amblypelta* in south-east Queensland (*Gryon meridionis* ;authority unknown and an Eulophid).

The three north Queensland parasitoids will be discussed in detail in a further chapter.

Pathogens

An unidentified entomophagous fungus caused problems in laboratory cultures of *A. cocophaga* (PHILLIPS, 1940).

2.7 Neem as a potential alternative to endosulfan

The neem tree, *Azadirachta indica* A. Juss originated in India (Burma) and the insecticidal effect of its seeds have been researched for more than 30 years [MORDUE (LUNTZ) & BLACKWELL 1993]. The most effective component of the seed is azadirachtin, which is a tetranortripenoid plant limonoid [DORN et al, 1986; MORDUE (LUNTZ) & BLACKWELL, 1993; SCHMUTTERER, 1995].

The three different main effects of azadirachtin are following:

1. Antifeedant: Impact on chemoreceptors to obtain a deterrent effect for example, and stop insects from feeding.
2. Growth regulator: Impact on ecdysteroid and juvenile hormone titres in the haemolymph.
3. Fitness suppressor: Impact on the insects ability to move and fly.

[MORDUE (LUNTZ) & BLACKWELL 1993].

The degradation of azadirachtin is rapid. Therefore its suitability is questionable in crops where no damage is tolerable, such as fruit and vegetables [MORDUE (LUNTZ) & BLACKWELL 1993]. The authors point out that the antifeedant potency of azadirachtin decreases by 50 % under exposure to sunlight for seven days, but the metabolites of azadirachtin can still be biologically active. In some cases, azadirachtin and neem extracts have given better control against certain insect pests than conventional pesticides and

positive results have been achieved with some pest species which are resistant to particular insecticides. The authors reported that neem had no harmful effect on different beneficials tested, but a negative effect cannot be discounted and neem-seed extract proved not entirely harmless to bees for example [MORDUE (LUNTZ) & BLACKWELL 1993].

The impact of neem has been studied on numerous insects, including several bugs, for example the red cotton bug *Dysdercus koenigii* F. (Heteroptera: Pyrrhocoridae) (KOUL, 1984; 1985), the large milkweed bug *Oncopeltus fasciatus* (Heteroptera: Lygaeidae) (DORN et al., 1986; 1987) and *Pseudotheraptus wayi*. In *O. fasciatus*, neem treatment resulted in suppression of adult ecdysis when injected into fifth instar larvae. Newly hatched adults, when injected with neem responded with a decrease in fecundity and longevity, as well as viability of their eggs (DORN, 1986; DORN, 1986a; DORN et al., 1986; 1987). In *D. koenigii* neem treatment resulted in unplasticisation of wing lobes in larvae, which cause wingless adults (KOUL, 1984). In adults, neem treatment again caused a higher mortality and decreased fecundity (KOUL, 1984a).

3 FIELD SITES, METHODS & MATERIALS

The research undertaken by the author can be divided into three main parts.

I. Laboratory rearing methods

II. Relationship between *A.l. lutescens* and host plants

III. Alternative control methods

3.1 General methods and materials

The following sites were utilised during the study:

1.- the facilities of the Entomology Branch of the Queensland Department of Primary Industries (QDPI) at the Agricultural Production Unit in Mareeba (APU);

2.- the 'Bicentennial Park', a council environmental park in Mareeba covering an area of approximately 8.4 ha;

3.- field sites at the QDPI research stations at Walkamin and Kairi on the Atherton Tableland.

3.1.1 Description of the laboratory facilities in Mareeba

All laboratory work was conducted at the APU Mareeba. The experiments were undertaken partly in the main laboratory of the Entomology Branch and mainly in the laboratory in the Entomology part in one of the side buildings (Head House), as well as in the insectary.
The first rearing experiments with *A.l. lutescens* were undertaken in the main laboratory. This facility is fully air-conditioned and the temperature is kept at 22°C. Initially, the eggs and nymphs were kept in a constant temperature room at about 27.5°C to hasten the development of the insect. Some eggs kept in a multi-range incubator with ten separate compartments (Lindner & May PTY. LTD) at 17°C had time till hatching of the nymphs lengthened by 10 to 14 days.
Most of the laboratory experiments were done in the Head House laboratory. This room was also air-conditioned and the temperature was kept between 23 and 28°C ± 5°C.

The insectary consists of two rooms in a side building, and a small laboratory in conjunction with them. The insectary and its laboratory were at ambient temperature. Both rooms of the insectary were 2.9 m long, 2.2 m wide and 2.2 m high. The ceiling and outside walls of the were fully screened with metal fly screen.

The plants which were used for the laboratory trials were grown in the glasshouse of the Entomology Branch.

Equipment used in the laboratory experiments:

1. Rearing/ experimental containers:

Figure 10: From left to right : 1. parasitoid container; 2. small rearing container; 3. large rearing container

Figure 11: From left to right: 1. dish with moist cotton wool; 2. souffle

Figure 12: Glass jar

Figure 13: Large rearing cage

a) *A.l. lutescens* was mainly reared in clear plastic screw top containers (ca. 250 ml), which will be referred to as large rearing containers (Fig. 10). The lid was removed and the container covered with fine gauze material (white 'Nylex' lining), which was held in place by a rubber band. A small plastic portion control cup or souffle (1 oz or 35 ml) with a 3 cm cotton dental roll through a hole in the lid served as a water source (Fig. 11).

b) The small rearing containers were clear screw top plastic containers (100 ml) (Fig. 10), which were again covered with fine gauze; a moist dental wick was used as a water source.

c) Clear plastic screw top containers (25 ml) were mainly used to keep eggs which were treated with neem or eggs which were parasitised. They will be subsequently referred to as parasitoid containers (Fig. 10).

d) The glass jars used were 2.2 l jars (Fig. 12), with the souffle (Fig. 11) as described above, to supply water. The top of the jar was covered with gauze.

e) The large rearing cage (Fig. 13) consisted of an aluminium frame (30 x 30 x 60 cm) with an aluminium bottom, three side walls and top made of metal screen and the fourth side made up with gauze (including a sleeve for adding and removing *A.l. lutescens* and food items). A small plastic dish (lid of 250 ml container) with moist cotton wool (Fig. 11) served as water supply.

f) The small rearing cage (Fig. 14) was also an aluminium frame cage (30 x 30 x 30 cm), with a cloth sleeve on one side. A souffle or plastic dish with cotton wool (Fig. 11) was used as a water source.

g) The collapsible field cages (30 x 30 x 30 cm) (Fig. 15) used for experiments were made with aluminium rod (diameter = 6 mm). The frame was covered in a loose fitting sleeve made of cloth gauze, tied with string on top and bottom. The cages sat on a metal stand which was about 50 cm high. A plastic dish with moist cotton wool supplied water. Host plants placed under the metal stand reaching into the cage, with the bottom end of the sleeve tied around the stem of the plant.

Figure 14: Small rearing cage

Figure 15: Collapsible field cage

3.1.2 Description of the field sites

The QDPI research stations at Walkamin and Kairi on the Atherton Tablelands were used as the main field sites. Geological, geographical and climatic details of the study sites are shown in Table 2. Fruit orchards on both research stations were employed for the field work. Population studies of *A.l. lutescens* parasitoids were also conducted on the grounds of the APU as well as in the 'Bicentennial Park' in Mareeba.

Description of the Atherton Tableland (location, geology, climate)

The Atherton Tableland is part of the Great Dividing Range in the north-eastern region of Queensland, about 60 km west of Cairns (ANONYMOUS, 1973-1974; ANONYMOUS, 1988) (Fig. 16). This plateau covers an area of 31,000 km^2 with an average elevation of 600-900 m (ANONYMOUS, 1973-1974). The geology of the Atherton Tableland is based on Tertiary basalt, which formed three distinct plateau levels of characteristic nature. The resulting soils are of volcanic origin and very fertile. The weather pattern has a distinct 'wet' and 'dry' season. The annual rainfall ranges from about 900 mm to 2500 mm (ANONYMOUS, 1988), with three-quarters of the rainfall occurring between November and March. The main agricultural products of this area are peanuts, maize, beef, dairy products and tobacco (ANONYMOUS, 1988). More recent is the production of avocado, mango, lychee, macadamia and other tropical and subtropical tree fruits and nuts.

Mareeba field sites

For population studies of *A.l. lutescens* and its parasitoids two different locations in the grounds of the APU and three different locations in the 'Bicentennial Park' were utilised. In the park, a wide range of exotic and native bushes and trees are planted along the banks of Granite Creek.

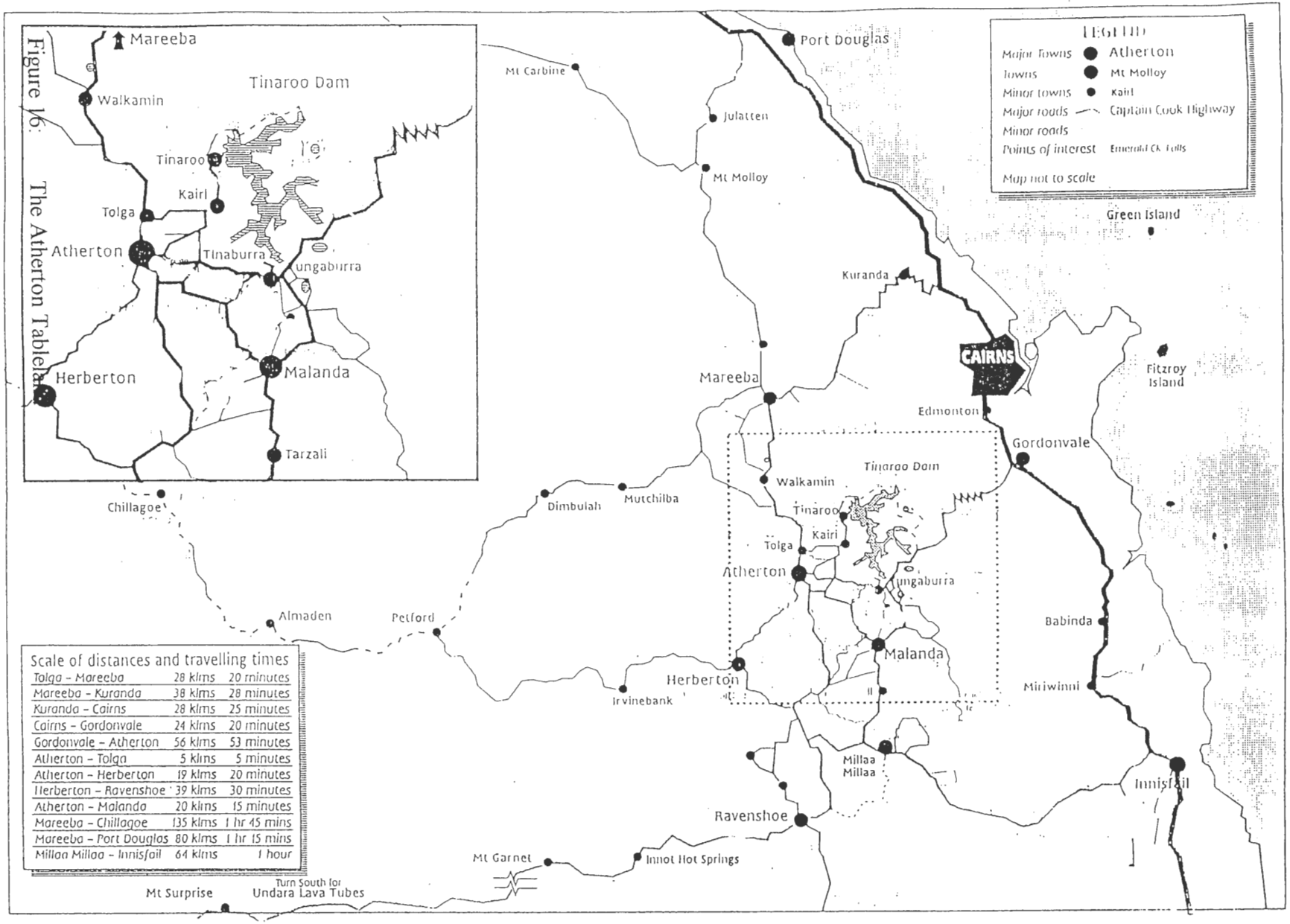


Figure 16:
The Atherton Tableland
Mareeba
Tinaroo Dam
Walkamin
Tinaroo
Kairi
Tolga
Atherton
Tinaburra
Yungaburra
Herberton
Malanda
Tarzali
Legend
Major Towns
Towns
Minor towns
Major roads
Minor roads
Points of interest
Map not to scale
Atherton
Mt Molloy
Kairi
Captain Cook Highway
Emerald Ck Falls
Port Douglas
Mt Carbine
Julatten
Mt Molloy
Green Island
Kuranda
CAIRNS
Fitzroy Island
Mareeba
Edmonton
Gordonvale
Tinaroo Dam
Walkamin
Tinaroo
Kairi
Tolga
Atherton
Yungaburra
Malanda
Herberton
Irvinebank
Dimbulah
Mutchilba
Chillagoe
Almaden
Petford
Babinda
Miriwinni
Millaa Millaa
Innisfail
Ravenshoe
Mt Garnet
Innot Hot Springs
Mt Surprise
Turn South for
Undara Lava Tubes
Scale of distances and travelling times
Tolga – Mareeba 28 kms 20 minutes
Mareeba – Kuranda 38 kms 28 minutes
Kuranda – Cairns 28 kms 25 minutes
Cairns – Gordonvale 24 kms 20 minutes
Gordonvale – Atherton 56 kms 53 minutes
Atherton – Tolga 5 kms 5 minutes
Atherton – Herberton 19 kms 20 minutes
Herberton – Ravenshoe 39 kms 30 minutes
Atherton – Malanda 20 kms 15 minutes
Mareeba – Chillagoe 135 kms 1 hr 45 mins
Mareeba – Port Douglas 80 kms 1 hr 15 mins
Millaa Millaa – Innisfail 64 kms 1 hour

Table 2: Geological, geographical and climatic details of the study sites

Details	Mareeba	Walkamin Research Station	Kairi Research Station
Latitude	[1] 17.00 S	[1] 17.08 S	[1] 17.12 S
Longitude	[1] 145.25 E	[1] 145.26 E	[1] 145.34 E
Elevation	[1] 335 m	[1] 591 m	[1] 715 m
Average annual rainfall	[2] 914 mm	[3] 1039 mm	[4] 1382 mm
Average temperature (°C)			
December: max.	[2] 32.1	[3] 30.5	[5] 28.8
December: min.	19.8	19.5	18.5
July: max.	25.3	23.3	20.9
July: min.	11.7	12.8	10.9
Mean hourly relative humidity			
December	N/A	[3] 71.91%	[4] 75%
July		73.6%	79%
Average evaporation (mm/day)			
December	N/A	[3] 6.22	[4] 5.64
July		3.63	2.89
Soil	N/A	[5] Euchrozem neutral pH	[5] Krasnozem acid pH
		[2] "Dark brown clay loam grading to reddish brown to red structured light clay" (ANONYMOUS, 1978, p. 40). These soils are formed on basalt. They can be very deep and have a good internal drainage (ANONYMOUS, 1978).	

1. [ANONYMOUS (B)], Meteorological Database, DPI Toowoomba
2. (ANONYMOUS, 1978), D.P.I. Mareeba Shire Handbook
3. [ANONYMOUS (C)], Meteorological Data, DPI Research Station Walkamin
4. [ANONYMOUS (D)], Meteorological Data, DPI Research Station Kairi
5. (ANONYMOUS, 1987), Kairi Research Station Information Handbook, DPI Queensland Government

Walkamin Research Station

Most of the field work for this study was done at the Walkamin Research Station, 15.5 km south-east of Mareeba. The research station covers an area of 259 ha.. A small orchard with various tropical fruits is maintained by Entomology Branch of the Queensland Department of Primary Industries [ANONYMOUS, (A)]. Information on climate and soil is presented in Table 2. The entomology orchard is approximately 1 ha in size and includes 80 carambola trees of five varieties, 60 avocado, 10 lychee and 80 mango, five cashew, 20 trees of various stone fruit, about 10 bananas, half a row of sugarcane and 80 papaya trees of eight different varieties. The only orchard management during the project were applications of herbicides, slashing of grass in the whole orchard and pruning of carambola and mango trees. Most of the field trials were carried out in the carambola and papaya sections of the orchard.

Layout of the carambola section:

The carambola orchard includes the varieties 'Arkin',' B2', 'B10', 'Fwang Tung' and 'Thai Knight'. The carambola orchard is divided into four blocks. Each block has four rows with five trees. Each row includes one tree each of the five different varieties, randomly distributed. The four blocks are replicas of each other. Mainly one block was employed in the field trials.

Carambola block:

5	1	3	5	1 = Arkin
3	4	2	1	2 = B2
1	2	5	4	3 = B10
4	3	1	2	4 = Fwang Tung
2	5	4	3	5 = Thai Knight

Table 3: Papaya varieties

PAPAYA VARIETIES IN WALKAMIN
1 = SL 91 - 3 C 2 = SL 91 - 4 B 3 = CB 87 - 1 - 1 4 = GD 3 - 1 - 19 - 2 Parent (Y 2)/ PRD 2/1/92 5 = GD 3 - 1 - 19 - 2 oval true line 6 = Thai Red 7 = B 1 (local male parent 2nd year/PRD 31/12/91) 8 = PZ 90 - 1 X PZ 90 - 1 The seeds for the different papaya varieties were provided by Mr. Bob Williams, D.P.I. Innisfail

Table 4: Layout of papaya trial in Walkamin

Block 1		Block 2		Block 3		Block 4		Block 5	
Row		Row		Row		Row		Row	
I	II	I	II	I	II	I	II	I	II
	4		3		2		1		5
8		6		8		3		4	
	3		4		3		4		6
7		7		4		8		7	
	2		5		5		5		2
6		8		6		6		3	
	1		2		8		7		1
5		3		7		2		5	
	8		1		1		8		4
3		4		2		1		8	
	7		6		6		3		3
4		5		3		5		6	
	6		8		7		2		7
1		2		1		4		1	
	5		7		4		6		8
2		1		5		7		2	

Layout of papaya trial:

Eight different papaya varieties were employed in this study (Table 3). A total of 80 papaya plants were planted staggered in two rows within one strip, divided into five blocks. Block 1 was the top end and Block 5 was the bottom end of the line. Two plants of each variety were planted in each block (Table 4). The different varieties were randomly allocated in each block.

Kairi Research Station

Kairi Research Station is located about 25 km south-east of Mareeba and covers an area of 250 ha [ANONYMOUS (E)]. Climatic, geographic and geological details are shown in Table 2. The main research undertaken on this station is on animal breeding and pasture development. Situated behind the main research station buildings is a small orchard with a variety of tropical fruit (macadamia nut, carambola, avocado, lychee, *Citrus* spp. for example). An avocado and lychee in the orchard as well as two old macadamia nut trees in the yard of the research station, were employed in the field experiments. No insecticides were used during the period of the studies.

Equipment used in field trials:

Bags made out of fine gauze ('Nylex lining') (27 cm X 40 cm) with a cord to close the bag, were used to 'bag' fruit or growth terminals on the branches (Fig. 18) .

Data analysis:

If not mentioned otherwise, data were analysed on a personal computer with the statistic program STATISTIX 4.0 (© Analytical Software). General Analyses of Variance (ANOVA) was used to analyse the data. Means were compared using the LSD-Test (rejection level was 5% if not mentioned otherwise).

To analyse experiments with different numbers of replicates for the different treatments, in-house DPI programs, RANB (randomised block designs & latin squares), as well as BALF (balanced factorial designs) were employed for the ANOVA.

Correlations were analysed using the method of Pearson (KÖHLER et al,1984).

Graphics in general were produced with the programs CoPlot 2.21 and CoDraw 2.21 (© CoHort Software)

3.1.3 Maintenance of adults and eggs of *Amblypelta l. lutescens*

Adult bugs were either kept as single pairs in large rearing containers, or up to ten adults in glass jars fed exclusively on french beans (*Phaseolus vulgaris* L.). Adults mated frequently and the females started laying eggs about ten days after moulting from final nymphal instar. Eggs were deposited anywhere in the jar or container, normally singly but sometimes in groups of about three. They have a translucent light green colour and they are on average (n=10) 1.94 mm long, 1.00 mm wide, 0.95 mm high and almost spindle shaped with a flat base (Fig. 17). The egg cross-section is virtually triangular. The eggs were collected into Petri dishes containing moist filter paper every second day, sometimes daily. During the development of the embryo the colour of the egg turns to a golden yellow and later to a reddish brown colour. It takes seven to ten days for the eggs to hatch at about 24°C. The percentage of nymphs hatching was 88 % of 377 eggs examined. The adults in the laboratory lived on average (n=19) for 5 months (maximum 328 days). The maximum number of eggs laid by an individual female was 434 over a period of 197 days (average of 2.2 eggs per day).

3.1.4 Establishing the laboratory colony

Rearing the bugs was difficult at first. In the beginning all stages of bugs were collected in the field. A low population of *A.l. lutescens* and their inconspicuous behaviour made it difficult to collect larger number of bugs at any one time. It took several months to establish a colony of adequate size. Bugs which were initially collected, as well as further field collected adults and nymphs, were added to the colony.

When the laboratory colony of the bugs produced sufficiently nymphs and eggs, experimental work on the relationship between the bugs and their host plants could be initiated.

The duration of the different nymphal stages largely corresponded to the data by SLOAN (1946), BRIMBLECOMBE (1948) and IRONSIDE (1981).

Hatching of nymphs:	after 6-7 days
L 1:	3 - 4 days
L 2:	4 - 6 days
L 3:	6 - 7 days
L 4:	5 - 7 days
L 5:	5 - 7 days
L 1 - adult	34 - 38 days

The development time to adults varied and took on average 34.8 days (n = 133). The whole life cycle from egg to egg took about 50 to 80 days.
BRIMBLECOMBE (1948) presumed that the bugs produce three generations a year (spring, summer and autumn generation) under the climatic conditions of south-east Queensland.
All different stages of the life cycle are shown in Figures 17 - 22.

At irregular intervals, mostly during the summer months, bugs were collected on different hosts (e.g. cashew, carambola, papaya) at different sites (e.g. 'Sunshine Orchard' at Davies Creek, cashew plantation near Dimbulah, Walkamin Research Station), but mostly in mock orange bushes at the APU. Any field collected *A.l. lutescens* nymphs and adults were added to the laboratory colony. After four months the number of individuals had increased to about 160 and the first experiments could be initiated. The colony from then on basically supported itself. A certain number of newly hatched nymphs and the field collected specimens were kept as breeding stock. During winter the bug population in the laboratory as well as the field, usually reached a low. The insects in the colony were reared on french beans (*Phaseolus vulgaris* L.) and sometimes on young papaya plants, except for experiments (which will be described later).

Establishing a colony of *A.l. lutescens* of suitable size in the laboratory was initially hindered by high nymphal mortality.

Figure 17: 1st instar nymph and egg

Figure 18: 2nd instar nymph

Figure 19: 3rd instar nymph

Figure 20: 4th instar nymph

Figure 21: 5th instar nymph

Figure 22: Adult

Therefore, a more successful method of rearing with lower nymphal mortality needed to be developed. Consequently, a better food source which was suitable for the bugs and readily available all year was required. A diet which would be easy to handle and would not have to be changed daily was desirable as well. The nature of the food too, was an important factor. Young plants have a relatively small surface area (stem and growth terminal) which is utilised by the bugs, whereas seedpods of legumes, such as beans, provide a much larger surface area. Different diets were assessed and their suitability for nymphs and adults evaluated.

Beans of various types are recorded as hosts of *A.l. lutescens* (BRIMBLECOMBE, 1948; BROWN, 1958). *A.l. lutescens* has also been found feeding on *Glycine max* (soybean) (L.) Merr. (SMITH, 1985). *A. nitida* had been reared successfully on french beans (WAITE et al., 1992) and snake beans *Vigna sinensis* subsp. *sesquipedalis* under laboratory conditions for up to six generations (BAKER et al., 1972).

French beans, young papaya plants, fresh bean seeds and different products of peas (*Pisum sativum* L.) were tested as different diets for the nymphs.

French beans were used at first to raise *A.l. lutescens* since they are commercially available all year. To remove potential residues of insecticides, beans were washed before use.

A.l. lutescens nymphs were either kept in large rearing containers, or on papaya plants in large rearing cages. Their development was checked and recorded regularly. To determine whether living plant material was a requirement for a low nymphal mortality under laboratory conditions, growing plants of french beans, which were grown in the glasshouse, were compared with commercial french beans. Beans picked from growing plants were also used to investigate if potential insecticide residues on commercial beans (even after washing) could be a cause of higher nymphal mortality.

As a third aspect an experiment was undertaken to investigate the effect of holding density on nymphal survival from first instar to adult.

Preliminary tests on fresh seeds of french beans and different products of peas

In preliminary tests fresh seeds of french beans, pea sprouts, dehydrated peas[1] and frozen peas were employed.

Nine nymphs were reared on pea sprouts and monitored over two weeks. The pea sprouts were cultivated by placing dried green peas into a large rearing container covered with fine gauze and set upside down on the lid with moist cotton wool.

Thirty nymphs were fed on dehydrated peas which were soaked in water and monitored over one month.

Eighteen nymphs were reared on frozen peas, which were thawed out, over a period of five weeks and 28 nymphs were kept on bean seeds over a period of six weeks.

Up to ten nymphs were kept in large rearing containers. The food items were changed every second day and mortality and metamorphosis (moulting) of the nymphs recorded.

Preliminary test on growth terminals of cashew

To establish whether nymphs could develop on growth terminals removed from a host plant, ten newly emerged nymphs were reared on terminals of cashew and six newly hatched nymphs were reared on french beans as a control. The nymphs on cashew growth terminals were confined in a small rearing cage. Two or three cashew growth terminals were placed in the cage in a small flask (100 ml) of water. The opening of the flask around the cashew growth terminals was sealed with cotton wool. The nymphs on beans were kept in large rearing containers. The nymphal development was monitored daily, cashew growth terminals were changed twice a week, beans were changed every day.

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[1] 'Farmland - Quick Dried Prepared Peas' (G.J. Coles & Coy Limited, Melbourne)

Rearing on french beans, young papaya plants or papaya plants followed by french beans

A) French beans:

Five nymphs, which had hatched over the previous 24 hours, were kept in a large rearing container. Two beans were presented to a group of five nymphs or about half a bean per individual nymph. The beans were changed every second day. Insect survival and their development was checked daily until all nymphs died or moulted to adults.

B) Papaya plants:

Ten newly emerged nymphs were kept in a large rearing cage, containing four to eight young papaya plants (about two months old). The food plants were changed every ten days. The nymphs were first checked after ten days, then every three days until the nymphs reached fifth instar, then daily until all nymphs were dead or developed to adults. Therefore, only approximate data mortality and moulting age are available. Only the total mortality and development time to adult will be compared with the other rearing methods.

C) Papaya plants followed by french beans:

In the third rearing method ten newly hatched nymphs were initially kept on papaya plants in large rearing cages. The second instar on all different diets tested seemed to be the most critical stage. After ten days most nymphs on papaya plants had reached the third instar. After this initial period they were transferred into large rearing containers, in groups up to five individuals per container, to be raised on french beans. As previously, the beans were changed every second day. The insects were first checked after ten days when the diet was changed. Therefore there is no detailed data on moulting and mortality of this first rearing stage. After the insects were transferred into the large rearing containers, records were taken daily.
The experiment was repeated five times for the different rearing methods.

Effect of holding density on nymphal development

Groups of five (20 replicates) and ten (10 replicates) first instar nymphs were kept in large rearing containers and raised on french beans. The insects were checked and food changed

every second day. Records were kept of when the last nymph in a container died or developed to an adult. The total number of nymphs which survived to adult was also noted.

3.2 Studies on nymphal development of *Amblypelta l. lutescens*

Bugs were reared on different plants to study their effect on nymphal development and then enable an assessment of their importance as a host plant. In several examples, also the varietal effects, as well as the importance of the fruit maturity were investigated to identify potential tolerance or resistance factors.

Preliminary tests:

Comparison of nymphal development on french beans, carambola fruit (cv. Thai Knight) and young papaya plants

French beans, carambolas and young papaya plants exemplify three different sources of food of *A.l. lutescens*: 1. growth terminals, 2. a juicy fruit and 3. a seedpod of a legume. This experiment assessed differences in nymphal development on these three types of hosts.

A) Ten second instar nymphs were individually confined in large rearing containers. In each case, five nymphs were reared on french beans or carambola fruits (cv. 'Thai Knight').

B) Five further second instar nymphs were individually enclosed on young papaya plants (ca. 65 cm high) within sleeves made of fine white gauze ('Nylex' lining) (ca. 70 cm long and 42 cm wide). These sleeves were secured by elastic band around the rim of the plant pot and tied with cotton cord on the top (Fig. 23). The food items within containers were changed every second day and the papaya plants were replaced as soon as the plants began to wilt. The development of each nymph was examined daily.

Figure 23: Gauze sleeves around papaya plants

Nymphal development on fruit on the tree and on picked fruit

Ten individuals of first or second instar nymphs which had not been exposed to food previously were each enclosed in gauze bags and reared on carambola (cv. 'Thai Knight'). Each gauze bag enclosed three to five fruit and was tied to a branch. Five further single nymphs were confined in a gauze bag with one picked fruit, which was then tied to the tree. The development of the nymphs was monitored and the picked fruit changed twice a week. This experiment was replicated once in the following year.

Nymphal development to third instar on mock orange fruit of three different maturity stages

Groups of two nymphs were kept in small rearing containers and were given either four mature red, four large green or eight small green mock orange fruit, without the stalk. The insects were monitored and food was changed every second day until all nymphs had reached the third instar or died. The experiment had four replicates.

Main experiments

Host testing I - Nymphal development on different hosts in the laboratory

Groups of five first instar nymphs were kept on one of the fruits or beans in large rearing containers, or on one of the host plants in large rearing cages. The nymphs reared on bananas were confined in a glass jar. The plants were changed twice a week and fruit items were changed every second day. The developing nymphs were examined daily and moults and mortality recorded. This experiment was repeated up to ten times for each individual host species.

Because of different numbers of replicates, results for all hosts together were analysed by employing the RANB-program.

Host testing II - Nymphal development on different hosts in the field

Groups of five newly hatched nymphs were enclosed in a gauze bag (Fig. 24) with unpicked immature fruit or growth tips of the host plant, and tied onto the branches of the trees. The development of nymphs was checked twice a week and moults and mortality recorded. Food was changed (bags changed onto another branch) when fruit showed numerous feeding marks or when growth terminals started to wilt. The experiment was repeated up to ten times on the individual hosts.

Because of different numbers of replicates, results for all hosts together were analysed by employing the RANB-program.

Figure 24: Carambolas enclosed in gauze bags

3.3 Feeding frequency and feeding duration experiments

The following experiments were undertaken to find out if the host suitability for *A.l. lutescens* could be determined by feeding frequency. These experiments were undertaken to compliment the development and survival experiments. It should be established whether the

acceptability of a host was reflected in the number of times a bug fed or the time it took to obtain the required nutrients.

A high feeding frequency could indicate a high suitability of a host (because of nutrient content). It could also mean, that the insect has to spend longer feeding to obtain a sufficient quantity of nutrients, because the amount of food required depends on the nutrients available and is also dependent on the metabolic rate (HOUSE, 1961).

The uptake of nutrients could also depend on the type of juice/sap or cell content, so that plant physiology could also play a role in food accessibility.

These experiments were also employed to investigate a potential preference for different varieties (e.g. papaya plants) and different maturity stages of a host (e.g. mock orange).

The method used in this experiment consisted of observing and timing feeding activity over set time intervals. This method was similar to the one described by SIMMONDS & YEARGAN (1988), who studied feeding frequency and feeding duration of the green stink bug *Acrosternum hilare* (Say).

Feeding frequency and feeding duration of second instar nymphs on different hosts including four different papaya varieties

A) FEEDING FREQUENCY AND FEEDING DURATION ON DIFFERENT HOSTS

When testing on young plants most of the top leaves were removed, so that only the growth terminal was left, which (with the nymph being tested) was covered with a small plastic bag (23 x 15 cm) (Fig. 25). Sticky tape was used to tie the bag around the plant stem. The nymphs on fruit were kept individually mostly in small rearing containers, only the nymphs on bananas were kept in a glass jar.

In each case five, 5 to 7 day old second instar nymphs were reared on one of the different hosts. The hosts included mock orange, banana, young plants of papaya, cashew, mango and cassava, using french beans as control. The insects either had one small banana (about 7 cm) or ½ a bean, 3 mock orange berries (of no particular maturity stage) or were kept on a single plant. The fruit was changed each day, but the plants were kept for the three days of the experiment. Each individual nymph was observed at 15 minute intervals over an eight hour period on three successive days. If a nymph was seen to feed at a 15 minute check, this was

Figure 25: Feeding frequency and feeding duration test on papaya plants

regarded as one feeding session. Feeding on consecutive checks was considered as the same feeding session. Because of a lack of insects of the same age, the experiment was replicated in time with new hosts.

Because of different numbers of replicates, results for all hosts together were analysed by employing the RANB-program.

B) FEEDING FREQUENCY AND FEEDING DURATION ON FOUR PAPAYA VARIETIES

The following papaya varieties were used in this experiment:

2 = SL 91 - 4 B

3 = CB 87 - 1 - 1

4 = GD 3 - 1 - 19 - 2 Parent (Y 2)/ PRD 2/1/92

7 = B 1 (local male parent 2nd year/PRD 31/12/91)

The set up and recording method used in this experiment were described above and included five plants of each of the four papaya varieties. This experiment was replicated once.

Feeding frequency and feeding duration on mock orange fruit and french beans

Five, 5 to 7 day old, second instar nymphs were kept separately in small rearing containers. Five nymphs were supplied each with half a bean and three mock orange fruit. The food items were replaced daily. The insects were examined every 15 minutes, for eight hour periods over three days, and the feeding frequency and feeding duration were determined and recorded as in the previous experiments.

Feeding frequency and feeding duration on different maturity stages of carambola fruit (cv. 'Thai Knight') and mock orange fruit

A) CARAMBOLAS (THAI KNIGHT) OF FIVE DIFFERENT MATURITY STAGES

Individual second instar nymphs, which had been withheld from food until moulting to second instar, were placed in clear plastic cylinders (31 cm high, 20 cm diameter). Round cake tins (20 cm diameter) were used as bottoms and lids. The top lid had airholes. Five carambola fruits of different sizes (1 ≈ 3 cm, 2 ≈ 5 cm, 3 ≈ 7 cm, 4 ≈ 8 cm, 5 ≤ 9 cm), of the variety 'Thai Knight' were randomly placed in the bottom of the cylinder. A moist cotton dental roll was used to supply water.

The insects were checked hourly over eight hours on three consecutive days and feeding or visits recorded. Carambolas were changed daily.

B) NYMPHS AND ADULTS ON THREE DIFFERENT MATURITY STAGES OF MOCK ORANGE FRUIT

Ten second instar nymphs as well as ten adults (8 females and 2 males) were confined individually in deep Petri dishes (9 cm diameter, 2 cm high).

Adult bugs were also employed in these experiments, to investigate potential differences in the preference behaviour of adults and nymphs. Three mock orange berries of different maturity (1 ≈ 2-3 mm, 2 = full size but green fruit, 3 = red mature fruit) were randomly placed in each Petri dish. The stalks were left on the fruit, as nymphs have been recorded to feed on these as well. A couple of leaves were also placed in the centre as well as a moist cotton dental roll.

The insects were observed hourly over eight hour periods on three consecutive days, and feeding incidences recorded. Fruit and leaves were replaced daily. This experiment was repeated once.

3.4 Studies on oviposition rates

Oviposition of *A.l. lutescens* was examined mainly under laboratory conditions. In some cases trials were also undertaken under field conditions to enable a comparison of both situations.

Oviposition rates on five different carambola varieties and french beans

Newly emerged adults were kept in large rearing containers. Two pairs were feed on french beans (as controls) and ten pairs were reared on the fruit of five different carambola varieties (two pairs on each variety). This test was undertaken to determine any variation in oviposition rate on the different carambola varieties. The varieties used in this experiment again were 'Arkin', 'B2', 'B10', 'Thai Knight' and 'Fwang Tung'. The food items were changed every second day. Eggs were collected and numbers recorded daily, as were numbers of hatched nymphs.

Oviposition rates on different carambola varieties in the field

Pairs of freshly emerged adults were enclosed in gauze bags tied on branches of carambola trees of the different varieties. After two weeks, fruit and bags were checked for eggs weekly until the bugs died.

Oviposition rates on different carambola varieties after rearing on french beans (until the beginning of oviposition)

To investigate if low oviposition rate, or even no egg production, was due to poor food quality which could be reversed by providing better quality food, adults were fed on carambolas and french beans. This would be of interest as adult fruitspotting bugs in the field move between hosts.

Pairs of newly emerged adults were kept in large rearing containers and reared on beans until females commenced egg laying. They were then transferred to carambolas ('Thai Knight', 'B2', 'B10', 'Fwang Tung' and 'Arkin'), also in large rearing containers. If a transferred female had stopped laying eggs for two weeks, it was given beans again, until oviposition was recommenced. The food items were changed every second day and the containers checked for eggs daily, with number of eggs and hatched nymphs recorded. The experiment had two replicates.

Oviposition rate of adults after different nymphal diets

Pairs of newly emerged adults, which were reared on papaya plants or papaya plants and french beans as nymphs, were kept separately in large rearing containers and feed french beans. The bugs were checked daily. The number of eggs laid and nymphs hatching were recorded, until the adults died. The food items were changed every second day.

Oviposition rates and longevity on different host plants

Pairs of adults were kept separately on french beans, carambolas (five different varieties) or mock orange fruit in large rearing containers in the laboratory or on one of the host plants (papaya, cashew, mango and cassava) in collapsible field cages in the insectary. French beans, mock orange and carambolas were changed every second day and plants were changed once a week. After the adults were two weeks old, containers and cages were checked daily for eggs. Eggs were kept separate for each pair of adults in Petri dishes and the number of nymphs hatching was recorded daily.

Oviposition rates with host plant choice

To study any preference of oviposition sites in larger areas, adults were released in the insectary and given a choice of hosts for feeding and oviposition.

Groups of three young seedlings of one host (papaya, cassava, mango and cashew) were placed in each corner of the insectary. A pot with a large basil plant was positioned in the middle of the room as a control. Twenty pairs of adults which had emerged between 17 and 21 of March 1993 were released in the insectary. All plants were checked for eggs and nymphs every day between 22 of March and 23 of April 1993, with plants changed when they started wilting (once or twice a week, depending on their condition).

3.5 Population studies

In order to obtain an understanding of the population dynamics of *A.l. lutescens* on certain hosts (in population numbers and structure over time), studies on the seasonal acceptability to *A.l. lutescens* were done on two different hosts. Changes in numbers of the insect population and breeding patterns are relevant to potential crop damage and need for preventative control measures.

Observations were undertaken on papayas as an example of a commercial crop in rows. As a contrast observations were done on mock orange as an example of an ornamental with sporadic distribution. This comparison could clarify the significance of different habitats to *A.l. lutescens* populations.

Study sites were papayas in the orchard at Walkamin Research Station and mock orange bushes in six different locations in the 'Bicentennial Park' and the APU. They were surveyed frequently.

Papayas were chosen for this work because they are a very susceptible commercial host of the bugs. Papayas are easily grown, develop quickly and it is also relatively easy to observe fruitspotting bugs on them. In papayas, the seasonal changes of the bugs was observed with special emphasis on variations in varietal susceptibility over a certain period of time.

Mock orange were also chosen for population studies because it is a common ornamental shrub in the study area and is invariably used as a host by the bugs. Although individual bushes at different locations do not always flower or bear fruit at exactly the same time, mock oranges (with at least some fruit) can be found nearly all year, making it a fairly reliable

breeding ground and host for the insect. On this host, seasonal influences on general availability of suitable nutrition, and how bugs respond to changes in crop dynamics, could be observed.

In connection with the observations on mock orange the population of egg parasitoids was examined. Adult bugs, nymphs and eggs were collected at regular intervals on different sites over one year. In mock orange bushes eggs of *A.l. lutescens* are repeatedly used by parasitoids (FAY & HUWER, 1993). Records of this survey were expected to provide information on the relationship between host phenology, seasonal as well as well as *A.l. lutescens* and wasp populations.

Population monitoring in papayas

The papaya trial at the Walkamin Research Station which was laid out as described on page 34 was checked weekly, between 14 of January 1993 and 24 of September 1993, for eggs, nymphs and adults of *A.l. lutescens*, which were recorded and removed.

Population monitoring in mock orange bushes

Mock orange bushes in two sites on the APU grounds and three sites in 'Bicentennial Park' in Mareeba were checked for *A.l. lutescens* every two weeks between 12 of August 1993 and 29 of August 1994. The bushes were searched for five minutes per visit at each site. The eggs, nymphs and adults were removed and numbers of each recorded.

3.6 Studies on the incidence of bug damage in different papaya and carambola varieties in the field

Varietal resistance, tolerance or preference also included observations of bug damage in different crop varieties in the field. Field observations were undertaken to compliment laboratory findings on papaya and carambola varieties.

Damage in young papaya plants of eight different varieties

This study was undertaken to investigate the possibility of varietal preference towards particular papaya varieties in the field at the Walkamin Research Station.

The papaya trial was laid out as described earlier (see page 34), was checked weekly, between 14 of January and 24 of September 1993 to rate the damage caused by *A.l. lutescens* on each individual plant. Between flowering and major fruit set, the number of female flowers or penducles of male flowers were counted, first once a month then every two weeks. During the main period of fruit development the number of fruit were counted every two weeks.

Bug damage was rated into on of the following four categories.:

1 - slight damage:	Obvious feeding evident; longitudinal grooves noticeable, but no further distortion or wilting of the stem or growth tip;
2 - medium damage:	Obvious feeding evident; showing distortion and the start of wilting of stem or growth terminal;
3 - heavy damage:	Major feeding damage; heavy distortion of stem and leaves; the growth terminal is completely wilted;
4 - plant dead	

Damage on five different carambola varieties

In carambolas, potential varietal differences in the level of damage and the relationship between damage and fruit maturity were examined.

Twenty second instar nymphs, which had moulted during the previous 24 hours, were enclosed separately in gauze bags tied to branches. The nymphs were enclosed with a bunch of either 2 or 5 fruit. There were bunches of small fruit (3 - 5 cm in length), or 5 large fruit (< 7 cm in length) of one of the different varieties. The bags were removed after a week and feeding marks on each fruit were counted (Fig. 26).

Figure 26: Damaged carambolas

3.7 Parasitoids of *Amblypelta l. lutescens*

Rearing of egg parasitoids

In the possibility of a later mass production of the parasitoids and to enable research experiments, an adequate laboratory colony of the insects needed to be established in the laboratory.

All three parasitoids were kept separately, but under similar conditions. Adult wasps were kept in glass jars. In the case of *Gryon* sp. and *Anastatus* sp., 10 to 50 wasps were kept per jar, and in the case of *Ooencyrtus caurus* about 100 wasps (DE FAVERI, 1995).

Jars were kept in a horizontal position. Adults were fed on a drop of honey smeared on top of a lid of a parasitoid container every two weeks. Eggs of *A.l. lutescens* were given to the adult

wasp once (*Gryon* sp. and *O. caurus*) a week or three times (*Anastatus* sp.) a week in a lid of a small rearing container. The number of eggs which were given each time was dependent on the number of eggs produced by the bug colony. Parasitised eggs were removed and transferred into parasitoid containers. For *Anastatus* sp. ten eggs were kept per container and in the case of *Gryon* sp. and *O. caurus* seven eggs per container (DE FAVERI, 1995). The development time for the parasitoids is depending on temperature, it took approximately 10 to 14 days for *O. caurus*, 14 to 17 days for *Gryon* sp. and 3-3½ weeks for *Anastatus* sp. (FAY, 1995). Since the number of eggs from the bug colony was a limiting factor in rearing the parasitoids, eggs of alternative hosts have been investigated (Table 5).

Table 5: Alternative hosts for egg parasitoids (DE FAVERI & FAY, 1995)

HOST			**PARASITOID**
ORDER	**FAMILY**	**SPECIES**	
Mantodea	Mantidae	*Neomantis* sp.	*Anastatus* sp.
Heteroptera	Pentatomidae	*Austromalaya* sp.	
Heteroptera	Coreidae	*Mictis profana* (F.)	*Anastatus* sp.
Heteroptera	Coreidae	*Mictis* sp.	
Lepidoptera	Saturniidae	*Opodiphthera eucalypti* (Scott)	*Ooencyrtus caurus*
Lepidoptera	Hesperidae	*Cephrenes augiades sperthias* (Felder)	*Anastatus* sp.
Lepidoptera	Bombycidae	*Brombyx mori* (L.)	
Lepidoptera	Thaumetopeidae	*Ochrogaster lunifer* (H.-Sch.)	

3.7.1 Effect of the age of host eggs on parasitoids

It was uncertain whether the level of egg parasitism would be influenced by the age of the host egg. This information would be important in situations of mass rearing the parasitoids, and determining effectiveness of the parasitoids in the field. Therefore an experiment was designed to determine any preference for host eggs of a particular age.

I. Preliminary test with *Ooencyrtus caurus*

Eggs of *A.l. lutescens* were removed from culture on five consecutive days. The eggs taken on the day before the experiment started were considered the control. Eggs collected each day were kept separate. In each case five eggs from one day were placed into a parasitoid container with two pairs of adult parasitoids which were collected out of their glass jar with an aspirator. The lids of the parasitoid containers were provided with a drop of honey as a food source for the wasps. The parasitoids were removed after one day. The containers with the eggs were then checked frequently for emergence of bugs or wasps, with the number of each recorded. This experiment had three replicates.

II. Preliminary test with *Ooencyrtus caurus* and *Anastatus* sp.

A.l. lutescens eggs were again collected on five consecutive days. Eggs collected on each day were kept separate and groups of five eggs were placed in lids of parasitoid containers. One lid of each collection day was put into the glass jars with the parasitoid culture (*O. caurus* or *Anastatus*). A lid of a parasitoid container with drop of honey on top provided food for the wasps. The lids with the different aged eggs were randomly distributed in the jar with the parasitoids and were removed after eight hours. The eggs were checked frequently over the following three weeks, for emergence of bugs or wasps, which was then recorded. This experiment was set up with three replicates and repeated once for *O. caurus*.

a) Only for *O. caurus*:

On one day, the containers with eggs were checked every 15 minutes over the eight hours, and it was recorded how many female wasps were sitting on eggs in each container on each 15 minute check. This part of the experiment was only carried through once, with three replicates.

Choice of different aged host eggs with *Anastatus* sp. and *Ooencyrtus caurus*

Eggs of *A.l. lutescens* were collected over eight consecutive days and kept separately. Groups of five eggs of one age were glued with honey into lids of parasitoid containers. One lid of each collection day was randomly positioned in a glass jar with the culture of *Anastatus* sp. as well as *Ooencyrtus caurus*. A further lid of a parasitoid container with a drop of honey provided food for the wasps. The lids with eggs were removed after eight hours. The containers with the eggs were checked daily for emergence of bugs or wasps, which then was recorded. This experiment was set up with three replicates and repeated once.

3.8 Control of *Amblypelta l. lutescens* with neem products

Natural insecticides have been used for quite some time, but their market share in comparison to the total of applied insecticides is very small. These products are still relatively expensive and therefore find it hard to compete with organic synthetic insecticides (HEITEFUß, 1987).
In Integrated Pest Management (IPM) programs it is desirable to employ control techniques which interfere minimally with existing natural control mechanisms. The medical usefulness of neem has been mentioned in thousand-year-old Sanskrit writings, but it's ability as an insect repellent was first been reported in 1928 and 1929 (NATIONAL RESEARCH COUNCIL, 1992).
In experiments the effect of neem extracts, as an alternative to conventional chemical control against *A.l. lutescens*, was looked at under several aspects. Neem was tested on eggs, nymphs (nymphal development, repellency effect and toxicity) and adults (oviposition rate, repellency effect and toxicity) mainly under laboratory conditions but also under ambient conditions. The

effectiveness of different neem products was compared as well. It was also important to determine the effect of neem on the parasitoids (adult wasps and parasitised eggs).

Neem products:

Three different products were used in the various experiments:

1. 'Green Gold One[2*]', which is an emulsifiable concentrate with 0.5% azadirachtin, stabilised with methylated spirits. It was recommended by the producer, to dilute the extract 1:25 with de-ionised water. It will be further referred to as GGO-(1:25).
2. A powdered neem product which contained 3.8% azadirachtin was diluted and stabilised with methylated spirits, at a ratio of 1 g powder to 7.6 ml spirit. This lowered the azadirachtin concentration down to 0.5%, to make it comparable with the 'Green Gold One' product. This mixture then was diluted with de-ionised water 1:25 [PN-(1:25)] before use.
3. The oil based emulsifiable concentrate 'Neem-Azal T/S[3*]' (1% azadirachtin) was diluted 1:50 with de-ionised water [NA-(1:50)] to enable comparisons with the two methylated spirits based products.

3.8.1 Effect of neem on nymphs

Neem has an impact on larval and nymphal development, such as disrupted or inhibited development or obstruction of moulting (NATIONAL RESEARCH COUNCIL, 1992). Insects of different orders are known to be effected by neem as for example: oriental fruit fly (Diptera), flea (Siphonaptera), head lice (Phthiraptera), colorado potato beetle (Coleoptera),

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2* Azadirachtin deterrent, Australian patent Nr. 599569,
by Entomology Workshop PTY LTD; 4 Furlong Street, Indooroopilly QLD 4068, AUSTRALIA

3* Trifolio-M GmbH, Sonnenstr. 22, D-35633 Lahnau 2, GERMANY.

western thrips (Thysanoptera), Diamond back moth (Lepidoptera), migratory locust (Orthoptera), *Oncopeltus fasciatus* (large milkweed bug) (Heteroptera), fire ant (Hymenoptera) (NATIONAL RESEARCH COUNCIL, 1992).

In the following study, the effect of neem on nymphal development of *A.l. lutescens* and it's potential as an antifeedant were tested in various experiments.

As the type of the neem preparations used could have an relevance, three different neem preparations - diluted to the same concentration of azadirachtin - were used in different experiments.

The efficacy of neem in the field and the period of its effectiveness is influenced by UV-rays. Simple neem extracts are only active for about eight days under sun light exposure (NATIONAL RESEARCH COUNCIL, 1992). Therefore the effectiveness of neem against *A.l. lutescens* was studied in laboratory tests as well as under ambient conditions.

Effect of neem on the development of nymphs under laboratory rearing conditions

Nymphs from the second instar onwards were reared on french beans treated with neem to determine if neem has a significant influence on the nymphal development of *A.l. lutescens*.

Four groups of five nymphs which were 2 - 4 days old and had moulted to the second instar over the previous 24 hours, were kept in large rearing containers. Three groups were reared on french beans which were dipped in a solution of GGO-(1:25) and one group was kept as a control and reared on untreated french beans. Nymphs were checked daily and development and mortality recorded. Beans were changed every second day. The experiment had 15 replicates.

Comparison of three different neem products in their effect on the development of nymphs under laboratory conditions

To determine the effectiveness of different neem products, two methylated spirits based products and an oil based neem product were compared (see 3.8).

Groups of five newly hatched nymphs were kept in large rearing containers. Three groups were reared on french beans which were dipped in a solution of either GGO-(1:25), PN-(1:25) or NA-(1:50); one group was reared on untreated french beans as a control. Nymphs were checked daily and moulting and mortality recorded. Beans were changed every second day. Ten replicates were employed in this test.

Effect of neem on nymphs reared under ambient conditions

To investigate the effect of UV-rays on the effectiveness of neem products over a certain time period, these products were applied with a paint brush at two week intervals to papaya plants and exposed to ambient conditions, and then nymphal development was observed.
Ten newly hatched nymphs were kept in large rearing cages and reared on papaya plants (6 to 8 plants per cage) which were treated with GGO-(1:25) by painting leaves and stems of the young plants with the neem extract. A cage with untreated plants was kept as a control. The cages were positioned outside a glasshouse and an automatic sprinkler system was turned on for one hour a day if it did not rain. Plants were changed every 14 days and the development stage and mortality of nymphs recorded. Once nymphs reached the fifth instar, they were checked daily, until they became adults.

Comparison of the impact of two neem products on nymphal development under ambient conditions

Ten newly hatched nymphs were kept in large rearing cages and reared on young papaya plants (6 to 8 plants per cage) which were treated with either GGO-(1:25) or NA-(1:50) by spraying the young plants with a small hand mister (500 ml) on upper as well as lower side of leaves, leaf stalks and stem until run off. One cage with untreated plants was kept as a control. The cages were positioned outside a glasshouse and an automatic sprinkler system was turned on for one hour a day if it did not rain. Plants were changed every 14 days and the development stage and mortality of nymphs recorded. Once nymphs reached the fifth instar, they were checked daily. This experiment had seven replicates.

Effectiveness of a neem product as an antifeedant against nymphs on french beans

A neem products were tested regarding their suitability as antifeedants with fifth instar nymphs in a 'Multiple Choice Test'.

Five nymphs were kept separately in large rearing containers. They were given a third of an untreated bean, one third of a bean which was dipped in GGO-(1:25) and one third of a bean treated with a mixture of methylated spirits. Since the tested neem product was based on methylated spirits, a mixture of methylated spirits and four drops of the wetting agent 'Agril' was used as a comparison, and also diluted 1:25 with de-ionised water. Each bean was checked for feeding marks after two and four days. The experiment was replicated 13 times over two days and the last five replicates continued on to four days.

Fifth instar nymphs were chosen as their feeding marks are quite obvious and also because the mortality at that stage is very low. With younger nymphs it is difficult to determine if mortality was due to the treatment or natural causes.

Testing the effectiveness of two different neem products on bananas

Five fifth instar nymphs, reared on french beans, were kept separately in small rearing cages. The nymphs were each offered four differently treated immature bananas (ca 10 cm long), randomly placed in the cages.

The following treatments were used:

1. untreated
2. methylated spirits
3. GGO-(1:25)
4. PN-(1:25)

A mixture of methylated spirits and four drops of the wetting agent 'Agril', diluted 1:25 with de-ionised water were again used as a comparison, as both neem products were stabilised with methylated spirits.

One untreated banana, as well as three differently treated bananas were then placed in each cage. After two and four days, the bananas were examined and the number of feeding marks on each banana recorded. The experiment had five replicates.

3.8.2 Effect of neem products on adults of *A.l. lutescens*

Adult *A.l. lutescens* can live in the laboratory for several months. Field longevity of adults is expected to be similar. Feeding damage and population changes are likely to be significant. Therefore both the repellent potential and the affect of neem on oviposition rate of the adult bugs are of interest. Since the economic threshold of fruitspotting bug damage is very low, neem would have to show repellency very rapidly and toxicity or effects on fecundity, mating and egg viability would have to be very high to control fruitspotting bugs adequately.

Effect of neem products on oviposition rate - Experiment I

In order to study the impact of neem on reproduction of *A.l. lutescens*, adults were fed on french beans treated with neem.

Pairs of newly emerged adults were kept in large rearing containers and fed on french beans dipped in GGO-(1:25). The beans were changed every second day. One pair of adults was kept as a control and fed on untreated beans. The eggs were collected daily and they were kept separate for the individual pairs. Eggs laid and number of hatching nymphs were recorded daily until all the adults had died. The experiment had eight replicates.

Experiment II

The effect of a methylated spirits and an oil based neem product (see 3.8) were compared in this series of experiments.

Newly emerged adults were kept in large rearing containers and fed on french beans dipped in one of two neem preparations used as treatments [GGO-(1:25) and NA-(1:50)]. Beans

were changed every second day. One pair of adults was kept as control and fed on untreated beans. The eggs were collected daily and they were kept separate for the individual pairs. Eggs laid and number of hatching nymphs were recorded daily over six weeks. This experiment had ten replicates.

Antifeedant effect of neem against adults on french beans

Five adults were kept separately in large rearing containers. They were given a third of an untreated bean, one third of a bean which was dipped in GGO-(1:25) and one third of a bean was treated with the mixture of methylated spirits (methylated spirits and the wetting agent 'Agril' diluted 1:25 with de-ionised water). Each bean was checked for feeding marks after two days and four days. This experiment had five replicates.

Repellent properties of three neem products against adult bugs - Experiment I

The repellent effects of neem against adults of *A.l. lutescens* were tested in a long term experiment by placing adult bugs with young papaya plants which were treated with one of the three different neem products or untreated. Young papaya plants (two per pot) were treated with either GGO-(1:25), PN-(1:25) or NA-(1:50). The neem was applied with a small hand mister (500 ml) and sprayed on the upper as well as lower sides of the leaves and stem until run off (approx. 20 - 25 ml). Untreated plants were used as a control. Three pots with plants were employed in each treatment and were randomly placed on the floor of one insectary room in which six pairs of adults were subsequently released. Visible feeding damage was recorded daily over 18 days.

Experiment II

Immature banana fruit were painted with GGO-(1:25), PN-(1:25) or NA-(1:50). Untreated fruit were kept as a control. In each case two bananas of one treatment were joined with wire

and hung from the ceiling in the insectary room. Three replicates of each treatment were randomly positioned in the room. Six pairs of adults were then released into the insectary room. The bananas were removed after four days and the number of feeding marks on each pair of bananas recorded. This experiment had three replicates and was repeated once.

Experiment III

This time the repellent effect of one neem product was tested in a short term experiment, using two different concentrations. As in the previous experiment, immature banana fruit were painted with neem preparations. This time two concentrations of Neem-Azal T/S [NA - (1:50) and NA - (1:25)] with azadirachtin concentrations of 0.02% and 0.04% respectively were used as treatments. Untreated fruits were kept as a control. Two bananas were again joined with wire and hung from the ceiling in the insectary room. Four replicates of each treatment were randomly positioned in the room. The bananas were removed after four days and the number of feeding marks on each pair of bananas recorded. This experiment had four replicates and was repeated once.

3.8.3 Effect of neem applications on eggs

Some insecticides used to control fruitspotting bugs only have poor ovicidal properties (e.g. methidathion), while others such as endosulfan are obviously very effective (FAY, 1995). To ensure that high pest populations are not maintained in those crops in which breeding occurs, controls must be effective against all stages. In exceptional cases, neem is known to have ovicidal effect, for example against eggs of fleas (NATIONAL RESEARCH COUNCIL, 1992). Therefore, as part of an effective control technique, the ovicidal effect if any of neem would be an important factor.

Effect of neem on eggs of different age

This test was undertaken to establish whether neem has any effect on the eggs at all, and whether there is a significant difference in the effect on different aged eggs.

Groups of five bug eggs, collected either the same day, one day or five days previously, were kept on moist filter paper in the moulds of a plastic tissue culture plates. Each tissue culture plate consists of two rows of three moulds, each 1 cm deep and 3 cm in diameter (Fig. 27). One group of five eggs collected on each of the three days were kept untreated as a control and a second group of five eggs were painted with GGO-(1:25). Eggs were checked daily and the number nymphs hatching recorded. This experiment had five replicates.

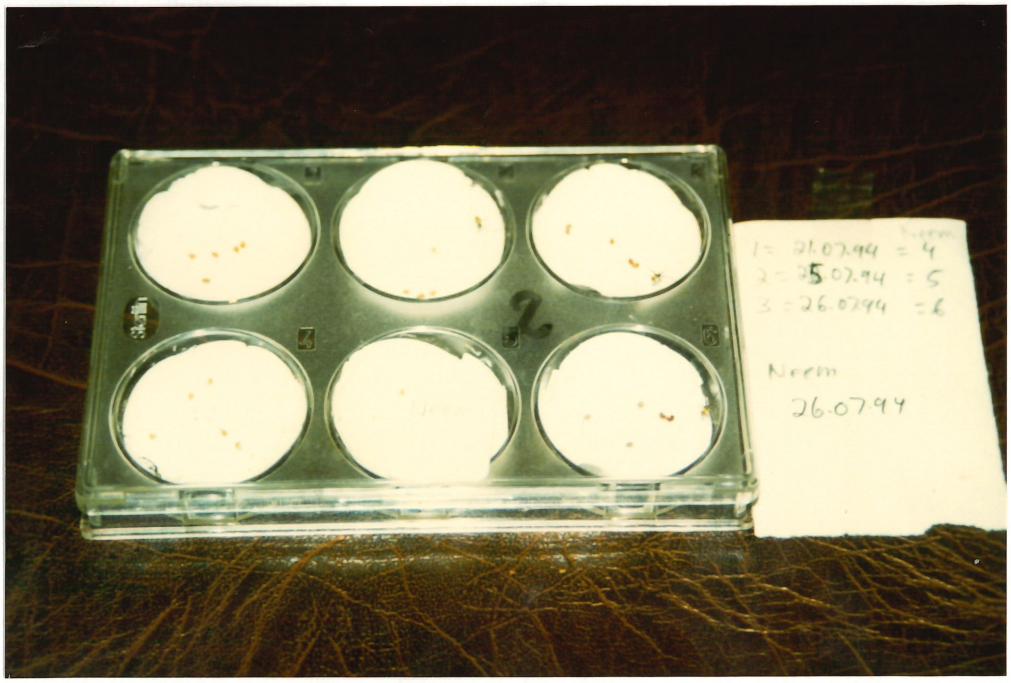

Figure 27: Eggs in tissue culture plate

Comparison of the effect of two different neem products on eggs

Another aspect of the authors study was the comparison of the effect of three different neem products on eggs. GGO-(1:25) and PN-(1:25) were prepared as described above. Three groups of five eggs each were collected before the experiment started and five days before. They were then placed in the moulds of a tissue culture plate (see previous experiment) on moist filter paper. One group of eggs was left untreated as a control and the remaining two groups were painted with one of the two neem preparations. The eggs again were checked daily and the number of hatching nymphs recorded. This test had five replicates.

Comparison of the effects of three different neem products on eggs

GGO-(1:25), PN-(1:25) and NA-(1:50) were used as treatment. Four groups of five eggs which were collected on either of the previous two days, were placed in the moulds of a tissue culture plate on moist filter paper. One group of eggs was left untreated as a control and the remaining three were painted with the neem preparations. The eggs again were checked daily and the number of hatching nymphs recorded. This experiment was repeated five times.

3.8.4 Effect of neem on parasitoids

As part of an IPM program the combined action of neem and parasitoids would be required i.e. to control bugs entering crops with the chemical and control breeding with the parasitoid. For neem to be suitable in IPM programs it would be necessary to show that effects on the performance of natural enemies such as egg parasitoids are minimal. Neem is known to be non-toxic to numerous beneficials e.g. parasitoids and predators of the cotton aphid (*Aphis gossypii*) and sweet potato whitefly (NATIONAL RESEARCH COUNCIL, 1992).

Adults of *Anastatus* sp.

To investigate if neem products have any toxic or repellent effects on adult *Anastatus* sp., adult wasps were released on papaya leaves which were treated with neem. Two papaya leaves were painted with the diluted neem product GGO. Two different concentrations of neem were used as treatments and untreated leaf material used as a control. Neem was diluted 1:25 with de-ionised water in the first treatment (equals 0.02 % azadirachtin) and 1:12.5 in the second treatment (equals 0.04 % azadirachtin). Five sections of approximately 2 cm x 2 cm were cut from each leaf and separately placed in parasitoid containers. The lid of each container was provided with a drop of honey as a food source for the wasps. Two adult wasps were put in each container. Over four days the survival of the wasps was checked daily and any mortality noted. This test had three replicates.

Effect of two neem products on eggs parasitised by *Anastatus* sp.

The effect of neem products on host eggs producing wasps was also tested in the following experiment.

Groups of five *A.l. lutescens* eggs, which were previously exposed to the parasitoids, were placed on sections of filter paper in lids of parasitoid containers. In the control, the filter paper was moistened with de-ionised water. One group of eggs was painted with GGO-(1:25) and for the second treatment, eggs were painted with NA-(1:50). The eggs were checked daily and the number of hatching parasitoids recorded. This experiment had three replicates and was later repeated once.

Effect of eggs with neem treatment on the parasitism rates for *Anastatus* sp. - Experiment I

Groups of ten *A.l. lutescens* eggs which were laid over the previous 48 hours, were glued with honey into the lids of parasitoid containers. One lid with eggs was left untreated as a control. Eggs in the second lid got sprayed with GGO-(1:25) and eggs in the third lid were

treated with NA-(1:50), by using a small hand mister (500 ml). One lid of each treatment was placed in a glass jar with parasitoids. Each jar contained about 20 adult wasps (13 females and 7 males) which were three to six days old. The eggs were removed after 24 hours and lids were screwed back onto empty containers. The eggs were checked daily for emergence of bugs or parasitoids. This experiment was set up with three replicates and was repeated once.

Experiment II

Groups of ten *A.l. lutescens* eggs, which were laid over the previous 24 hours, were glued with honey into the lids of parasitoid containers. One lid with eggs was left untreated as control, the eggs in the second lid were sprayed with GGO-(1:25) and in the third lid, eggs were treated with NA-(1:50), by using a small hand mister (500 ml). Lids of each treatment were placed in separate glass jars with parasitoids. Each glass jar contained about 8 adult wasps (6 females and 2 males), three to six days old. The eggs were removed after 48 hours. The lids were screwed back onto empty containers. The eggs were checked daily for emergence of bug nymphs or parasitoids. This experiment had two replicates and was later repeated once.

4 RESULTS

4.1 Establishing the laboratory colony

Preliminary tests on fresh seeds of french beans and different products of peas

A small sample (16 nymphs) reared on frozen peas, dehydrated peas (30 nymphs) and pea sprouts (13 nymphs) had a mortality rate of 100%. None of these nymphs lived longer than 10 to 17 days and some died in the first instar. None of the nymphs developed further than the second instar. The mortality on fresh bean seeds (33 nymphs) was 90.9 %. Here again, most of the nymphs died within the first ten days in the second instar.

Preliminary test on growth terminals of cashew

All nymphs on cashew terminals died between 4 and 18 days; nine of the ten nymphs had moulted to second instar. Nymphs on french beans lived for 6 to 40 days, and one out of the six nymphs reached the fifth instar.

Rearing on french beans, young papaya plants or papaya plants followed by french beans

The results of average mortality and average development time from first instar nymph to adult is shown in Table 6.

The mortality rate of the nymphs on papaya plants followed by french beans was expected to be 50 - 60 %, but in fact was 44.0 %, and therefore not much higher than nymphs reared only on papaya plants.

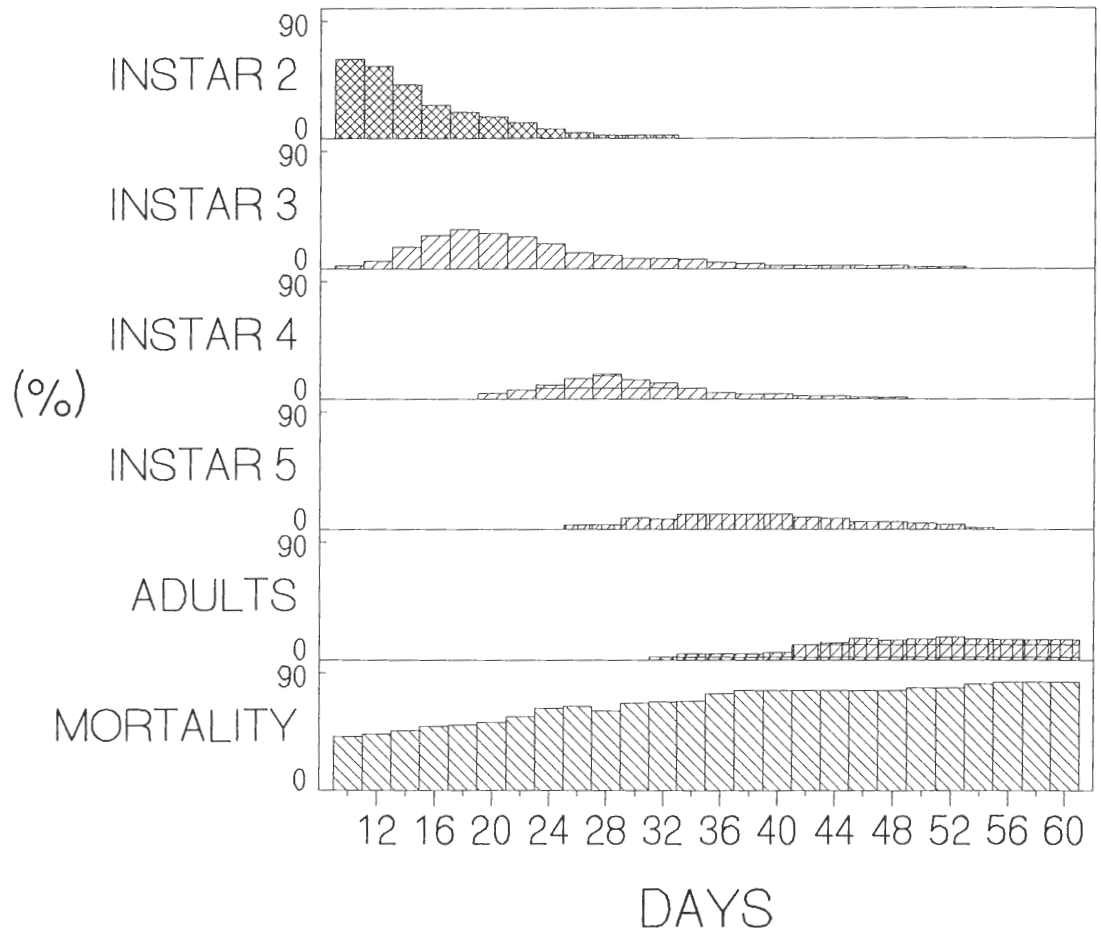

Figure 28: Rearing on french beans

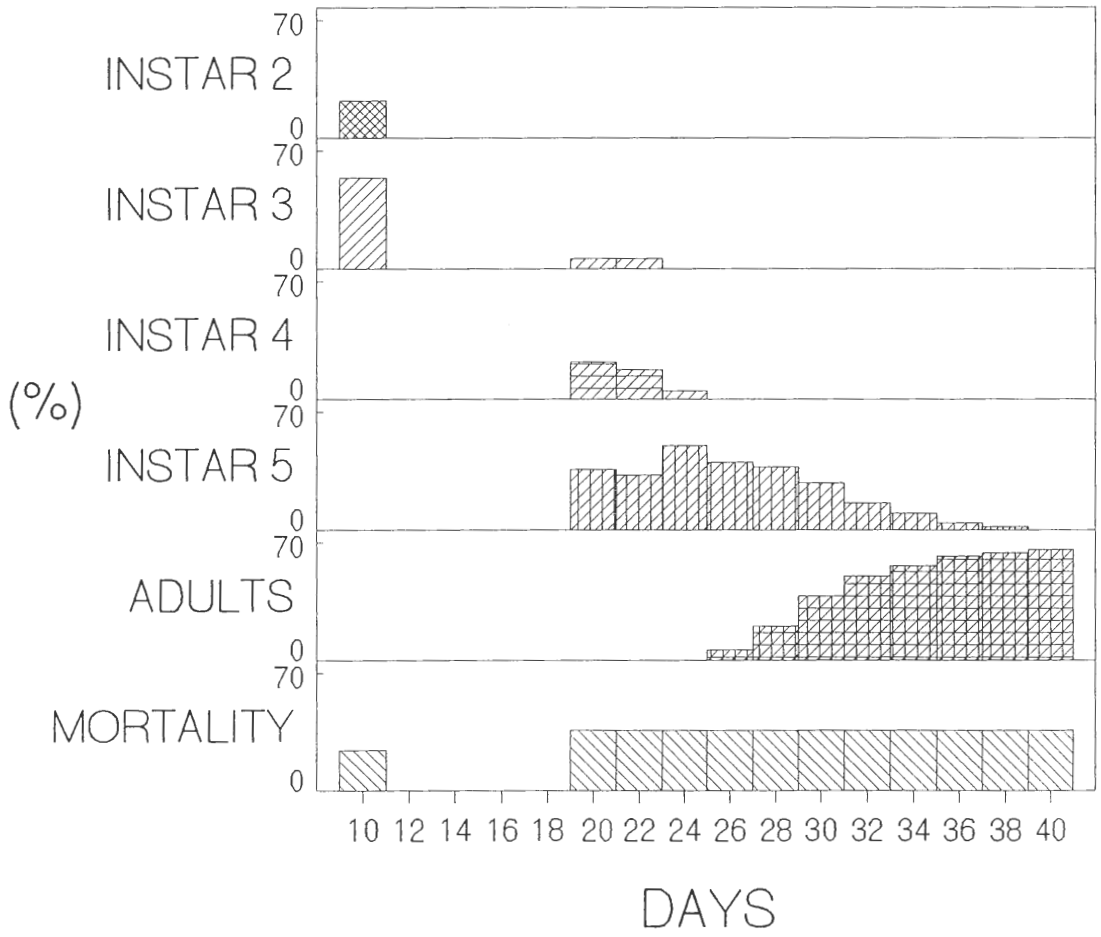

Figure 29: Rearing on papaya

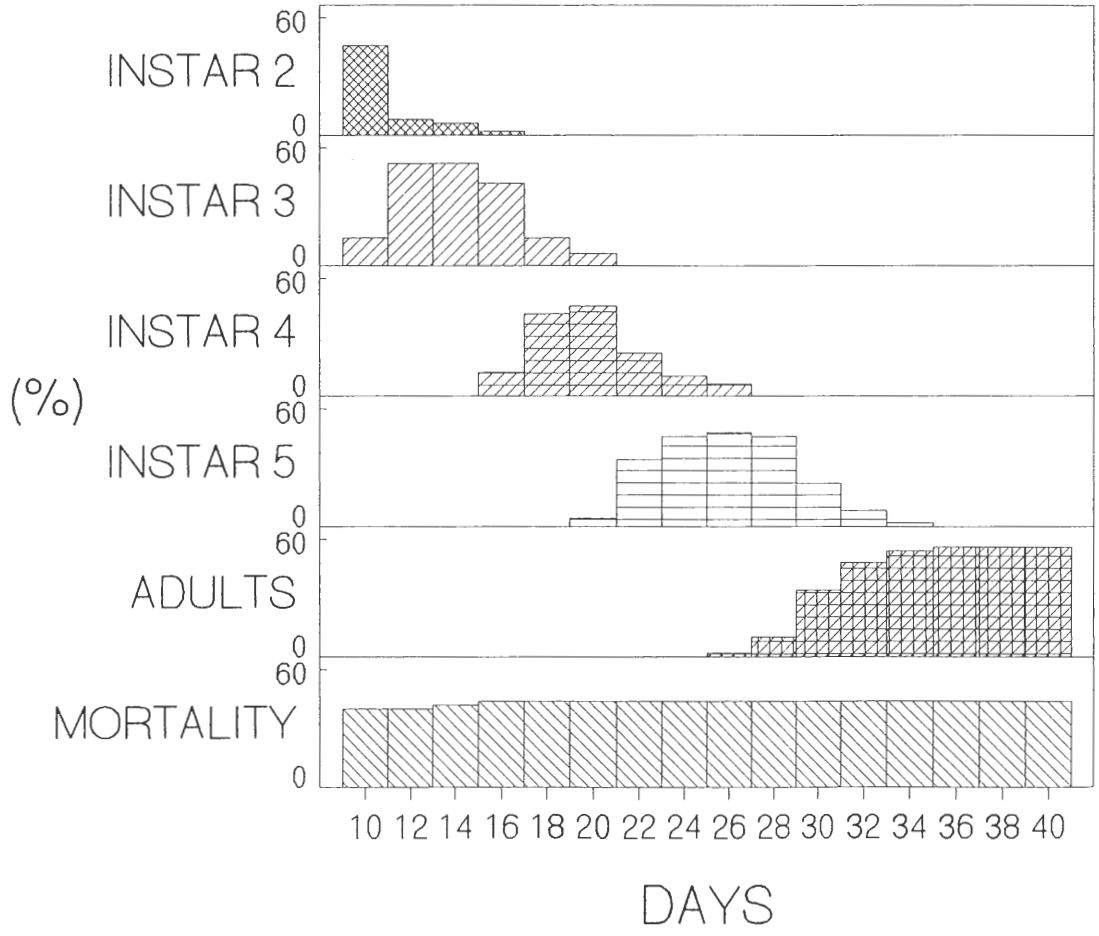

Figure 30: Rearing on papaya followed by french beans

Table 6: Effect of different rearing methods on nymphal development and mortality of *A.l. lutescens*

Host plant	Average mortality	Average development time (in days)
French beans	72% **a***	43.5 (31-67days) **a**
Papaya plants	34% **a**	30.5 (25-38 days) **b**
Papaya and beans	44% **a**	30.2 (26-36 days) **b**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

When analysed for development time, it was significantly longer for french beans than for papaya or papaya and french beans [(ANOVA) $\mathbf{F_{2,6}=8.7, P=0.0168}$]. There were no significant differences in mortality on the different host plants ($\mathbf{F_{2,8}=3.28, P=0.0909}$).

Details on the development stages and mortality over the experiment period are shown in Figures 28-30. The highest mortality occurred during the first two weeks and before moulting to the third instar, confirming the preliminary test results.

Effect of holding density on nymphal development

At five nymphs per container, out of 100 nymphs a total of only seven survived to adults (mortality = 93 %). When ten nymphs were reared per container, ten out of 100 survived (mortality = 90 %). The ANOVA by employing the RANB-program did not show any significant difference in the two methods ($\mathbf{F_{1,19}=0.57, P>0.05}$).

4.2 Studies on nymphal development of *Amblypelta l. lutescens*

Preliminary tests:

Comparison of nymphal development on french beans, carambola fruit (cv. Thai Knight) and young papaya plants

The nymphal mortality on different hosts was following:

Carambola: 100 %

French beans: 40 %

Papaya plants: 40 %

At a 10 % level [(ANOVA) $\mathbf{F_{2,12}=3.00, P=0.0878}$), nymphs reared on carambola show a significantly higher mortality.

The development time to adult was significantly longer on french beans (39.3 days), than on papaya plants (23.6 days) ($\mathbf{F_{1,4}=16.66, P=0.0151}$).

Nymphal development on fruit on the tree and on picked fruit

The longevity for nymphs on picked and unpicked fruit during the two yearly assessment is shown in Table 7.

Table 7: Longevity of nymphs on picked and unpicked fruit

YEAR	TREATMENT	AVERAGE LONGEVITY (in days)
1	picked fruit	8.4
1	unpicked fruit	28.8
2	picked fruit	5.6
2	unpicked fruit	9.6

Nymphs on unpicked fruit always lived longer than nymphs on picked carambolas. In the first experiment nymphs on unpicked fruit lived significantly longer than the nymphs on picked fruit [(ANOVA) $\mathbf{F_{1,8}=9.96, P=0.0135}$]. In the second year, there was no significant difference ($\mathbf{F_{1,8}=1.54, P=0.2504}$). When the results of both replicates were analysed together, the longevity on unpicked fruit was significantly longer than on picked fruit ($\mathbf{F_{1,16}=11.40, P=0.0038}$).

All nymphs died within seven weeks and no nymph developed further than third instar.

Nymphal development to third instar on mock orange fruit of three different maturity stages

The survival to third instar was significantly higher on large green fruit [(ANOVA) $\mathbf{F_{1,10}=13.86, P=0.0013}$]. The development time to third instar could not be compared, because most nymphs on small green and red fruit died before reaching this stage.

Main experiments

Host testing I - Nymphal development on different hosts in the laboratory

Results on survival to adult and last instar are shown in Table 8. Only on four of the 14 hosts did the nymphs develop to adults. Often the insects would remain in one instar for a long time, especially the second, before they died. Longevity (in number of days) therefore seemed to be misleading as a measurement for the success of nymphal development. Consequently, only the information of the last instar reached or percent survival to adults on different host plants was used. The survival of nymphs was significant different in various hosts ($\mathbf{F_{13,98}=3.17, P<0.05}$).

On young papaya and cashew plants and fruit of beans and mock orange significantly more nymphs survived to adult. Therefore the development was most successful on these host plants.

Nymphs on papaya plants, french beans and cashew plants developed significantly further than the nymphs on avocado, banana, carambola, cassava plants, guava and mango plants [(ANOVA) $\mathbf{F_{13,98}=4.37, P<0.05}$].

On carambolas, nymphs developed significantly further on the variety 'B2' than on the varieties 'Thai Knight' and 'Fwang Tung' ($\mathbf{F_{4,36}=3.24, P=0.0227}$). Since no nymphs survived to adult on any of the five carambola varieties, there was no difference in the percentage of mortality.

Table 8: Development to adults and average last instar reached on different host plants in the laboratory

HOST	N	DEVELOPMENT TO ADULTS	LAST REACHED NYMPHAL INSTAR
Avocado	6	0% **c***	1.90 **c**
Banana	3	0% **c**	1.60 **c**
Carambola - Arkin	10	0% **c**	1.84 **c**
Carambola - B2	10	0% **c**	2.03 **b,c**
Carambola - B10	10	0% **c**	1.96 **c**
Carambola - Fwang Tung	10	0% **c**	1.78 **c**
Carambola - Thai Knight	10	0% **c**	1.80 **c**
Cashew plants	8	12.5% **a,b**	2.68 **a**
Cassava plants	8	0% **c**	1.93 **c**
French beans	8	10.0% **b,c**	2.59 **a**
Guava	5	0% **c**	1.96 **c**
Mango plants	8	0% **c**	1.83 **c**
Mock orange	8	10.0% **b,c**	2.53 **a,b**
Papaya plants	8	22.5% **a**	2.83 **a**

N= number of replicates

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

Table 9: Development to adults and average last instar reached on different host plants in the field

HOST PLANT	N	DEVELOPMENT TO ADULTS	LAST REACHED NYMPHAL INSTAR
Avocado	7	0% **b***	1.31 **c**
Carambola - Arkin	10	0% **b**	1.70 **b,c**
Carambola - B2	10	0% **b**	1.74 **b,c**
Carambola - B10	10	0% **b**	1.69 **b,c**
Carambola - Fwang Tung	10	0% **b**	1.74 **b,c**
Carambola - Thai Knight	10	0% **b**	1.76 **b,c**
Cashew	8	12.5% **a**	1.95 **a,b**
Lychee	10	0% **b**	1.68 **b,c**
Macadamia nut	8	0% **b**	1.48 **c**
Mango	8	12.5% **a**	2.13 **a**

N= number of replicates

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

Host testing II - Nymphal development on different hosts in the field

Results on survival to adult and the average last instar reached, are shown in Table 9. Mango and cashew shoots appeared to be the best hosts. Only one nymph on mango shoots and another on cashew shoots developed to adults. The development on mango and cashew shoots showed, with regard to the last instar reached, significantly the best results [(ANOVA) $\mathbf{F_{9,80}=2.95, P<0.05}$].

No significant varietal effect was revealed between the five different carambola varieties ($\mathbf{F_{4,44}=0.07, P>0.05}$).

Comparison: Laboratory vs. Field trials:

The data for the nymphal development on avocado, carambola (5 varieties), cashew and mango (BALF-program) were compared for field and laboratory trials. Analysis of survival to

adult [(ANOVA) $F_{1,384}=2.57$, $P<0.05$] indicated no difference in laboratory and field trials. The developmental progression in the laboratory was significantly better than in the field trials ($F_{1,384}=9.65$, $P<0.01$).

4.3 Feeding frequency and feeding duration experiments

Feeding frequency and feeding duration of second instar nymphs on different hosts including four different papaya varieties

A) FEEDING FREQUENCY AND FEEDING DURATION ON DIFFERENT HOSTS

There is a very strong positive correlation between the number of feeding sessions and feeding duration (r = 0.9088) (KÖHLER et al., 1984) and this is shown in Figure 31.

Table 10: Feeding frequency and feeding duration on different host plants

HOST PLANTS	N	AVERAGE FEEDING SESSIONS PER DAY	AVERAGE FEEDING TIME PER DAY (in minutes)
Banana	6	1.8 **a***	41.00 **b**
Cashew plants	6	1.25 **a**	29.35 **b**
Cassava plants	3	3.4 **a**	84.67 **a,b**
French beans	21	2.19 **a**	65.27 **b**
Mango plants	3	1.70 **a**	30.50 **b**
Mock orange	3	2.73 **a**	81.50 **a,b**
Papaya plants	18	2.89 **a**	103.64 **a**

N= number of replicates x number of days

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

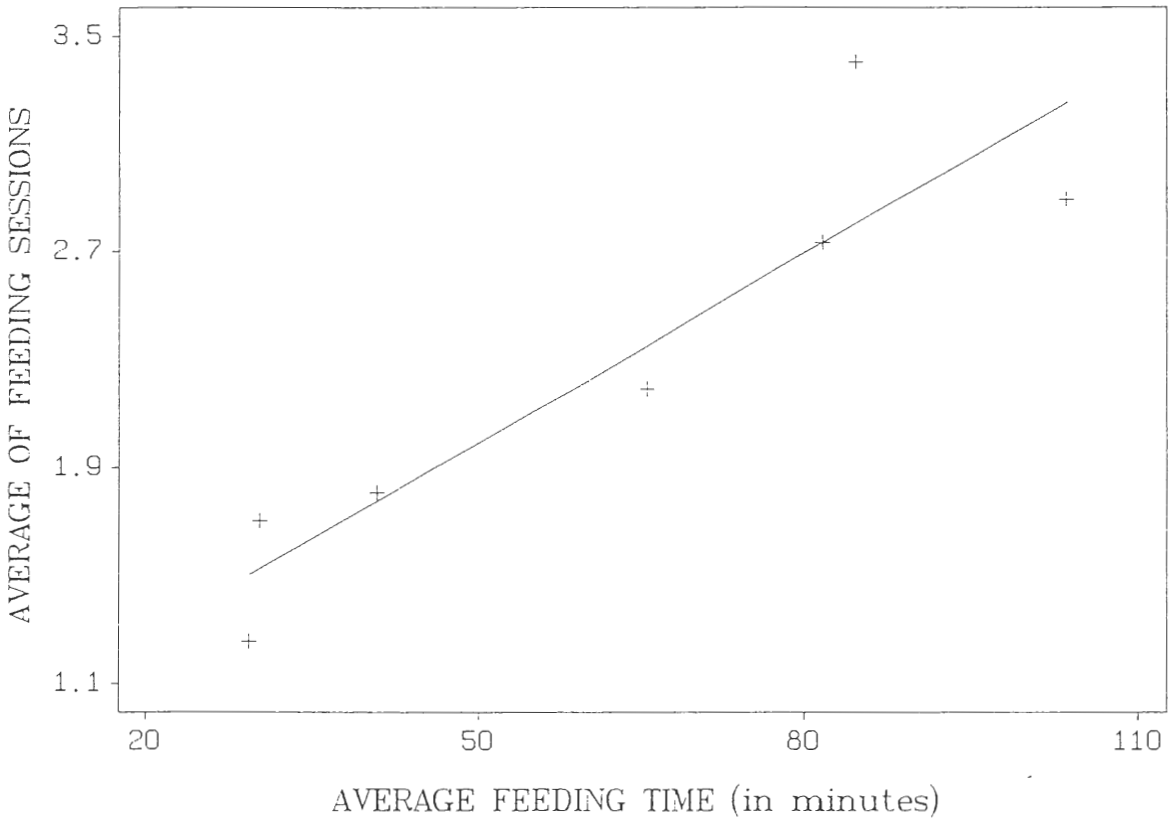

Figure 31: Correlation between the number of feeding sessions and the total feeding time

Table 11: Feeding frequency and total feeding duration on different papaya varieties

DAY	VARIETY	AVERAGE NO OF FEEDING SESSIONS PER DAY	AVERAGE FEEDING TIME PER SESSION (in minutes)
1	**2 = SL91-4B**	4.80 **a***	232.50 **a**
	3 = CB87-1-1	2.20 **b**	91.50 **b**
	4 = GD3-1-19-2 Parent	1.80 **b**	51.00 **b**
	7 = B 1	1.85 **b**	59.88 **b**
2	**2 = SL91-4B**	5.10 **a**	154.50 **a**
	3 = CB87-1-1	2.25 **b**	87.75 **a**
	4 = GD3-1-19-2 Parent	4.00 **a,b**	101.25 **a**
	7 = B 1	3.00 **b**	114.50 **a**
3	**2 = SL91-4B**	2.50 **a**	84.00 **a**
	3 = CB87-1-1	2.40 **a**	65.50 **a**
	4 = GD3-1-19-2 Parent	2.00 **a**	67.50 **a**
	7 = B 1	2.20 **a**	54.00 **a**
Total for 3 days			
1-3	**2 = SL91-4B**	12.40 **a**	471.00 **a**
	3 = CB87-1-1	6.20 **b**	225.00 **b**
	4 = GD3-1-19-2 Parent	6.60 **b**	186.00 **b**
	7 = B 1	6.19 **b**	197.40 **b**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

The results of the feeding frequency and feeding duration experiments are shown in Table 10. Cassava plants, papaya plants and mock orange were the hosts with the most feeding sessions, there was no significant difference in feeding frequency on the various hosts

[(ANOVA) $F_{6,50}$=2.27, P=0.051] at a significance level of 5 %. The feeding time on papaya plants was significantly longer than on french beans, bananas, mango plants and cashew plants (**$F_{6,50}$=3.26, P=0.009**).

B) FEEDING FREQUENCY AND DURATION ON FOUR PAPAYA VARIETIES

The results of the feeding frequency and feeding duration are shown in Table 11.

When results were analysed on a day-by-day basis, the feeding duration on the first day, on the variety 'SL91-4B' was significantly longer [(ANOVA) **$F_{3,30}$=9.84, P=0.0001**] and the number of feeding sessions significantly greater (**$F_{3,30}$=6.08, P=0.0023**) than on the other varieties. On the second day there was no significant difference in the feeding time (**$F_{3,26}$=1.54, P=0.2285**), but the number of feeding sessions was significantly higher (**$F_{3,26}$=4.96, P=0.0074**) on the variety 'SL91-4B' than on the varieties 'CB87-1-1' and 'B1 (local male parent 2nd year/PRD 31/12/91)'. On the third day, there was neither a significant difference in the feeding time (**$F_{3,25}$=0.35, P=0.7887**) nor in the number of feeding sessions (**$F_{3,25}$=0.16, P=0.9198**).

When the three days were analysed together, feeding time on the variety 'SL91-4B' was significantly longer (**$F_{3,30}$=6.94, P=0.0011**) and the number of feeding sessions significant greater (**$F_{3,30}$=6.57, P=0.0015**) than on the other varieties.

Feeding frequency and feeding duration on mock orange fruit and french beans

On the first day only two, on the second day none and on the third day four out of the five nymphs were feeding (one nymph died). During the first two days nymphs were feeding only on mock orange fruit. This experiment showed an obvious preference for mock orange fruit in comparison to french beans. The average feeding frequency and duration on both hosts are shown in Table 12.

Table 12: Feeding frequency and feeding duration on mock orange fruit and french beans

DAY	N	TREATMENT	FEEDING SESSION			FEEDING DURATION (in minutes)		
			Mean	C 95 %	S.D.	Mean	C 95 %	S.D.
1	5	Mock orange	1.20	-1.49 - 3.89	2.17	42.00	-46.74 - 130.74	71.47
1	5	French beans	0	0	0	0	0	0
2	5	Mock orange	0.2	-0.36 - 0.76	0.45	6.00	-10.66 - 22.66	13.42
2	5	French beans	0	0	0	0	0	0
3	4	Mock orange	2.25	1.45 - 3.05	0.5	97.5	18.34 - 176.66	49.75
3	4	French beans	0.25	-0.55 - 1.05	0.5	3.75	-8.18 - 15.68	7.50

N = number of nymphs

FEEDING SESSION: Mean = average feeding sessions per nymph, per day

FEEDING DURATION: Mean = average feeding time per nymph, per day

C 95 % = confidence interval at 95 %

Feeding frequency and feeding duration on different maturity stages of carambola fruit (cv. 'Thai Knight') and mock orange fruit

A) CARAMBOLAS (THAI KNIGHT) OF FIVE DIFFERENT MATURITY STAGES

The average number of visits or feeding sessions by nymphs on different carambola varieties is shown in Table 13. The exact differentiation between „just visiting" and feeding was unfortunately not possible in this experiment without disturbing the nymphs.

On the first and second day, the average number of visits or feeds on large green carambola (8 cm) was higher than on all other sizes of carambolas. On the third day the average number of visits or feeds was the highest on more mature carambolas (9 cm).

A statistical analysis of the results was not possible.

Table 13: Number of visits and feeding on carambolas of different size

Day	TREATMENT	N	AVERAGE NO. OF VISITS	C 95 %	S.D.
1	Carambola 3 cm	5	0.20	-0.35 - 0.76	0.45
	Carambola 5 cm	5	0	0	0
	Carambola 7 cm	5	0.60	-0.51 - 1.71	0.89
	Carambola 8 cm	5	2.00	-1.04 - 5.04	2.44
	Carambola 9 cm	5	0.20	-0.36 - 0.76	0.44
	Cage	5	6.00	2.17 - 9.83	3.08
2	Carambola 3 cm	5	0	0	0
	Carambola 5 cm	5	0.20	-0.36 - 0.76	0.45
	Carambola 7 cm	5	1.00	-1.15 - 3.15	1.73
	Carambola 8 cm	5	1.60	-0.28 - 3.48	1.52
	Carambola 9 cm	5	0.60	-0.08 - 1.28	0.55
	Cage	5	5.80	2.24 - 9.36	2.86
3	Carambola 3 cm	5	0.80	-0.24 - 1.84	0.84
	Carambola 5 cm	5	0.60	-0.08 -1.28	0.55
	Carambola 7 cm	5	0.20	-0.36 - 0.76	0.45
	Carambola 8 cm	5	1.20	0.16 - 2.24	0.84
	Carambola 9 cm	5	2.00	-1.51 - 5.51	2.83
	Cage	5	4.20	1.81 - 6.59	1.92

C 95 % = confidence interval at 95 %

B) NYMPHS AND ADULTS ON THREE DIFFERENT MATURITY STAGES OF MOCK ORANGE FRUIT

The average number of feeds on mock orange fruit of different stages by nymphs and adults is shown in Table 14 and Table 15.

Nymphs:

On mock orange, on all three days, the feeding duration was greater on large green fruit than on small fruit, red fruit or leaf stalks and fruit stalks. The feeding activity was greater on small green fruit than on red fruit. The fruit was preferred to the vegetative parts, although on the second and third day the fruit stalks were more important than leaf stalks.

Table 14: Feeding on different stages of mock orange fruit - I

Day	Insect stage	Mock orange	Average feeding duration (% of observation time)	C 95 %	S.D.
1	Nymphs	Fruit 1	9.00 min. (1.88%)	-4.74 - 22.74	29.36
		Fruit 2	93.00 min. (19.38%)	37.98 - 148.02	117.57
		Fruit 3	6.00 min. (1.25%)	-6.56 - 18.56	26.83
		Fruit stalks	6.00 min. (1.25%)	-2.64 - 14.64	18.46
		Leaf stalks	9.00 min. (1.88%)	-1.29 - 19.29	21.98
2	Nymphs	Fruit 1	18.00 min. (3.75%)	-2.57 - 38.58	43.96
		Fruit 2	33.00 min. (6.88%)	3.51 - 62.49	63.00
		Fruit 3	9.00 min. (1.88%)	-1.29 - 19.29	21.98
		Fruit stalks	21.00 min. (4.38%)	2.16 - 39.84	40.25
		Leaf stalks	0 min. (0%)	0	0
3	Nymphs	Fruit 1	21.00 min. (4.38%)	-1.82 - 43.82	48.76
		Fruit 2	24.00 min. (5.00%)	7.20 - 40.80	35.90
		Fruit 3	0 min.(0%)	0	0
		Fruit stalks	3.00 min. (0.63%)	-3.28 - 9.28	13.42
		Leaf stalks	0 min.(0%)	0	0
1	Adults	Fruit 1	15.00 min. (3.13%)	-0.45 - 30.45	33.01
		Fruit 2	111.00 min. (23.13%)	63.42 - 158.58	101.67
		Fruit 3	33.00 min. (6.88%)	4.96 - 61.04	59.92
		Fruit stalks	18.00 min. (3.75%)	1.96 - 34.04	34.27
		Leaf stalks	6.00 min. (1.25%)	-2.64 - 14.64	18.47
2	Adults	Fruit 1	12.00 min. (2.50%)	-5.29 - 29.29	36.94
		Fruit 2	66.00 min. (13.75%)	34.57 - 97.43	67.15
		Fruit 3	42.00 min. (8.75%)	4.33 - 79.67	80.50
		Fruit stalks	9.00 min. (1.88%)	-1.29 - 19.29	21.98
		Leaf stalks	3.00 min. (0.63%)	-3.28 - 9.28	13.42
3	Adults	Fruit 1	27.00 min. (5.63%)	-2.49 - 56.49	63.00
		Fruit 2	96.00 min. (20.00%)	34.61 - 157.39	131.16
		Fruit 3	39.00 min. (8.13%)	5.81 - 72.19	70.93
		Fruit stalks	21.00 min. (4.38%)	-1.82 - 43.82	48.76
		Leaf stalks	0 min. (0%)	0	0%

C 95 % = confidence interval at 95 %

Fruit 1 = small green fruit

Fruit 2 = large green fruit

Fruit 3 = red fruit

Table 15: Feeding on different stages of mock orange fruit - II

Day	Insect stage	Mock orange	Average feeding duration (% of observation time)	C 95 %	S.D.
1	Nymphs + Adults	Fruit 1	12.00 min. (2.50%)	2.09 - 21.90	30.98
		Fruit 2	102.00 min. (21.25%)	67.18 - 136.82	108.87
		Fruit 3	19.50 min. (4.06%)	4.21 - 34.79	47.82
		Fruit stalks	12.00 min. (2.50%)	3.09 - 20.91	27.85
		Leaf stalks	7.50 min. (1.56%)	1.07 - 13.93	20.10
2	Nymphs + Adults	Fruit 1	15.00 min. (3.13%)	2.15 - 27. 85	40.19
		Fruit 2	49.50 min. (10.31%)	28.26 - 70.74	66.41
		Fruit 3	25.50 min. (5.31%)	6.12 - 44.88	60.59
		Fruit stalks	15.00 min. (3.31%)	4.58 - 25.42	32.58
		Leaf stalks	1.50 min. (0.31%)	-1.53 - 4.53	9.49
3	Nymphs + Adults	Fruit 1	24.00 min. (5.00%)	6.19 - 41.81	55.69
		Fruit 2	60.00 min. (12.50%)	27.48 - 92. 52	101.68
		Fruit 3	19.50 min. (4.06%)	2.45 - 36. 55	53.30
		Fruit stalks	12.00 min. (2.50%)	0.34 - 23.66	36.46
		Leaf stalks	0 min. (0%)	0	0

C 95 % = confidence interval at 95 %

Fruit 1 = small green fruit

Fruit 2 = large green fruit

Fruit 3 = red fruit

Adults:

With adults, on all three days the feeding duration was also the longest on large green fruit. Red fruit always were preferred to small green fruit. Fruit stalks and leaf stalks were again less important with adults, although fruit stalks were preferred to leaf stalks.

Nymphs and adults:

Generally the large green fruit were the preferred food source in mock orange bushes for nymphs and adults.

A statistical analysis of the results was not possible.

4.4 Studies on oviposition rates

Oviposition rates on five different carambola varieties and french beans

The average number of eggs laid on different carambolas and french beans were the following:

French beans:		91
Carambola:	B10:	6
	Fwang Tung:	3
	Thai Knight:	0
	B2:	0
	Arkin:	0

The average number of eggs laid was significantly higher on green beans than on any of the carambola varieties [(ANOVA) $\mathbf{F_{5,5}=665.93, P=0.000}$]. When the egg production on the different varieties of carambolas was compared, no significant difference showed up ($\mathbf{F_{4,5}=3.60, P=0.0963}$).

Oviposition rates on different carambola varieties in the field

No eggs were laid in the field experiment, even though eggs of the field population have been recorded on carambolas at other occasions.

Oviposition rates on different carambola varieties after rearing on french beans (until the beginning of oviposition)

The average number of eggs for the different treatments laid during the first two weeks after the first oviposition are shown in Table 16.

Table 16: Average number of laid eggs on carambola after a different diet until the beginning of the oviposition

TIME OF EXPERIMENT	DIET	AVERAGE NUMBER OF EGGS
Week 1	French beans	16.5 **a***
	Arkin	10.0 **b,c**
	B2	14.0 **a,b**
	B10	8.5 **c**
	Fwang Tung	6.5 **c**
	Thai Knight	11.5 **a,b,c**
Week 2	French beans	37.0 **a**
	Arkin	15.5 **b,c**
	B2	18.5 **b**
	B10	8.5 **c**
	Fwang Tung	7.5 **c**
	Thai Knight	12.0 **b,c**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

After the first eggs were laid and, in case of carambola, the diet was changed, the average number of eggs laid in the first week was significantly higher on french beans, 'B2' and 'Thai Knight', than on 'B10' and 'Fwang Tung' [(ANOVA) **$F_{5,6}$=5.35, P=0.0324**].

In the second week, the number of eggs on french beans was significantly higher than the number of eggs laid on any carambola variety (**$F_{5,6}$=19.15, P=0.0013**).

In one case, on the variety 'Fwang Tung', the female commenced egg laying when changed back to beans after she had stopped laying for two weeks on the carambola.

Oviposition rate of adults after different nymphal diet

The average number of eggs of adults on the two different nymphal diets are shown in Table 17.

Table 16: Average number of laid eggs on carambola after a different diet until the beginning of the oviposition

TIME OF EXPERIMENT	DIET	AVERAGE NUMBER OF EGGS
Week 1	French beans	16.5 **a***
	Arkin	10.0 **b,c**
	B2	14.0 **a,b**
	B10	8.5 **c**
	Fwang Tung	6.5 **c**
	Thai Knight	11.5 **a,b,c**
Week 2	French beans	37.0 **a**
	Arkin	15.5 **b,c**
	B2	18.5 **b**
	B10	8.5 **c**
	Fwang Tung	7.5 **c**
	Thai Knight	12.0 **b,c**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

After the first eggs were laid and, in case of carambola, the diet was changed, the average number of eggs laid in the first week was significantly higher on french beans, 'B2' and 'Thai Knight', than on 'B10' and 'Fwang Tung' [(ANOVA) **$F_{5,6}$=5.35, P=0.0324**].

In the second week, the number of eggs on french beans was significantly higher than the number of eggs laid on any carambola variety (**$F_{5,6}$=19.15, P=0.0013**).

In one case, on the variety 'Fwang Tung', the female commenced egg laying when changed back to beans after she had stopped laying for two weeks on the carambola.

Oviposition rate of adults after different nymphal diet

The average number of eggs of adults on the two different nymphal diets are shown in Table 17.

Table 18: Oviposition rate and longevity on different hosts

HOST	AVERAGE NUMBER OF EGGS		AVERAGE LONGEVITY
	after 4 weeks	after 6 weeks	(in days)
Green beans	70.5 **a****	91.0 **a****	35.50 **b,c***
Carambola - Arkin	0 **b**	0 **b**	50.00 **b**
Carambola - B2	0 **b**	0 **b**	49.50 **b**
Carambola - B10	-	-	45.75 **b,c**
Carambola - Fwang Tung	-	-	12.75 **c**
Carambola - Thai Knight	0 **b**	1.5 **b**	18.00 **c**
Cassava plants	-	-	15.25 **b,c**
Cashew plants	0 **b**	6.0 **b**	16.50 **b,c**
Mango plants	-	-	12.75 **c**
Mock orange	8.5 **b**	15.0 **b**	91.50 **a**
Papaya plants	12.0 **b**	22.5 **b**	28.00 **b,c**

In columns means followed by the same letter are not significantly different (ANOVA, F-test; $^{**}P\leq0,05$);($^{*}P\leq0,1$).

Oviposition rates with host plant choice

During the time the insects in the insectary were observed, no offspring of the adult bugs were recorded.

4.5 Population studies

Population monitoring in papayas

The field population of *A.l. lutescens* nymphs and adults during the observation period started to increase in early March. The population reached a peak in the middle of March and then decreased in late April to early May. Effectively, over the eight to nine months observation period, bugs were really only present for about two months (Fig. 32).

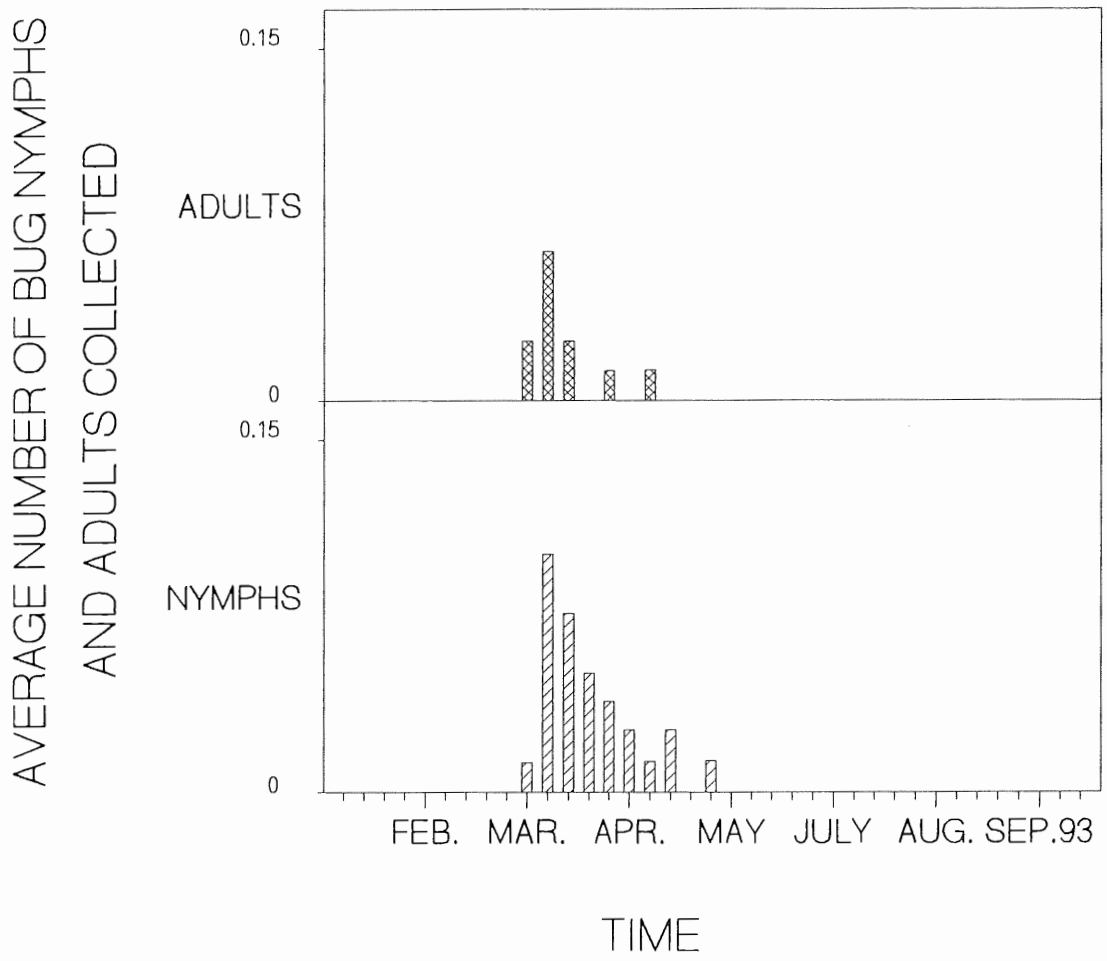

Figure 32: *Amblypelta* population in papaya

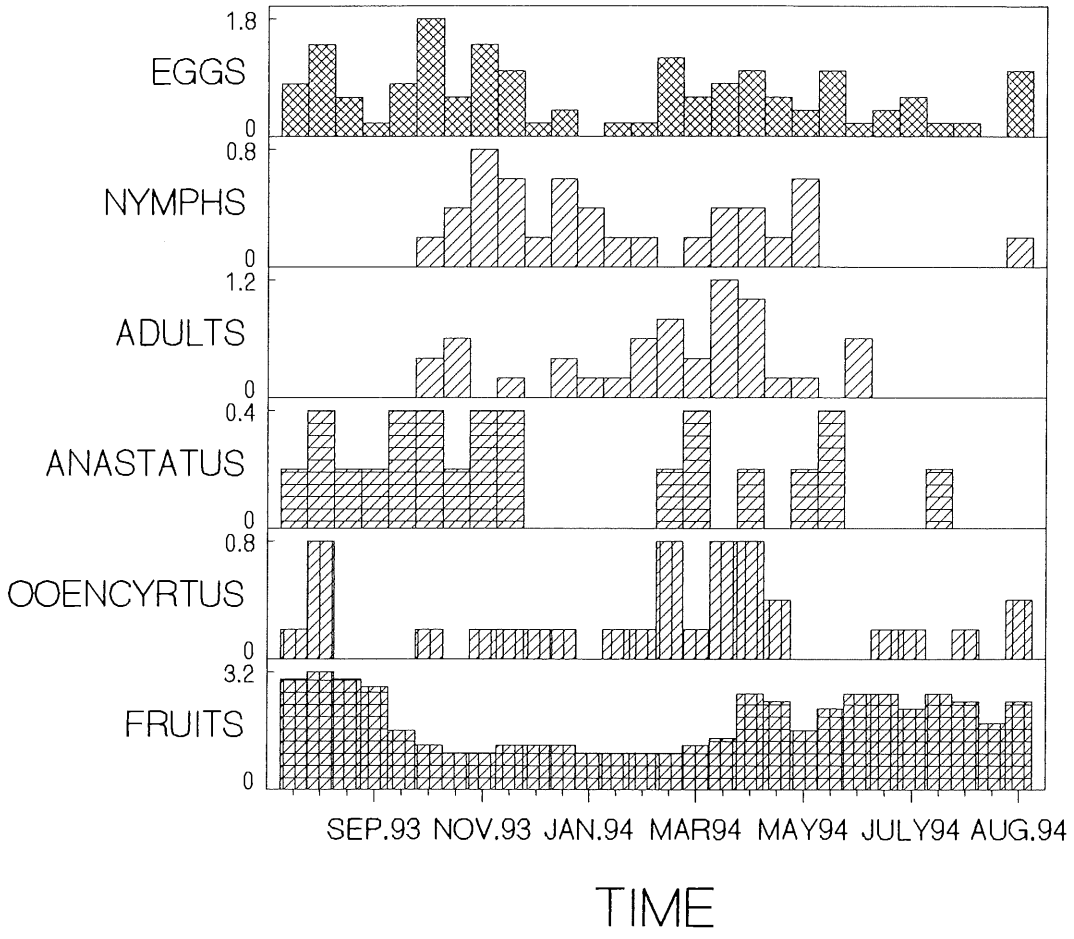

Figure 33: Population of *Amblypelta* and their parasitoids in mock orange bushes

Population monitoring in mock orange bushes

The different locations not looked at separately. Adult bugs were mainly present in mock orange, between October and June. Nymphs were found between October and May and eggs were collected throughout the year. These observation suggest that bugs are present all year, but between June and October they are at a fairly low population density.

The population of nymphs seems to have a first peak in November and a second peak in May, before the population dropped completely. The population of adults had only one peak, between March and April. A peak in the number of eggs collected occurred in October (Fig. 33). The total collection was 35 adults, 28 nymphs and 89 eggs.
Out of a total of 89 eggs, 17 where damaged, former occupation by nymph or parasitoids could not be determined or the egg was lost.

Out of the remaining 72 eggs,

9.7 % (7)	were infertile		
15.3 % (11)	had bug nymphs hatching		
75.0 % (54)	were parasitised:	0.0 % (0)	*Gryon* sp.
		30.6 % (22)	*Anastatus* sp.
		44.4 % (32)	*Ooencyrtus caurus*

Anastatus was mostly collected between August and December and *Ooencyrtus caurus* had a peak in August and a second peak between February and May (Fig. 33). There was no correlation between the quantity of fruit available and the presence of different stages of *A.l. lutescens* or the parasitoids (Table 19).

Table 19: Correlation between the fruit available and the presence of *Amblypelta* and parasitoids

DEVELOPMENT STAGE OF BUGS/ PARASITOIDS	CORRELATIONS (Pearson) (r=)
A.l. lutescens : eggs	0.0730
nymphs	-0.0374
adults	-0.0047
Parasitoids: *Anastatus*	0.0277
Ooencyrtus caurus	0.0979

4.6 Studies on the incidence of bug damage in different papaya and carambola varieties in the field

Varietal resistance, tolerance or preference studies included observations on bug damage in different crop varieties in the field. Field observations were undertaken to compliment laboratory findings on papaya and carambola varieties.

As part of this study papaya plants were monitored over a period of about eight months and carambola fruit were exposed to *A.l. lutescens* nymphs for a week at a time, and the damage in the different varieties was compared.

Damage in young papaya plants of eight different varieties

There was no damage on any plant for the first ten weeks. Detailed results on the evaluation of damage level, after rating the damage by using the criteria described on page 55, are shown in Table 20.

In week 14, the damage was the highest on the variety 'GD3-1-19-2Parent(Y 2)/PRD 2/1/92' and the lowest on 'PZ90-1XPZ90-1'. There was no significant varietal difference in the damage ($\mathbf{F_{7,28}=1.05, P=0.4197}$).

Likewise in week 19 ($F_{7,28}$=**1.65, P=0.1620**), in week 24 ($F_{7,28}$=**1.65, P=0.1620**) and week 29 ($F_{7,28}$=**1.47, P=0.2180**) there was no significant difference in the level of damage in the different papaya varieties.

Over all, the variety 'PZ90-XPZ90-1' had the least damage, however the difference in comparison to the other varieties was not significant.

Table 20: Damage level on different papaya varieties

WEEK	VARIETIES	DAMAGE LEVEL
14	1 = SL91 - 3C	0.90
	2 = SL91 - 4B	0.80
	3 = CB87 - 1 - 1	0.70
	4 = GD3 - 1 - 19 - 2 Parent(Y 2)/PRD2/1/92	1.00
	5 = GD3 - 1 - 19 - 2 oval true line	0.60
	6 = Thai Red	0.55
	7 = B1 (local male parent 2nd year/PRD 31/12/91)	0.70
	8 = PZ90 - 1 X PZ90 - 1	0.20
19	1 = SL91 - 3C	1.30
	2 = SL91 - 4B	0.80
	3 = CB87 - 1 - 1	0.70
	4 = GD3 - 1 - 19 - 2 Parent(Y 2)/PRD2/1/92	1.35
	5 = GD3 - 1 - 19 - 2 oval true line	1.25
	6 = Thai Red	0.70
	7 = B1 (local male parent 2nd year/PRD 31/12/91)	0.85
	8 = PZ90 - 1 X PZ90 - 1	0.35
24	1 = SL91 - 3C	1.30
	2 = SL91 - 4B	0.80
	3 = CB87 - 1 - 1	0.70
	4 = GD3 - 1 - 19 - 2 Parent(Y 2)/PRD2/1/92	1.35
	5 = GD3 - 1 - 19 - 2 oval true line	1.25
	6 = Thai Red	0.70
	7 = B1 (local male parent 2nd year/PRD 31/12/91)	0.85
	8 = PZ90 - 1 X PZ90 - 1	0.35
29	1 = SL91 - 3C	1.30
	2 = SL91 - 4B	0.80
	3 = CB87 - 1 - 1	0.70
	4 = GD3 - 1 - 19 - 2 Parent(Y 2)/PRD2/1/92	1.35
	5 = GD3 - 1 - 19 - 2 oval true line	1.25
	6 = Thai Red	0.85
	7 = B1 (local male parent 2nd year/PRD 31/12/91)	0.85
	8 = PZ90 - 1 X PZ90 - 1	0.35

There was no correlation between the damage and the number of flowers or the damage and the number of fruit for any of the varieties or flower gender (Table 21).

Table 21: Correlation between damage, number of flowers and fruit in the different varieties and genders of papaya plants

DAMAGE IN	IN CORRELATION TO (r=)	
	No. of flowers	No of fruit
Papaya variety		
SL 91 - 3C	-0.5345	-0.3971
SL91 - 4B	-0.7517	-0.6511
CB87 - 1 - 1	-0.2831	-0.5102
GD3-1-19-2Parent (Y2)/PRD2/1/92	-0.3377	-0.4966
GD3-1-19-2 oval true line	-0.5850	-0.400
Thai red	-0.3962	-0.4141
B1 (local male 2nd year/PRD 31/12/91)	-0.2050	-0.1748
PZ 90 - 1 X PZ 90 - 1	-0.1799	-0.2308
Gender of plant		
female	-0.5017	-0.4223
male	0.2686	-0.0297

This experiment showed a significant block effect (Table 22). In week 14 the damage in block 3 was significantly higher than in all other blocks. In week 19, week 24 and week 29 the damage in block 3 was similar to block 2 but significant different from all other blocks. Blocks 2 and 3 were adjacent to an avocado orchard which showed some damage. It therefore can be assumed that the bugs moved from avocado to papaya once they became more attractive.

Table 22: Damage in different blocks of the papaya orchard

WEEK	DAMAGE	ANOVA
14	Block 1=0.00 Block 2=0.63 Block 3=1.44 Block 4=0.59 Block 5=0.75	**$F_{4,39}$=7.37, P=0.0003**
19	Block 1=0.00 Block 2=1.19 Block 3=1.81 Block 4=0.75 Block 5=0.81	**$F_{4,39}$=9.24, P=0.0001**
24	Block 1=0.00 Block 2=1.19 Block 3=1.81 Block 4=0.75 Block 5=0.81	**$F_{4,39}$=9.24, P=0.0001**
29	Block 1=0.09 Block 2=1.19 Block 3=1.81 Block 4=0.75 Block 5=0.81	**$F_{4,39}$=7.85, P=0.0002**

Damage on five different carambola varieties

The average number of feeding marks on the different carambola varieties or sizes were as follows:

Thai Knight:	11.80	small fruit:	5.49
Fwang Tung:	4.10	large fruit:	2.37
B2:	2.24		
Arkin:	1.21		
B10:	0.28		

The number of feeding marks was significantly higher in the variety 'Thai Knight' than on the other varieties (**$F_{4,28}$=12.66, P=0.000**) and significantly higher on small fruit than on large fruit (**$F_{1,28}$=7.21, P=0.0120**).

The results therefore confirm previous observations, that the variety 'Thai Knight' appears to be the most susceptible variety of those studied (FAY; 1991a).

4.7 Parasitoids of *Amblypelta l. lutescens*

The three parasitoids discovered in November 1992 (FAY & HUWER, 1993), are considered to be potential control agents against *A.l. lutescens*. To pursue a study of their biology and their effect on *A.l. lutescens*, they needed to be examined first under laboratory conditions.

4.7.1 Effect of the age of host eggs on parasitoids

I. Preliminary test with *Ooencyrtus caurus*

The percentages of parasitised eggs of different age are shown in Table 23:

Table 23: Parasitism of bug eggs of different age by *Ooencyrtus caurus*

AGE OF EGGS	AVERAGE OF PARASITISED EGGS	CONFIDENCE INTERVAL (95 %)	S. D.
1 day	46.67 %	-29.23 - 122.56	30.55
2 days	6.67 %	-22.02 - 35.35	11.55
3 days	20.00 %	-66.05 - 106.05	34.64
4 days	46.67 %	17.98 - 75.5	11.55

Although there were great differences in the parasitism rates of eggs of different ages, significant differences could not be confirmed because of the enormously scattered results.

II. Preliminary test with *Ooencyrtus caurus* and *Anastatus* sp.

Ooencyrtus caurus:

Over the whole day of the first series of the experiment, 2 day old eggs were visited significantly more often than eggs of any other age [(ANOVA) $\mathbf{F_{4,318}=1.71, P=0.0205}$].

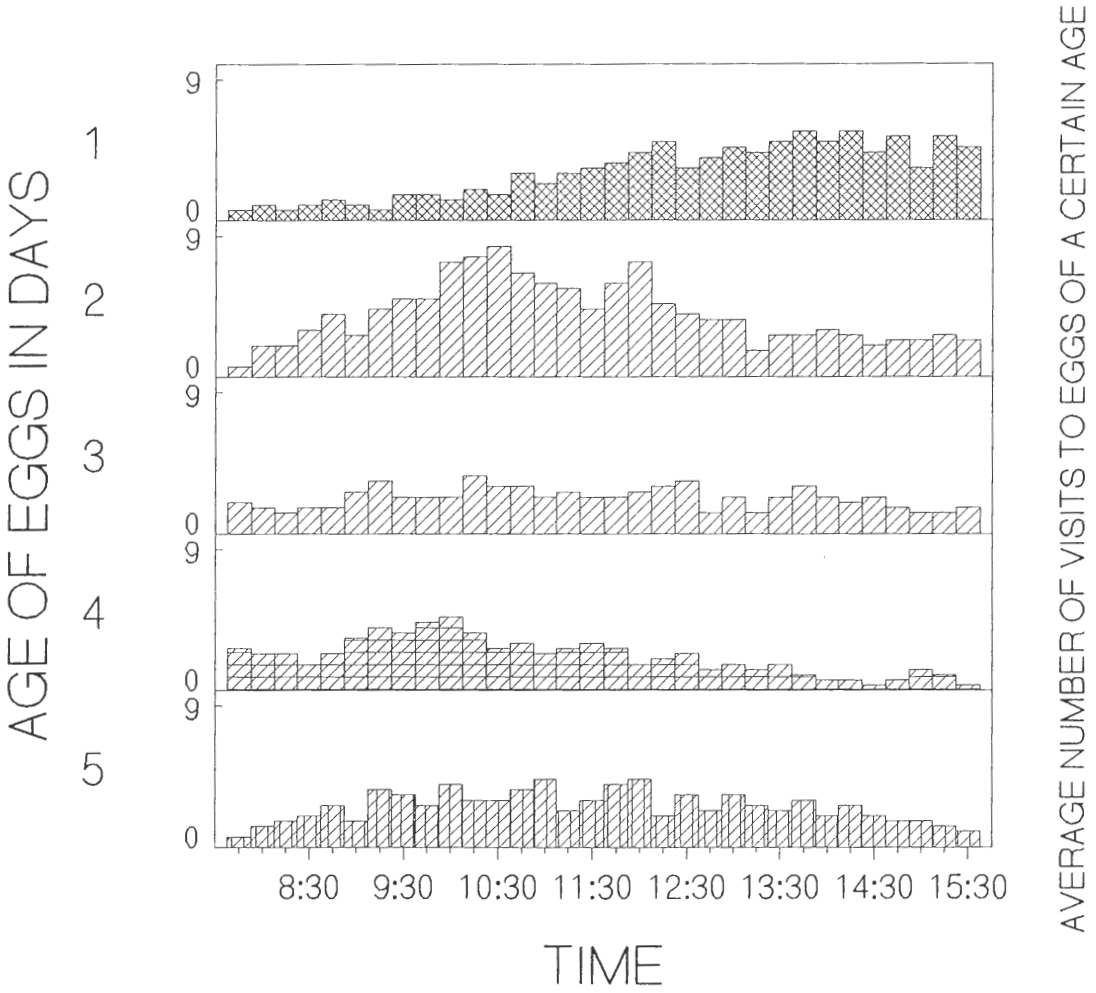

Figure 34: Attractiveness of host eggs of different age to *Ooencyrtus*

Between 8:30 h and 13:00 h the 2 day old eggs were visited most by the wasps, with decreasing a little later in the day (Fig. 34). One day old eggs were not visited very frequently until about 11:30 h. Afterwards the visits increased to a higher level. It appears that the young eggs, where the bug embryos have developed to a certain stage within the first two days are the most attractive to *O. caurus*. Therefore the 2 day old eggs were visited first, while in the meantime the 1 day old eggs developed to the stage where they became more attractive (Fig. 34).

The average percentages of parasitised eggs of different ages are shown in Table 24.

Table 24: Average percentage of parasitism in eggs of different age

PARASITOID	**AGE OF EGG IN DAYS**	**AVERAGE PARASITISM IN %**		
		REPLICATES		
		1	**2**	**1+2**
Ooencyrtus caurus	1	91.67	77.78	84.72
	2	100.00	46.66	73.33
	3	63.54	100.00	80.00
	4	86.67	66.67	76.67
	5	93.33	83.33	88.33

When the two different series of the experiment were analysed together, there was no significant difference in the parasitism of different aged eggs [(ANOVA) $\mathbf{F_{4,18}=0.13}$, **P=0.9634**]. When both series were analysed separately, no significant difference showed up in the parasitism of different aged eggs, neither in the first series ($\mathbf{F_{4,7}=2.13}$, **P=0.1801**), nor in the second ($\mathbf{F_{4,7}=2.75}$, **P=0.1149**).

Anastatus sp.:

The average percentages of parasitised eggs of different age are shown in Table 25.

Table 25: Parasitism of bug eggs of different ages by *Anastatus* sp.

AGE OF EGGS	AVERAGE PARASITISM	CONFIDENCE INTERVAL (95 %)	S. D.
1 day	41.11 %	20.27 - 61.95	8.39
2 days	23.33 %	-39.18 - 85.85	25.17
3 days	20.00 %	-29.68 - 69.68	20.00
4 days	46.11 %	-27.53 - 119.75	29.64
5 days	0 %	0	0

Although there were great differences in the parasitism of eggs of different age, again significant differences could not be confirmed because of the enormously scattered results.

Choice of different aged host eggs with *Anastatus* sp. and *Ooencyrtus caurus*

Ooencyrtus caurus:

The average percentages of parasitised eggs of different age are shown in Table 26.

In the first series [(ANOVA) $\mathbf{F_{7,14}=0.70}$, **P=0.6742**] and the second series ($\mathbf{F_{7,14}=1.12}$, **P=0.4018**) of the experiment, as well as in the joint analysis of both series ($\mathbf{F_{7,32}=1.45}$, **P=0.3173**), *O. caurus* showed no preference for a particular age of *A.l. lutescens* eggs.

Anastatus sp.:

The average percentages of parasitised eggs of different age are shown in Table 26.

In the first series [(ANOVA) $\mathbf{F_{7,14}=2.00}$, **P=0.1275**] and the second series ($\mathbf{F_{7,14}=0.57}$, **P=0.7691**) of the experiment, as well as in the joint analysis of both series ($\mathbf{F_{7,32}=0.75}$, **P=0.6441**), as in the case of *O. caurus*, there was no significant difference in parasitism of eggs of different age.

Table 26: Average percentage of parasitism in bug eggs of different age

PARASITOID	AGE OF EGG IN DAYS	AVERAGE PARASITISM IN %		
		REPLICATES		
		1	2	1+2
Ooencyrtus caurus	1	50.00	88.33	69.17
	2	30.00	78.33	54.17
	3	0	35.56	17.78
	4	41.67	66.67	54.17
	5	33.33	65.00	49.17
	6	53.33	28.33	40.83
	7	66.67	58.33	62.50
	8	46.67	50.00	48.33
Anastatus sp.	1	35.00	20.00	27.50
	2	60.00	36.67	48.33
	3	28.33	26.67	27.50
	4	23.33	23.33	23.33
	5	41.67	0	20.83
	6	0	33.33	16.67
	7	44.44	21.67	33.06
	8	16.67	24.44	20.56

4.8 Control of *Amblypelta l. lutescens* with neem products

4.8.1 Effect of neem on nymphs

Effect of neem on the development of nymphs under laboratory rearing conditions

The nymphal mortality is shown in Table 27. The percentage of nymphal mortality was analysed for day 4, 10, 20, 40, 50 and 66. The survival to adults on the control with untreated beans was 13.7% and therefore significantly higher than on the neem treatment where none of the nymphs reached the adult stage [(ANOVA) $\mathbf{F_{3,42}=17.50, P= 0.0000}$].

Table 27: Effect of neem (GGO - 1:25) on nymphal mortality of *A.l. lutescens*

EXPERIMENT DAY	TREATMENT	MORTALITY IN %	ANOVA	
			$F_{3,42}$	P
4	Control	20.00	8.43	0.0002
	GGO-(1:25) - 1	62.67		
	GGO-(1:25) - 2	68.00		
	GGO-(1:25) - 3	70.00		
10	Control	36.00	14.67	0.0000
	GGO-(1:25) - 1	78.67		
	GGO-(1:25) - 2	86.67		
	GGO-(1:25) - 3	86.33		
20	Control	66.00	10.95	0.0000
	GGO-(1:25) - 1	89.78		
	GGO-(1:25) - 2	96.00		
	GGO-(1:25) - 3	93.00		
40	Control	84.00	15.32	0.0000
	GGO-(1:25) - 1	100.00		
	GGO-(1:25) - 2	100.00		
	GGO-(1:25) - 3	100.00		
50	Control	84.00	15.32	0.0000
	GGO-(1:25) - 1	100.00		
	GGO-(1:25) - 2	100.00		
	GGO-(1:25) - 3	100.00		
66	Control	85.67	18.03	0.0000
	GGO-(1:25) - 1	100.00		
	GGO-(1:25) - 2	100.00		
	GGO-(1:25) - 3	100.00		

The percentage mortality of nymphs on control and neem treatment is also demonstrated in Figure 35.

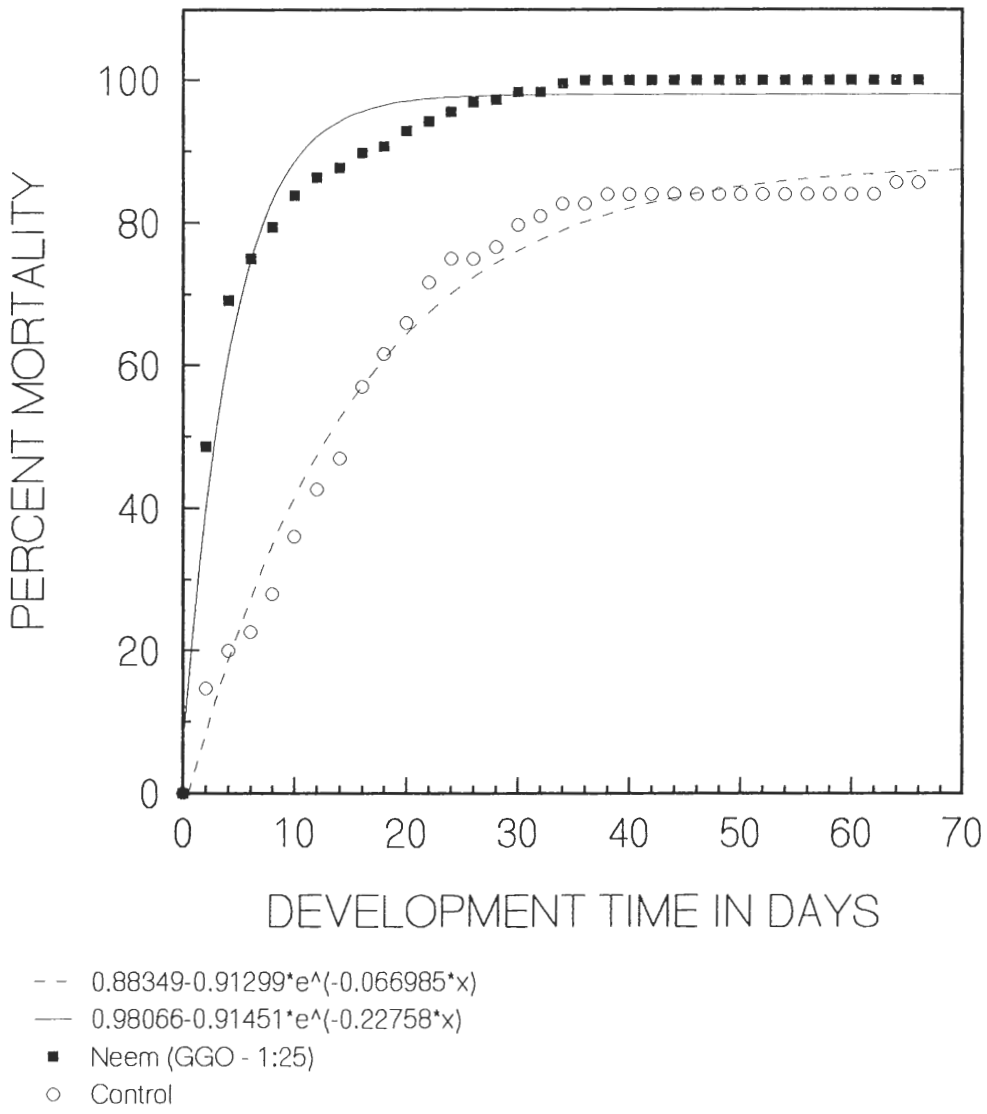

Figure 35: Development of nymphs on french beans with neem treatment

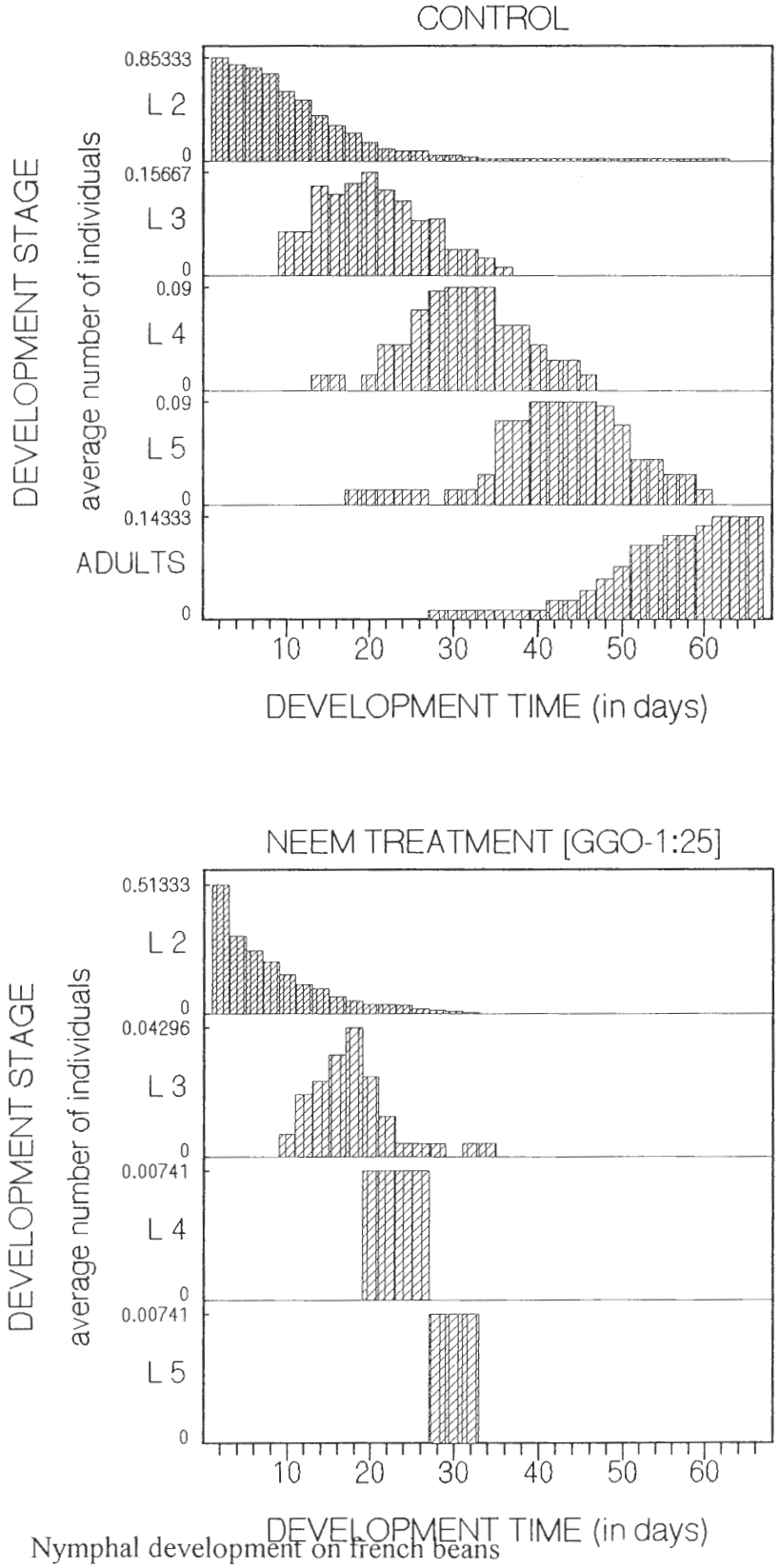

Figure 36: Nymphal development on french beans

The nymphal mortality in the treatment and control increased rapidly during the first 20 days. Later, the mortality increased more slowly. Nymphs on neem treatment all died within the 40 days of the experiment. After 66 days of the experiment, the difference in mortality between the control and neem treatments, was still significant (85.7% in control and 100.0% in neem treatment). Out of the 225 nymphs on neem treatment, 11 nymphs reached the third instar and only one nymph developed to the fifth instar.

The surviving nymphs in the control had developed to adults within 36 to 65 days. Figure 36 shows the development to different instars and adult on control and neem treatment over time. Considering only the small number of nymphs surviving the second instar in the neem treatment, the development time to fifth instar was similar in control and neem treatment.

Comparison of three different neem products in their effect on the development of nymphs under laboratory conditions

Results of the effect of different neem products on nymphal development (after two and ten weeks) are shown in Table 28.

Table 28: Nymphal mortality after application of three different neem products in the laboratory

TREATMENT	TIME	PERCENT	TIME	PERCENT
Control	2 weeks	24.50% **a***	10 weeks	51.50% **a**
GGO-(1:25)	2 weeks	76.17% **b**	10 weeks	100.00% **b**
PN-(1:25)	2 weeks	58.00% **c**	10 weeks	100.00% **b**
NA-(1:50)	2 weeks	96.00% **d**	10 weeks	100.00% **b**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

After two weeks the nymphal mortality for all treatments was significantly different [(ANOVA) $\mathbf{F_{3,27}=24.24, P=0.0000}$]. After ten weeks, the nymphs on all neem treatments died

and the mortality in these treatments was therefore significantly higher than in the control **($F_{3,27}$=23.65, P=0.0000)**.

Effect of neem on nymphs reared under ambient conditions

The neem treatment had an significant impact on nymphal mortality under ambient conditions for the first two week. After the fourth weeks almost all nymphs in the neem treatment died. Three out of the 40 nymphs in the neem treatment developed to the third instar and one nymph even reached the fourth instar. None of the nymphs on the neem treatment and only 10% in the control survived to adults. Details of mortality rates over the experiment time are shown in Table 29.

Table 29: Nymphal mortality on papaya plants treated with neem (GGO - 1:25) under ambient conditions

TIME in weeks	**TREATMENT**	**MORTALITY (%)**	**ANOVA**	
			$F_{1,3}$	**P**
2	Control GGO-(1:25)	47.5% 72.5%	75.00	**0.0032** sign. diff.
4	Control GGO-(1:25)	70.0% 95.0%	8.33	0.0632
6	Control GGO-(1:25)	82.5% 97.5%	9.00	0.0577
8	Control GGO-(1:25)	90.0% 100.0%	1.00	0.3910
10	Control GGO-(1:25)	90.0% 100.0%	1.00	0.3910
12	Control GGO-(1:25)	90.0% 100.0%	1.00	0.3910

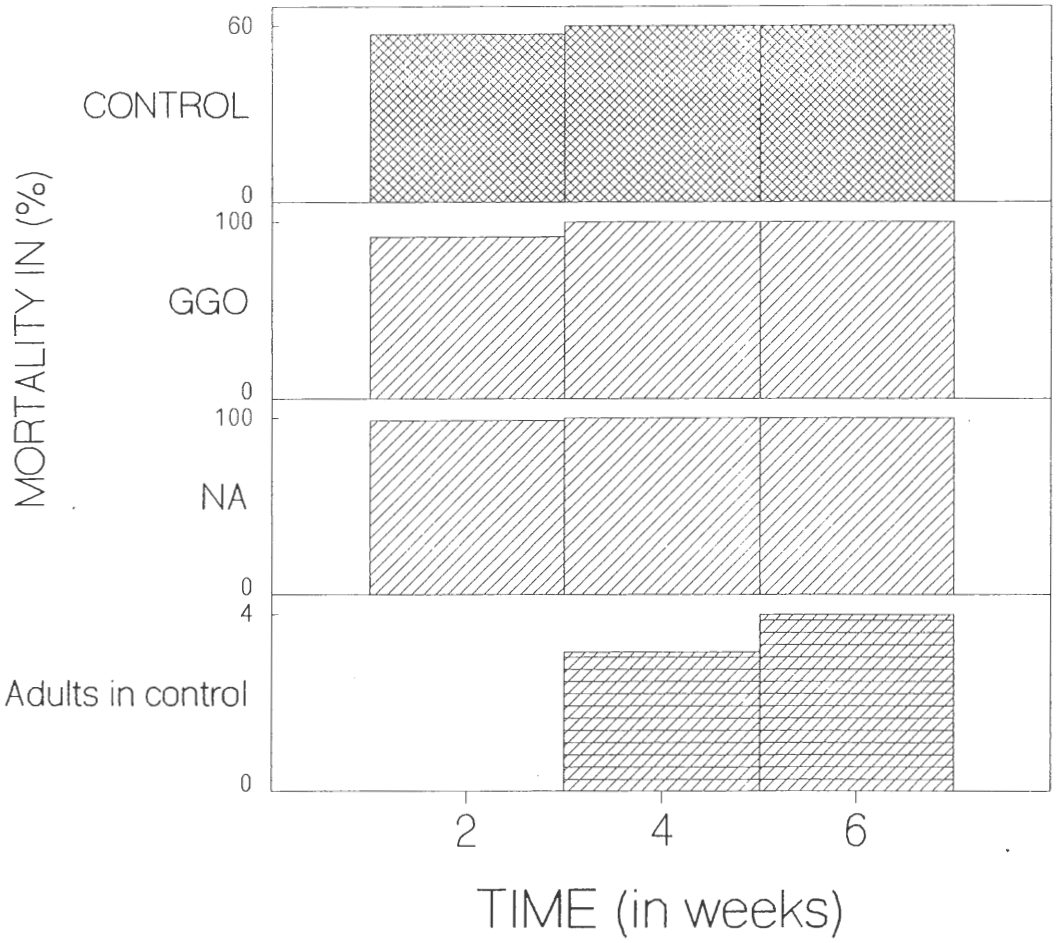

Figure 37: Nymphal development on papaya with neem treatment under ambient conditions

Comparison of the impact of two neem products on nymphal development under ambient conditions

The nymphal mortality in two neem treatments was significantly different from the mortality in the control after two and six weeks of the experiment, but there was no significant difference between both neem treatments (Table 30). In the GGO-(1:25) treatment, five out of 70 nymphs developed to third instar, one to fourth instar. All nymphs died within four weeks and none survived to adult.

Table 30: Nymphal mortality on papaya plants using two different neem products

TIME in weeks	TREATMENT	MORTALITY (%)	ANOVA	
			$F_{2,12}$	P
2	Control GGO-(1:25) NA-(1:50)	57.14% 91.43% 98.57%	10.66	**0.0022** sign. diff.
6	Control GGO-(1:25) NA-(1:50)	60.00% 100.00% 100.00%	13.44	**0.0009** sign. diff.

In the NA-(1:50) treatment, out of 70 nymphs one developed to fourth instar and died within four weeks. All other nymphs died in the second instar within the first two weeks of the experiment. In the control 40% of the nymphs developed to adults which emerged after four to six weeks. Details on nymphal mortality and survival to adults is shown in Figure 37.

Effectiveness of a neem product as an antifeedant against nymphs on french beans

The average percentage of beans with feeding evidence in the different treatments is shown in Table 31.

Table 31: Feeding evidence on french beans with neem treatment

TIME	TREATMENT	AVERAGE PERCENTAGE OF BEANS WITH FEEDING EVIDENCE
day 2	GGO-(1:25)	12.13 **b***
	Spirits	23.85 **a,b**
	Control	33.08 **a**
day 4	GGO-(1:25)	25.00 **a**
	Spirits	34.00 **a**
	Control	54.00 **a**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

After two days [(ANOVA) $\mathbf{F_{2,24}=5.35, P=0.0120}$] of the experiment, the feeding evidence on untreated french beans was significantly higher than on beans treated with GGO-(1:25), but there was no significant difference after four days ($\mathbf{F_{2,8}=3.98, P=0.0631}$). Feeding evidence on french beans treated with methylated spirits is not significantly different from the other two treatments.

Table 32: Number of feeding marks on bananas with different neem treatments

TIME	TREATMENT	AVERAGE NUMBER OF FEEDING MARKS
day 2	GGO-(1:25)	0.24
	PN-(1:25)	0
	Spirits	0.32
	Control	0.12
day 4	GGO-(1:25)	0.72
	PN-(1:25)	0.32
	Spirits	1.28
	Control	1.52

Testing the effectiveness of two different neem products on bananas

The average percentage of beans with feeding evidence in the different treatments is shown in Table 32. There was no significant difference in number of feeding marks between the various treatments after two [(ANOVA) $\mathbf{F_{3,12}=0.62, P=0.6152}$] or four days ($\mathbf{F_{3,12}=1.71, P=0.2177}$).

4.8.2 Effect of neem products on adult *Amblypelta l. lutescens*

Effect of neem products on oviposition rate - Experiment I

The average number of eggs laid per female on GGO-(1:25) treated and untreated french beans was not significantly different after 20 [(ANOVA) $\mathbf{F_{1,3}=0.81, P=0.4354}$] or 60 days ($\mathbf{F_{1,4}=0.04, P=0.8567}$). Females on GGO-(1:25) laid an average of 13.0 eggs over 20 days and 47.0 eggs over 60 days. Females on untreated french beans laid an average of 8.0 eggs over 20 days and 53.3 eggs over 60 days.
After 20 days of the experiment 6 adults on the control and 5 adults on the neem treatment were missing or died. After 60 days of the experiment 8 adults on the control and 12 adults on the neem treatment were missing or dead.

The average hatching rate of nymphs was higher in the control (62.90 %) than in the neem treatment (38.68 %), but the ANOVA did not show a significant difference between the two treatments ($\mathbf{F_{1,10}=2.21, P=0.1676}$).

Experiment II

The average number of eggs laid in each treatment is shown in Table 33.
After four weeks, the average number of eggs laid per female was significantly different in the two neem treatments, but the two neem treatments were not significantly different from the control. After eight weeks, the average number of eggs laid per female was significantly higher in the control than in the two neem treatments. There was no significant difference between the two neem treatments.

Table 33: Average number of eggs laid per female on two neem treatments

TIME	TREATMENT	AVERAGE NO. OF EGGS	ANOVA	
over 4 weeks	Control GGO-(1:25) NA-(1:50)	16.9 **a*** 30.2 **a** 11.0 **a**	**$F_{2,14}$= 3.72**	**P=0.0508**
over 8 weeks	Control GGO-(1:25) NA-(1:50)	50.3 **a** 31.0 **b** 25.7 **b**	**$F_{2,9}$= 9.78**	**P=0.0055**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

The average hatching rate of nymphs in the different treatments was following:

Control: 44.56 %

GGO-(1:25): 44.60 %

NA-(1:50): 43.33 %

There was no significant difference between the different treatments (**$F_{2,17}$=0.00, P=0.9974**).

Table 34: Feeding activity of adults on french beans after neem treatment

TIME	TREATMENT	AVERAGE PERCENTAGE OF FEEDING EVIDENCE
day 2	GGO-(1:25) Spirits Control	12.00 12.00 27.00
day 2 + 4	GGO-(1:25) Spirits Control	18.00 27.00 31.00

Antifeedant effect of neem against adults on french beans

The average percentage of beans with feeding evidence in the different treatments is shown in Table 34.

There was no significant difference between the feeding evidence in different treatments after two [(ANOVA) $\mathbf{F_{2,8}=0.80, P=0.4808}$] and four days ($\mathbf{F_{2,8}=0.48, P=0.6364}$)

Repellent properties of three neem products against adult bugs - Experiment I

The average percentage of plants with feeding evidence in the different treatments is shown in Table 35.

Table 35: Percentage of damaged papaya plants with different neem treatments

TIME	TREATMENT	PERCENTAGE OF PLANTS WITH FEEDING DAMAGE
4 days	GGO-(1:25) PN-(1:25) NA-(1:50) Control	0 0 11.11 0
10 days	GGO-(1:25) PN-(1:25) NA-(1:50) Control	11.11 0 11.11 0
14 days	GGO-(1:25) PN-(1:25) NA-(1:50) Control	22.22 0 22.22 22.22
16 days	GGO-(1:25) PN-(1:25) NA-(1:50) Control	33.33 0 22.22 22.22
18 days	GGO-(1:25) PN-(1:25) NA-(1:50) Control	33.33 33.33 22.22 22.22

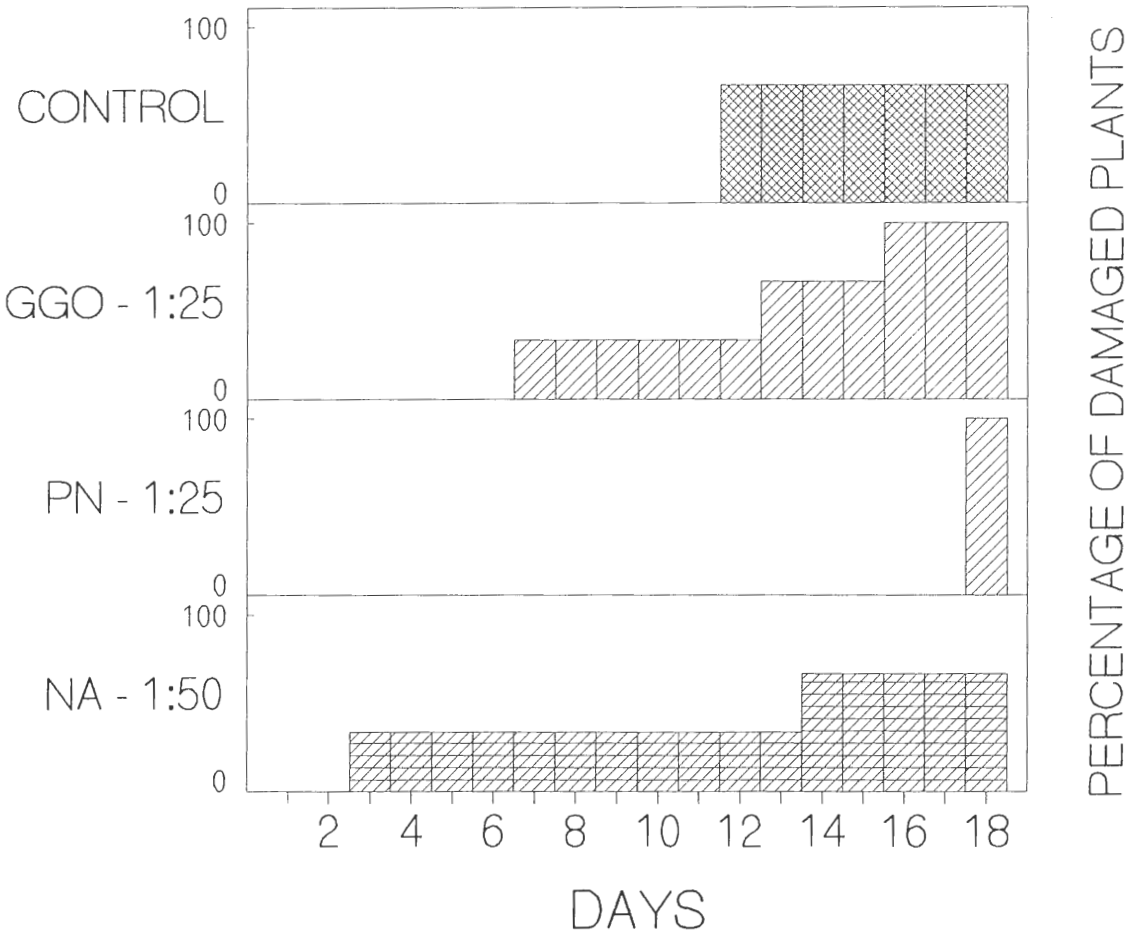

Figure 38: Antifeedant effect of neem after application of three different products in a choice situation

Feeding evidence was analysed for day 4 [(ANOVA) $\mathbf{F_{3,8}=1.00, P=0.4411}$], day 10 ($\mathbf{F_{3,8}=0.67, P=0.5957}$), 14 ($\mathbf{F_{3,8}=1.33, P=0.3300}$), 16 ($\mathbf{F_{3,8}=3.17, P=0.0855}$) and 18 ($\mathbf{F_{3,8}=0.67, P=0.5957}$) of the experiment. There was never a significant difference between the different treatments. The percentage of damaged plants in different treatments over the duration of the experiment are shown in Figure 38. The treatment with PN-(1:25) showed the longest control against fruitspotting bug attack. GGO-(1:25) and NA-(1:50) treatments were damaged even earlier than the control treatment.

Experiment II

The average number of feeding marks caused by adults after bananas were treated with different neem products and in the untreated control were the following:

GGO-(1:25): 10.5
PN-(1:25): 10.2
Control: 9.1
NA-(1:50): 5.1

The only treatment with less feeding evidence than the control was the NA-(1:50) treatment. There was no significant difference in number of feeding marks between the different treatments [(ANOVA) $\mathbf{F_{3,16}=0.54, P=0.6638}$].

Experiment III

The average number of feeding marks caused by adults after bananas were treated with different concentrations of neem and in the untreated control were following:

NA-(1:25): 10.1
NA-(1:50): 8.6
Control: 6.3

There was no significant difference in the number of feeding marks for the different treatments [(ANOVA) $\mathbf{F_{2,18}=1.18, P=0.3311}$)].

4.8.3 Effect of neem applications on eggs

Effect of neem on eggs of different age

The hatching rate of nymphs from fertile eggs was 100 % in the [GGO-(1:25)] treatment and the control as well as for all different ages.

Comparison of the effect of two different neem products on eggs

The hatching rate of nymphs from fertile eggs was 100 % in all different treatments [GGO-(1:25), PN-(1:25) and control] and for all different ages.

Comparison of the effects of three different neem products on eggs

The hatching rate of nymphs from fertile eggs was 100 % in all different treatments [GGO-(1:25), PN-(1:25), NA-(1:50) and control].

4.8.4 Effect of neem on parasitoids

Effect of neem on adults of *Anastatus* sp.

None of the wasps died in any of the different treatments during the first three days. On day four, two wasps in the GGO-(1:25) treatment died, but none of the others. The results for the fourth day did not show any significant difference between the different treatments as well [(ANOVA) $\mathbf{F_{2,12}=2.67, P=0.1101}$].

Effect of two neem products on eggs parasitised by *Anastatus* sp.

The percentage of parasitoids hatching from eggs treated with neem is shown in Table 36. There were no significant differences between the different treatments, neither in the first [(ANOVA) $\mathbf{F_{2,36}=0.6, P=0.5787}$], nor in the second ($\mathbf{F_{2,36}=3.79, P=0.0862}$) series of experiments at a 5 % level. When both series were analysed together, there was also no significant difference ($\mathbf{F_{2,72}=0.94, P=0.5150}$).

Table 36: Hatching of parasitoids from neem treated eggs

SERIES	TREATMENT	PERCENTAGE OF PARASITOIDS HATCHING
1	GGO-(1:25) NA-(1:50) Control	46.67 26.67 26.67
2	GGO-(1:25) NA-(1:50) Control	46.67 13.33 86.67
1 + 2	GGO-(1:25) NA-(1:50) Control	46.67 20.00 56.67

Effect of eggs with neem treatment on the parasitism rates for *Anastatus* sp. - Experiment I

The results are shown in Table 37. In the first series of the experiment, the percentage of parasitoids hatching was significantly higher in the control than in both neem treatments [(ANOVA) $\mathbf{F_{2,6}=45.98, P=0.0002}$]. In the second series there were no significant differences between the different treatments ($\mathbf{F_{2,6}=4.87, P=0.0554}$). When the results from both series were analysed together, again, the percentage of parasitoids hatching in the control was significantly higher than in both neem treatments ($\mathbf{F_{2,12}=11.18, P=0.0018}$).

Table 37: Percentage of hatched parasitoids after neem treatment of the host eggs

SERIES	TREATMENT	PARASITISM BY *Anastatus* sp.
1	GGO-(1:25) NA-(1:50) Control	0 % **b*** 0 % **b** 29.91 % **a**
2	GGO-(1:25) NA-(1:50) Control	24.29 % **a** 0 % **a** 60.00 % **a**
1 + 2	GGO-(1:25) NA-(1:50) Control	12.14 % **b** 0 % **b** 44.95 % **a**

* In columns means followed by the same letter are not significantly different (ANOVA, F-test; $P \leq 0.05$).

Experiment II

The percentage of parasitism for the different treatments was the following:

Treatment	***Anastatus* sp.**
Control:	60%
GGO-(1:25):	0%
NA-(1:50):	0%

None of the neem treated eggs were parasitised, but a significant difference between the different treatments could not be confirmed statistically.

4.9 Summarised results

Laboratory rearing methods

In the preliminary tests the mortality of the nymphs was 100 % when nymphs were reared on dehydrated peas, frozen peas, and cashew growth terminals and 90.9 % on seeds of french beans, which was unacceptable for a laboratory rearing.

Rearing first two instars on papaya plants followed by french beans seemed to be the most suitable rearing method because of the relatively low mortality (44%), the short development time (26-36 days) and the easy handling. A lower mortality than 34 % on papaya plants, could not be achieved with any other rearing method.
The holding density did not effect the survival rate to adult.

Relationship between *A.l. lutescens* and its hosts

a) Nymphal development of *A.l. lutescens* on different hosts

Tests in the laboratory and in the field showed significant differences in the survival to adult and development time on different host plants. In laboratory trials, nymphs survived to adult only on four of the ten host plants tested, and in field trials only on two of the six host plants tested. The most suitable hosts for rearing nymphs were young growth terminals (papaya and cashew plants). There were no significant differences between the results of laboratory and field trials.

b) Studies on the feeding behaviour of nymphs and adults

Feeding frequency and feeding duration on different hosts

Results showed a positive correlation between the feeding frequency and duration and the quality of the host plant. The host plants, on which the nymphs fed more frequently and longer, were also the most suitable for the development of the nymphs (papaya plants, french beans).
When four different papaya varieties were tested, the results showed varietal differences, nymphs showing a preference for the variety 'SL91-4B'. If the nymphs were given a choice between french beans and mock orange fruit, they preferred mock orange fruit.
In experiments with fruit of different maturity, with carambolas and mock orange fruit for example, in the case of carambolas, there was no clear preference noticeable. On the

contrary, in the case of mock orange, fruit which were still immature, but where development had reached a certain stage were preferred like by nymphs and adults.

c) Oviposition rate of female bugs on different hosts

Different host plant species and even varieties can have a significant effect on the oviposition rate of adults. The oviposition rate was the highest on the host plants showing the best nymphal development (papaya plants, french beans). Further tests showed, that with less suitable food (carambolas) the egg production is reduced or ceases, but is resumed after feeding on an adequate host plant (french beans).

Different nymphal diet (papaya plants, or papaya plants and french beans) did not seem to have an effect on adult ovipositon rate of *A.l. lutescens*.

In experiments under ambient conditions with different carambola varieties, and in experiments with a choice of host plants in the insectary, no oviposition was recorded.

Population studies of *A.l. lutescens* and parasitoids

A population study of *A.l. lutescens* in the field confirmed that papaya and mock orange are two hosts of very different character, and the population dynamic of the bugs are very different on these two hosts.

In papaya, during the observation of nine months, the actual period with the highest infestation only lasted two months, whereas in mock orange bushes, the bugs were observed almost all year round and a clearly defined infestation period was not noticeable.

Observations confirmed the assumption that the bugs migrate between the host plants.

The two parasitoids, *Anastatus* sp. and *Ooencyrtus caurus* were active in the field at different times, which led to the presumption that they complement each other in their control of the bugs.

Alternative management methods

a) Resistance or tolerance in host plants

In the eight different papaya varieties tested, no significant varietal resistance could be proved, but a distinct tendency for a lower damage level was noticed in the variety 'PZ90-1XPZ90-1'.

In the studies on different carambola varieties, small fruit of the variety 'Thai Knight' were significantly more damaged than the fruit of the other varieties.

b) Natural enemies

Studies on two egg parasitoids *Ooencyrtus caurus* and *Anastatus* sp. showed, that both are capable of parasitising bug eggs almost until the end of the development of the bug embryo. A preference for a certain age of host eggs could not be proved statistically.

c) Neem as a potential alternative to endosulfan

Effect on nymphs

In laboratory trials as well as under ambient conditions, 100 % mortality of nymphs was achieved with all neem products tested.

'Neem-Azal T/S' had a more rapid effect than the other two neem products in laboratory tests as well as under ambient conditions. Significant differences occurred only under laboratory conditions. A very high nymphal mortality (ca. 80 - 90 %) was achieved within the first ten days.

The feeding activity of nymphs was reduced when the food was treated with neem, but a significant repellent effect could not be proved.

Effect on the oviposition rate.

The intake of neem treated food caused a reduced oviposition rate in adults in the long term. A significant effect could not be proved. Here again the treatment with 'Neem-Azal T/S' had a greater effect than the treatment with 'Green Gold One'.

In further studies neem had no significant repellent or antifeedant effect on adults, although the feeding activity was reduced.

Effect on eggs

Non of the neem products tested had an ovicidal effect.

Effect on parasitoids

Non of the neem products tested had a lethal effect on adults of *Anastatus* sp.

Bug eggs which were treated with neem products did not get parasitised by *Anastatus* sp.

When eggs which were parasitised by *Anastatus* sp. were treated with neem, the hatching rate of parasitoids was reduced compared to the untreated control, but a significant effect on the hatching rate of parasitoids could not be proved statistically.

5 DISCUSSION

At this point of the study, I will discuss the difficulties which appeared during the experimental part of this work. Obtaining an adequate number of insects for the various experiments was always a problem.

In the field, as mentioned earlier, the population density of *A.l. lutescens* is generally very low. The bugs are very well adapted to their environment and were well hidden in the canopy, which made it difficult to find them. Adults are very mobile and escaped before they could be caught and nymphs, at attempts to catch them, let themselves drop onto the ground, where they disappeared. As reported earlier in chapter 2.4. already, many growers have never seen the bug itself.

The experimental work therefore was entirely dependant on a strong laboratory culture of *A.l. lutescens*, which proved to be a problem due to a very high nymphal mortality.

5.1 Laboratory rearing methods

As mentioned earlier, breeding *A.l. lutescens* under laboratory conditions was very difficult, taking four to six months to obtain adequate numbers of individuals for experimentation.

The reasons for the high nymphal mortality are unclear. Insecticide residues on food plants did not appear to be the reason for high nymphal mortality, since a trial with untreated french beans did not show a significant lower mortality than on commercial french beans.

The high mortality in nymphs is probably due to an inadequate nutrient supply. Feeding initiation is presumably the greatest problem, especially in the second instar when mortality is very high and can be considered the most critical stage of the nymphal development. It is the growth stage when the insect begins to feed, since the bugs do not necessarily require food during the first nymphal instar. It has also been observed, that nymphs of *Nezara viridula* (L.) start feeding after the first moult and when nymphs are disturbed mortality during the first instars was very high (VELASCO & WALTER, 1992).

Preliminary studies with pea sprouts, soaked dehydrated peas, seeds of french beans and cashew growth terminals only showed unsatisfactory results. Rapid fermentation was a problem with different pea products. In cashew growth terminals, fast wilting had a disadvantageous effect on their quality. If considered for mass-rearing, it would be a difficult and very elaborate procedure to guarantee a continuous supply of fresh material in sufficient quantities.

COTTRELL-DORMER & PHILLIPS (1938) had similar experiences with the laboratory culture of *A. cocophaga* in the Solomon Islands. They first tried to rear the nymphs on potted cowpea plants, which was not very successful, as the plants were killed by the sucking bugs. Freshly-cut coconut inflorescences were a better food source. Even when rearing the bugs on living plants of beans and *Ficus* sp., the mortality was still high.

In a study on *Oncopeltus fasciatus*, feeding difficulties in young nymphs have also been observed. Seeds of the host *Asclepia syriaca* are often not accessible for the nymphs of the first three instars, since their mouthparts are too short to penetrate the seed pods. This caused a slower development and higher mortality than on exposed seeds (RALPH, 1976).

Therefore it can be assumed, that in the case of young nymphs of *Amblypelta*, the seeds of french beans in pods are only limited accessible. Preliminary tests showed that the mortality of nymphs on seeds of french beans was always very high and comparatively high costs and work expenditure would be a problem in a mass-rearing situation. Growth

terminals of living plants proved to be the most suitable food source in the first nymphal instars.

The reason why young growth terminals are important for the first nymphal instars of *A.l. lutescens*, could be that accessibility to the phloem and the osmotic pressure is easier; nutrients in the phloem sap of young shoots are certainly more available.

As the tests in chapter 3.1.4 showed, rearing nymphs first on young papaya plants for two weeks, then on french beans, was the best laboratory rearing method, with nymphal mortality very low and the development time very short. Changing the diet after the second instar did not slow down nymphal development.

When rearing nymphs exclusively on papaya plants the mortality was indeed a little lower and the development time was similar, but the large number of cages employed and large quantity of plant material required, would cause problems when rearing a larger number of nymphs.

In comparison, rearing on papaya plants followed by french beans was a better laboratory rearing method. Nymphs of the first two to three instars only require a small amount of papaya plants and cages were not occupied for longer than about ten days. This enabled rearing of a larger number of nymphs in the laboratory and therefore a colony could be build up much faster. Therefore this method appeared to be the best of all tested rearing methods.

The holding density did not have any effect on the survival rate to adult. The number of nymphs per cage can vary to a certain extend (probably up to 35), without affecting the rearing success. At a higher holding density, cages, plants and time can therefore be employed more effectively.

On account of the high nymphal mortality, it was especially difficult to get enough newly emerged adults for the different experiments, since together with the relatively low reproduction rate, a large number of adults had to be kept to maintain the laboratory colony. The experiments with adult bugs often could only be done with a small number of replicates.

For adult bugs, holding of single pairs in large rearing containers with french beans proved to be most suitable and practical. Adult bugs bred successfully in the relatively small containers.

Adults of *A.l. lutescens* lived under laboratory conditions on average five months (maximum 328 days), which is quite long for insects. The longevity of adult bugs in the field is unknown, but it can be assumed that longevity in the field is similar, possibly longer.
The adults of the shield bug *Nezara viridula* presumably utilise several hosts in the field and their life expectancy and chances to survive are higher in the field, than on a one host diet in the laboratory (VELASCO & WALTER), which is probably the true for *A.l. lutescens* as well.

5.2 Relationship between *Amblypelta l. lutescens* and their host plants

The most important aspects of the relationship between *A.l. lutescens* and their host plants were the suitability of the host plants for development and reproduction of the bugs.
BECK (1956) mentioned in his study on the relationship between the European corn borer (*Ostrinia nubialis* (Hb.) (Lepidoptera: Pyralidae) and its host plant, that the term 'nutritional requirements' should only refer to the chemical factors which are important to the suitability of the ingested diet. The author further distinguishes between 'chemical feeding requirements' for chemical factors, which are important for a normal feeding behaviour and 'physical feeding requirements' for physical factors such as texture of the food, position or light intensity which affect the feeding behaviour (BECK, 1956). The suitability of a specific host is dependent in how far these three requirements are fulfilled.
Numerous bug species attack preferentially buds, fruits, growth terminals and maturing seeds in which the nutrients concentrate (DOLLING, 1991) which is also true for *Amblypelta* species.

It cannot be generalised, and conclusions cannot be made from nutrient requirements about host specificity, due to the relationship between insect and host plant (BECK,

1956). VELASCO & WALTER (1992) mentioned, that a specific host can be suitable only for certain aspects of the biology of the insect.

A comparison of results from laboratory and field trials on a choice of hosts showed that laboratory conditions did not have a significant effect on survival rate of nymphs. In the laboratory, nymphs certainly developed to a higher instar than in field trials.

Preliminary tests on picked and unpicked carambola fruit and the study on laboratory rearing with cashew growth terminals showed that cut plant material is less suitable for nymphal development than living plant material. The excision of plant material causes biochemical degradation such as changes in the relationship of water and hydrogen ions and allows microbial attack, which again causes further chemical and physical changes (BECK, 1956), whereupon the low suitability of the cut material probably can be explained.

The severity of the bug damage differs with the susceptibility or attractancy of the host.
Generally in younger plants, the growth terminal or immature fruit are most attacked. In young papaya seedlings bug damage can be fatal, but older papaya plants usually survive bug attacks (SLOAN, 1946).
In tests with mock orange fruit, different maturity stages appeared to have an effect on the nymphal development. Large green fruit proved to be the most suitable.
Lychees are usually only attacked as long as the fruit is still green, causing fruit drop. Even though some damage might occur later on ripe fruit, fruit drop does not occur (WAITE et al., 1993).
In studies on the European corn borer it was observed, that young, small corn plants are unsuitable for the larval development and oviposition, their suitability for the larvae increases with the plant age (BECK, 1956).
Attacks in orchards by *A.l. lutescens* generally occur in early periods of fruit maturity or growth flushes. Possibly this early attack can be traced back to a higher content of nutrients (i.e. nitrogen). WAITE and FAY designed seasonal profiles for a number of commercial crops in south east and north Queensland (WAITE et al., 1993).

5.2.1 Host preference

a) Nymphal development of *Amblypelta l. lutescens* on various hosts

In Studies on nymphal development of *Nezara viridula* on various hosts, significant differences were detected in development time and survival rate on the various hosts (PANIZZI & MENEGUIM, 1989), and development time on a host was reciprocal to the bugs survival (VELASCO & WALTER, 1992).
A similar observation was made with nymphs of *A.l. lutescens*. In preliminary tests on nymphal development, the development time to adult stage was significantly longer in nymphs reared on french beans (39.3 days) than in nymphs reared on young papaya plants (23.6 days). Due to high nymphal mortality, it was not practical to do this experiment with other hosts.

Studies including the survival rate to adult as well as development time, showed that not all recorded host plants are equally suitable for the development of the nymphs. In laboratory studies, nymphs survived only on four of the ten tested known hosts and in field studies only on two of the six.

The reason for the low suitability of numerous hosts of *A.l. lutescens* for nymphal development is still unclear.
In the case of *A.l. lutescens*, physical factors (e.g. thickness of the skin in avocados) or secondary substances in plants could play roles for the inadequacy for nymphal development.
In the case of the European corn borer for example, the insufficiency of small corn plants as a host could not be traced back to nutrient deficiency in the plant tissue (BECK, 1956). It was first assumed, that young corn plants contain a repellent substance, which led to starvation of the larvae. This hypothesis could not be confirmed by further investigations.

In *A.l. lutescens*, mortality decreased significantly after the third nymphal instar. With regard to host suitability studies, development to the third nymphal instar would be a relatively quick and adequate screening method.

Most economic damage by *A.l. lutescens* occurs when crops are surrounded by remnant rainforest, which acts as a refuge and breeding ground for the bugs (WAITE et al., 1993; RYAN, 1994).

The fact that nymphs will feed on a wide variety of plant species shows, that they are able to breed and develop in forest areas with a highly diverse flora, where the bugs find acceptable hosts all year round. This would support the theory that *Amblypelta* has its original hosts in the native bush and adapted later to exotic commercial crops. COTTRELL-DORMER & PHILLIPS (1938) described *A. cocophaga,* which they studied in the Solomon Islands, as a 'bush insect', utilising *Macaranga tanarius* (L.) Muell. Arg., *Ficus septica* Burm. (*Ficus leucantotoma*) and other trees and shrubs as their natural hosts. About 20 years after the coconut plantations were established, immature nutfall started to become a serious problem, especially in locations adjacent to bush. The authors also noted that another member of the genus *Amblypelta, A. manihotis* occurs in the bush and suggested that since cassava is only attacked sporadically, the insect might not have completely adapted to cassava (COTTRELL-DORMER & PHILLIPS, 1938).

b) Feeding behaviour studies of nymphs and adults of *Amblypelta l. lutescens*

Feeding frequency and feeding duration on different host plants

The feeding behaviour in the field of *A.l. lutescens* should give information on the suitability of various hosts plants. Feeding frequency and feeding duration appears superficially linked to host suitability. SIMMONS & YEARGAN (1988) compared the feeding frequency and feeding duration of male and female nymphs, and of different instars of the pentatomid *Acrosternum hilare*. They found, that feeding increased with development, and also immediately after moulting feeding increased to a maximum, before it decreased again. The feeding duration was generally similar on each feeding occasion and there was no difference between male and female nymphs.

Results of the trials with *A.l. lutescens* in this study, let us assume that there is a positive correlation between the feeding frequency and duration and the quality of the host plant, since

hosts which had showed the best rearing results, were also the hosts plants on which nymphs feed more frequently and longer.

As part of this study, the influence of four different papaya varieties on the feeding frequency of *A.l. lutescens* nymphs was also investigated, showing significant varietal differences in frequency and duration of the feeding activity. Nymphs fed most frequently and longest on plants of the variety 'SL91-4B'. In this trial the differences were greatest on the first day of the experiment. This is probably linked to the condition of the plant material, which, because of repetitive feeding, deteriorated over the three experiment days. Since the number of available plants was limited for each papaya variety, these varietal differences could not be complemented by studies on the nymphal development.

When nymphs had the choice between french beans and mock orange fruit, a clear tendency for a preference of mock orange fruit was noticeable.

In the studies on carambolas and mock orange fruit of different maturity, no clear preference could be noted in the case of carambolas, which was probably due to their general unsuitability as a host. In mock orange, a distinct preference for fruit which were still immature but had developed to a certain stage was observed. Nymphs and adults showed a similar behaviour in this experiments with fruit of different maturity.

This again would confirm the observations that *Amblypelta* show a preference for growing fruit (SCHAEFFER & MITCHELL, 1983), which is probably due to the nutrients, especially nitrogen levels.

In studies on the attraction of hosts to *Nezara viridula*, the number of adults visiting each single plant were counted, and the time they spent on each plant recorded, with a choice between 12 different hosts (VELASCO & WALTER, 1992). Differences in the attractiveness of the hosts could not be shown and indications of a preference were contradictive.

Trials on feeding frequency and duration supplement the study on nymphal development, and both together, represent a potential screening method. A study on feeding frequency and duration is a very quick and easy test, since significant differences usually show up on the first of the three observation days.

c) Oviposition rate on different host plants

The results of all experiments show, that different host plants and even different host plant varieties can have a significant influence on the oviposition rate of adults.

Several experiments in the study on *Nezara viridula* led to the assumption that the development of nymphs and adults as well as their reproduction success is significantly affected by the host plant species and the part of the plant they are feeding on (PANIZZI & SLANSKY, 1991; VELASCO & WALTER, 1992).

The number of eggs laid per female was highest when adults of *A.l. lutescens* were fed on french beans. It is still unclear what caused this effect. Possibly the nutrient content, especially the nitrogen level plays an important role.

Studies on *Loxostege sticticalis* (L.) (Lepidoptera: Pyralidae) showed a positive correlation between the fecundity of the female and the content of linoleic acid in the larval diet (BECK, 1965). Fecundity and longevity of the Colorado potato beetle [*Leptinotarsa decemlineata* (Say)] were dependent on a high lecithin and a low glucose content in leave of the host plant.

First laboratory trials as well as experiments in the orchard showed that carambolas are an inadequate food source for adults. Egg production was neglectibly low.

The results of the study on ovipositon of *A.l. lutescens* on a alternate diet of french beans and carambolas showed, that females stop or reduce egg production when feeding on a unsuitable host leads to a nutrient deficiency. The results also indicate that feeding on a less suitable host can possibly be compensated by subsequent feeding on a more adequate host and that egg production can then be resumed again.

In the case of *A.l. lutescens* it can be assumed that if several suitable hosts are available, adults move between them and cover their nutrient requirement from more than one host plant species. Adults can tolerate lower food quality better than nymphs.

The movement of adults are not known in detail, but it would be interesting to know, what their movements are within an orchard of one host plant or between orchards of different hosts.

SLANSKY & PANIZZI (1987) noted that males of seed sucking insects can reduce mating while starving or feeding on non-hosts. Females keep laying a few eggs in this situation.

The intake of a certain amount of food of adequate quality and/or storage of a certain level of nutrient, can start neurohormonal processes which control egg production. The authors also

noted that reduced feeding, due to inadequate food, can cause a delay in egg production in females. In this case, more time is required to store an adequate level of nutrients which are necessary to stimulate egg production. In females of *Oncopeltus fasciatus* about 40% of their nutritional intake goes into egg production (SLANSKY & PANIZZI, 1987).

Generally the oviposition rate is also highest on the host plants, which showed the best results for nymphal development (french beans, papaya plants and mock orange fruit). This could indicate that in the case of *A.l. lutescens*, the requirements of adults and nymphs are similar.
In experiments with different diet for nymphs of *A.l. lutescens*, rearing on papaya plants or papaya plants and french beans, did not seem to effect the oviposition rate later. Because of the high nymphal mortality on other hosts in the laboratory, it was not possible to do experiments on further host plants.
Studies on *Nezara viridula* indicated that nymphs and adults of this bug have different food requirements (SLANSKY & PANIZZI, 1987). When nymphs and adults had the same diet and were feed on *Sesbania emerus* (Aublet) Urban (Fabales: Fabaceae), the high performance of nymphs was carried over to the adult stage, which resulted in a high oviposition and hatching rate (>50 %).

PANIZZI & MENEGUIM (1989) concluded from their studies on nymphs and adults of *N. veridula* and a choice of alternative host plants, that despite a distinct polyphagy, various diets have a different affect on the biology of the insect.
The authors noted that a change of food could be an important part of the feeding ecology, which could possibly be the case for *A.l. lutescens*, too.

The reasons for the failure of egg production under ambient conditions and in the insectary remain unclear and need further investigation.

5.2.2 Population studies on *Amblypelta l. lutescens* and parasitoids

Population studies on *A.l. lutescens* in the field confirmed that papaya and mock orange are two hosts of different character and the population dynamics of the bugs on both host plants differs enormously.

In the case of papaya, the period of attack is only very short, the attractiveness to *A.l. lutescens* was observed over a period of only two months.

The block effect in the population study on papaya plants is due to migration of bugs from adjacent avocado trees. This confirms the theory that these bugs can move from one host to a more attractive one. The incentive for this migration remains to be investigated (WAITE et al., 1993).

VELASCO & WALTER (1992) found in their studies on *Nezara viridula*, that changes in the availability of the hosts cause changes in the presence of a bug population, as it is typical for polyphagous insects.

These observations are of interest for the timing and extent of control measures. A clearly defined 'season' would mean that insecticide applications can be limited to this period (during the fruit development or growth flush). Seasonal profiles as FAY and WAITE determined for a number of host plants of *Amblypelta* spp. are therefore important (WAITE et al., 1993). In his observations FAY noted a strong interdependence between the damage level and the phenology of carambola and recommended starting a spraying program before the end of flowering. He also pointed out, that costs could possibly be reduced by stopping the spraying program early (WAITE et al., 1994).

Since at present, there are no means of monitoring bug numbers with pheromone or other traps, the design of seasonal profiles would surely be a helpful method and at present the only way to determine the period of attack and limit the spraying program with insecticides (WAITE et al., 1994).

Possibly 'indicator plants' could be an alternative monitoring tool, which has to be further investigated. It has been observed for example, that custard apples, of which a small number of plants were planted outside an avocado orchard, were attacked by the bugs, before the first damage was recorded in avocados (LAVERS, 1993). In this case, the first damage in custard apples could be used as an indicator for insecticide use in avocados. Studies on similar relationships between 'attack 'season and different host plants would therefore be important. As part of this study it was planned to plant some papaya plants as indicator plants on the earlier mentioned avocado farm, which was not undertaken for different reasons.

In mock orange, in the contrast to many commercial crops, no clear seasonality could be observed, since the bushes produce fruit more or less continuously and therefore provide a

suitable food source almost all year round. A similar situation can be expected in the case of cashew, since almost all plant tissue (flower panicles, growth terminal, cashew apples as well as cashew nuts) are attacked, and therefore suitable food is available almost all year. Any control program in these cases has to start relatively early. On the basis of studies on the effect of feeding damage by *A.l. lutescens* on the yield in cashew nuts it was recommended to apply insecticides before flowering (STRICKLAND & WILLIAMS, unpublished).
The population study on mock orange bushes showed a trend dependent on the season, where the bug population increased during spring and summer and then decreased to very low density. It can be assumed, that beside temperature, factors such as day length can also be important in development time, since under laboratory conditions, a decrease in size of the population has been observed during the winter months, caused by low reproduction.

The population studies showed differences in population size with season in both parasitoid species. The different times, when populations of *Anastatus* sp. and *Ooencyrtus caurus* reached their peaks, could allow them to complement each other in controlling the bugs. In earlier observations on three sites, the ratio of eggs which were parasitised by *Anastatus* sp. to eggs parasitised by *Ooencyrtus caurus* was 5.5:1 (FAY & HUWER, 1993). In this study on three further localities, the ratio of eggs which were parasitised by *Anastatus* sp., to the ones parasitised *Ooencyrtus caurus* however was 1:1.5. The significance of both parasitoids for the control of *A.l. lutescens* has to be investigated further. Also the relationship between parasitoids and hosts plants of their hosts remains unclear.

Eggs of *A.l. lutescens* are very difficult to find, since eggs are laid individually, which made monitoring of the bugs and their parasitoids extremely difficult (FAY & HUWER, 1993).

Population studies on *Gryon* sp. were impossible until now. It is unclear what roll this parasitoid plays in the control of *A.l. lutescens*, in relation with the two other parasitoids, since it has only been recorded in one locality for a short period of time. It can be assumed that *Gryon* sp. is a very specific parasitoid and, because of its limited appearance, would be less important in reducing of bug populations in the field.

Very similar complexes of parasitoids were found in the case of the related bug species *Pseudotheraptus wayi* in East Africa, *Amblypelta cocophaga* in the Solomon Islands, *Dasynus piperis* and *Amblypelta manihotis* Indonesia, as well as *Amblypelta lutescens*

papuensis in Papua New Guinea (FAY & HUWER, 1993). To reduce economic damage, caused by the bugs effectively, because of the low economic threshold, parasitism would have to be continuously very high, which could probably be achieved only by mass-rearing and mass-release. The employment of parasitoids to control *A.l. lutescens* is certainly a possibility which has to be considered. Detailed studies need to be done on mass-rearing and mass-release of these parasitoids. The question, whether the parasitoids are primary parasites or operate as hyperparasites is not yet clear. Laboratory experiments showed that *O. caurus* can be hyperparasites of *Anastatus*, whereas *Anastatus* has not been observed to be a hyper-parasite of *O. caurus* (FAY & HUWER, 1993).
OSWALD (1990) in his study on *Pseudotheraptus wayi* also studied the biology and population dynamics of *Ooencyrtus albicrus*, and based on the results of his studies he drew attention to the enormous potential of this egg parasitoid for biological control of the bugs.

Since the economic threshold of *Amblypelta* species is very low, a very high percentage of parasitism is necessary for an effective control of the bugs. Whether a higher effectiveness can be achieved by mass-release of the parasitoids into the field, remains to be studied in detail.
At the present there has been no study on the two egg parasitoids which occur only in south east Queensland.

5.3 Alternative management methods

5.3.1 Resistance or tolerance in host plants

Of eight papaya varieties tested significant differences could not be proved statistically, but a distinct tendency to lower damage in the variety 'PZ90-1XPZ90-1' was recognisable.
The studies on different carambola varieties showed significant varietal differences in the level of bug damage. Fruits of the variety 'Thai Knight' were significantly more damaged than the other varieties tested, which confirmed previous observations in a carambola orchard (FAY, 1991a). The reason for these varietal differences remains unclear.

Experiments on nymphal development in the field and on oviposition rate on different carambola varieties showed no significant varietal differences. In laboratory trials nymphs

developed significantly further on the varieties 'Thai Knight' and 'Fwang Tung', than on the other varieties.

The reason for significant higher damage in the variety 'Thai Knight' is possibly secondary plant products. It is unlikely that it is a matter of exclusively physical characteristics, such as skin thickness, colour or different fruit shapes. More important characteristics could be nitrogen levels, odour or possibly water content.

None of the carambola varieties tested were particularly suitable as hosts to the bugs, but nevertheless, the damage recorded in the variety 'Thai Knight' was relatively high. It can therefore be expected that high damage level is not necessarily correlated with the suitability as a host.

In studies on the preferential behaviour of *Pseudotheraptus wayi* to different coconut varieties, no significant varietal preference could be proved (OSWALD, 1989).

A tendency to tolerance or resistance to bug damage is known in some late maturing lychee varieties in south east Queensland (WAITE, 1990) and also thick skinned avocado varieties (WAITE et al., 1993). However, because these avocado varieties mature at different times, seasonal activity confounds the resistance issue (FAY, 1995). Such a varietal tolerance also needs to be studied on further host plants. It certainly depends on the environment in how far resistance or tolerance are effective. It can be assumed that in an environment without more suitable hosts, either different crops or varieties, which under other circumstances are less likely to be attacked, would get damaged.

Since the economic threshold for fruitspotting bug damage is extremely low, the potential of utilising the most susceptible varieties as 'trap crops', in situations where several varieties are planted, seems doubtful but this would depend on the number of individual fruit damaged. If fewer fruit is damaged on resistant varieties, and not just fewer feeding marks, 'trap crops' might be beneficial. In a situation with only one variety available, it can be assumed that regardless of the susceptibility in comparison to other varieties, it would be vulnerable to damage. This remains to be studied in detail.

5.3.2 Natural enemies

In this study the potential of two egg parasitoids to control the bugs was investigated. A further parasitoid, *Gryon* sp., was not included in these studies, because the occurrence of this species in the field and therefore the prospect for laboratory rearing, was only very limited. On the contrary, *Ooencyrtus caurus* and *Anastatus* sp. were frequently found in the field. Since eggs of alternative hosts could also be employed in breeding up wasp numbers (DE FAVERI & FAY, 1995), the maintenance of a laboratory colony of both wasp species was possible on a large scale and as a consequence, several experiments were made possible.

The availability of bug eggs was a limiting factor. Alternative hosts have not been reared successfully in the laboratory. Their eggs were almost exclusively collected in the field.

OSWALD (1990) had similar problems breeding up *Ooencyrtus albicrus* in eggs of *Pseudotheraptus wayi*. With regard to mass-rearing and mass-release, a more efficient breeding method needed to be developed. All experiments showed that both parasitoids (especially *O. caurus*) are capable of parasitising fruitspotting bug eggs up to a fairly late development stage of the embryo, almost until they are fully developed. The observation on *O. caurus*, made every 15 minutes over 8 hours, indicated that the parasitoid seems to have a preference for eggs which have developed to a very early stage. This observation could not be confirmed in further experiments. Neither *Anastatus* nor *O. caurus* were significant differences in the parasitism of eggs of different ages proved statistically.

OSWALD (1989) undertook similar experiments with *Ooencyrtus albicrus* using different aged eggs of *P. wayi*. *O. albicrus* did not show any preference for a certain age of the host egg and the parasitoid was able to utilise the host eggs until one day before hatching. The fact that parasitoids of the genus *Ooencyrtus* can parasitise the bug eggs effectively up to a late development stage of the embryos, is an important aspect for their potential significance in mass-release to control *A.l. lutescens*.

Ooencyrtus albicrus (OSWALD, 1990) and *Anastatus* sp. (WAITE et al.) proved to be tolerant of endosulfan applications.

In laboratory trials as well, a population study showed that *Anastatus* sp. and *O. caurus* are capable of parasitising the eggs of *A.l. lutescens* effectively. Whether these egg parasitoids

could reduce bug populations to a level under the economic threshold after a mass-release, has to be studied in field trials. In studies on *Ooencyrtus albicrus* , attempts did not succeed in reducing the population of *Pseudotheraptus wayi* to a level under the very low damage threshold (OSWALD, 1989).

It would also be a requirement in achieving significant reduction of the bug population in the adjacent bush after a mass-release, since from there new bugs continuously migrate into the orchard.

The importance of the parasitoids in any potential IPM program also has to be investigated.

For results of the population study on *Anastatus* sp. and *O. caurus* see chapter 5.2.2 (page 132).

Until the present study, ants played an important role in research studies on natural enemies of *A.l. lutescens* and related bug species in East Africa, the Solomon Islands, Indonesia and Papua New Guinea.

The employment of ants as a biological control agent of *Amblypelta cocophaga* in the Solomon Islands (PHILLIPS, 1940; PHILLIPS, 1956) and *Pseudotheraptus wayi* in Zanzibar (LÖHR & OSWALD, 1989; OSWALD, 1990) were studied in detail and gave satisfying results.

In a study on cashew farms in the Northern Territory, *Oecophylla smaragdina* provided a certain level of protection against *A.l. lutescens* attack (PENG et al., 1994).

Generally the use of ants as protection against the bugs would not be a method, accepted by the fruit growers in Australia, and therefore this aspect has not been further investigated in this study.

5.3.3 Neem as a potential alternative to endosulfan

A) Effect on the bugs

Impact on nymphs

In all experiments the concentration of azadirachtin was kept at a low level so that the costs for the application are acceptable. Therefore a recommendation of 0.02 %

azadiractin was followed. In a few trials this concentration was doubled, to allow the study of impact of concentration on results.

The effect of neem was studied on several different development stages of *A.l. lutescens*. Effect were greatest on young nymphs. A mortality of 100 % was recorded in laboratory trials as well as trials under ambient conditions, with most nymphs dying within the first two weeks. The exact impact of neem on nymphs of *A.l. lutescens* is still unclear. Metamorphosis of the nymphs (failure of moulting or deformation after moulting) are known neem effects in other insect species (NATIONAL RESEARCH COUNCIL, 1992; SCHMUTTERER, 1995). Moulting disruptions were not observed in trials with *A.l. lutescens* here.

OSWALD (1989) investigated neem as an alternative insecticide for control of *Pseudotheraptus wayi*. He tested different neem extracts, such as neem seed water extract, neem oil, neem sesame oil and diflubenzuron. Nymphs were reared on coconut inflorescences which were sprayed with different neem treatments for three, five, seven or fourteen days. Over a period of three to five days, all neem extracts caused significantly higher mortality mostly causing of moulting problems. Neem-oil gave the best control results. Treating nymphs with neem did not effect fertility of the females resulting from these nymphs (OSWALD, 1989).

In the laboratory, the neem products tested in this study showed differences in their effectiveness. In the laboratory, and under ambient conditions 'Neem-Azal T/S' worked faster than the two other products tested. Under ambient conditions though, there were no significant differences to the results on 'Green Gold One'. Very high nymphal mortality was achieved within the first ten days. The comparison of the results from laboratory and semi-field experiments suggest that application intervals of 2 weeks would probably be adequate to control nymphs of *A.l. lutescens* satisfactorily.

OSWALD (1989) in his studies on *Pseudotheraptus wayi* found no indications for differences in the effectiveness of neem on different nymphal instars.

In studies on *Oncopeltus fasciatus* medium dosages (0.0625-0.25 µm/nymph) and high dosages (0.5-16 µm/nymph) of azadirachtin inhibited maturation of nymphs which survived several weeks (DORN et al., 1986; 1987).

In a study on *Dydercus koenigii* F., normal development up to the 5th instar was often observed. After that, the moult to the adult stage failed (KOUL, 1984). During the 5th nymphal instar the highest mortality rate, and maximum number of deformities were recorded. The author also noted that the antifeedant property of azadirachtin was independent from the disruptions in development.

Despite reduced feeding activity, which has been recorded in all feeding experiments after the food was treated with neem, the effect of neem was only significant in one trial. A certain repellent effect also exists, but this remains to be investigated in detail with higher concentrations of azadirachtin.

Effect on oviposition rate

In two experiments of this study adults were offered food which was treated with neem, to check the effect of neem on the oviposition rate of *A.l. lutescens*. In the first experiment the number of eggs after 60 days was lower in the neem treatment than in the control treatment, but there were no significant differences. In the second experiment, the number of eggs was also lower in the neem treatment, but a significant effect was only noticeable after 8 weeks. 'Neem-Azal T/S' gave better results than 'Green Gold One', but significant differences could not be proved statistically.

It can therefore be assumed, that - if at all -, neem only in the long term has a significant negative effect on reproduction. Direct spraying of adults, could probably intensify the effect of neem, but this remains to be investigated.

OSWALD (1989) investigated the effect of neem on adults of *Pseudotheraptus wayi*. The author kept male adults on coconut inflorescences sprayed with neem-water-extract, neem oil or neem-sesame oil. The neem-oil and neem-sesame oil treatment resulted in an increased mortality of the bugs. Mating of neem treated males with untreated females caused reduced egg production and significant lower hatching rate of the eggs, as well as an extension of the preoviposition period from 11.6 to 17 days (OSWALD, 1989).

In studies on the effect of azadirachtin on females of the large milkweed bug (*Oncopeltus fasciatus*), neem reduced longevity significantly and fecundity decreased up to 85% (DORN et al., 1987).

Studies on the repellent effect or antifeedant effect against adults of *A.l. lutescens*, neem showed no significant effect, even though feeding activity was reduced. Further studies should be done, for example with higher concentrations of azadirachtin.

OSWALD (1989) investigated the repellent effect of neem against adults of *Pseudotheraptus wayi*, where coconut inflorescences where either treated with neem-water extract, neem oil and glove oil or water as control. Within 24 hours all substances tested except water, showed a distinct repellent effect (OSWALD, 1989).
Because of the low economic threshold of *A.l. lutescens*, the repellent effect would have to be very high to reduce financial losses significantly. The number of fruit attacked would have to be reduced, not just the intensity of attack.
By controlling nymphs alone, a significant reduction of the damage can probably not be achieved.
The economies of neem in comparison to common control methods (endosulfan) also has to be investigated. At the present the prices of commercial neem products are very high.

Effect on bug eggs

Neem products showed no ovicidal effect, which was also found after a neem treatment of *Oncopeltus fasciatus* eggs (DORN, 1986) and eggs of *Dysdercus koenigii* (KOUL, 1984).
DORN (1986) remarked that it is unclear whether the chorion is impermeable to azadirachtin or whether an immunity exists against this substance.
This important aspect of controlling the insect would thus not be achieved with neem.
Compared with the known ovicidal effects of endosulfan, neem would have a disadvantage, but this could possibly be overcome in combination with efficient egg parasitoids.
The results of these studies need to be further investigated with detailed field studies. Here again the impact of the adults which fly in from the adjacent scrub and bush, has to be considered.

B) Side effects on parasitoids

As part of the this study, the effect of neem on egg parasitoids was studied, using *Anastatus* sp. as an example, to investigate the suitability of neem products in IPM programs. The neem products tested proved to be nontoxic against adult wasps of *Anastatus* sp. In many other examples neem has proved to be relatively harmless against adults of beneficials. In a study with *Cotesia glomerata* (L.) (Hymenoptera: Braconidae), a parasitoid of *Pieris brasicae* (L.) (Lepidoptera: Pieridae), azadirachtin did not have any negative effects on the parasitoid, when later instar larvae of their host were treated, but if young instar larvae of *Pieris brasicae* were treated, the parasitoid was killed together with the host [SCHMUTTERER, 1992; MORDUE (LUNTZ) & BLACKWELL, 1993].

When *Anastatus* sp. were offered neem treated bug eggs, non of these eggs were parasitised. A repellent effect on parasitoids can therefore be assumed. This effect would be undesirable with regard to IPM programs.
When eggs which had been parasitised by *Anastatus* sp. were treated with neem, the hatching rate of parasitoids, on average, was higher in the control than in both neem treatments. A significant effect on the hatching rate of parasitoids, however, could not be proved statistically.
Both neem oil and coconut oil had significant impacts on the hatching rate of *Ooencyrtus albicrus*, which led to the conclusion that it was not the toxicity of neem, but inhibited respiration in the egg which caused the mortality in the parasitoids (OSWALD, 1989). That author noted, that the positive effect of neem in laboratory trials has yet to be confirmed by field experiments.
The side effect of neem on parasitoids of *A.l. lutescens* also remains to be investigated in detail in field trials. To achieve an optimum effect of the parasitoids, it would be important to exclude or reduce the impact of neem on the parasitoids.

5.4 Conclusion

This study should be a first introduction to detailed studies on *A.l. lutescens* and an initiation of alternative control methods of this bug. *A.l. lutescens* wide host range, low economic threshold as well as the enormous damage done by low population densities,

make the control of this insect difficult. A big problem is also the lack of adequate monitoring tools, such as pheromone traps. Techniques to reduce the up to now prophylactic insecticide applications, certainly requires exact seasonal profiles, which could limit the spraying of insecticides. The possibility of employing indicator plants as a further monitoring tool and planting these outside an orchard, remains to be investigated. Papaya plants probably would be a very suitable candidate for this. They are very susceptible to the bugs, the damage can fairly easy be recognised and the plants can be planted and monitored without great expense.

To avoid a high level of damage by *A.l. lutescens* in some host plants, it is possible to use less susceptible varieties in new plantations, such as thick skinned avocado varieties for example.

To reduce bug damage, it should be a long term goal to reduce bug populations in the native bush around the orchard, since the bush is certainly a more important breeding ground than the orchard itself. A mass-release of egg parasitoids could possibly be helpful. Better methods for mass-rearing of the parasitoids would have to be investigated.

The potential of neem as an alternative to endosulfan requires thorough investigation.
As part of an IPM program, a combination of strategically timed insecticide applications, with help of the above mentioned indicator plants and the use of egg parasitoids, is a feasible possibility.

In the short-term the complete elimination of *A.l. lutescens* as a pest is probably not possible, but the studies shown, however, give an indication for potential alternatives, which should be investigated in detail, so that in the long term, a solution of the problem will be closer.

6 SUMMARY

The banana-spotting bug, *Amblypelta lutescens lutescens*, a coreid bug, is one of the most important pests of tree fruit and nut crops in tropical and near tropical Australia.

A.l. lutescens has an enormous host range and a small population of bugs can cause a large amount of damage. The symptoms of banana-spotting bug damage are: wilted growth tips where the vegetative parts of the host are affected; black spots at the feeding sites which are caused by fungi and bacteria penetrating into the already injured plant tissue.

At the present, the only control method used against the bugs is chemical control. Endosulfan is mostly applied repetitively, and sprays are usually prophylactic as there are no means of adequately monitoring the insect (FAY, 1990). This type of control method can be environmental hazardous and causes disruption to other alternative controls employed in affected crops.

The research project was divided into the following four main parts:

1. Developing optimal laboratory rearing methods
2. Determining relationship between *A.l. lutescens* and its hosts
   a. Development of nymphs of *A.l. lutescens* on various hosts, including different varieties a) in the laboratory and b) in the field.
   b. Feeding behaviour studies of *A.l. lutescens* on nymphs and adults
   c. Oviposition rate of female bugs on different hosts
3. Population studies of *A.l. lutescens* and its parasitoids in the field
4. Alternative control methods
   a. Resistance or tolerance in hosts
   b. Natural enemies
   c. Neem - a natural insecticide

Laboratory rearing methods:

Adult bugs were either kept as single pairs in large rearing containers, or up to ten adults in glass jars, and exclusively reared on french beans.

Rearing nymphs of *A.l. lutescens* first on papaya plants in large rearing cages and then on beans in large rearing containers after the second week appears to be the easiest and most practical of all the various techniques tested. The mortality rate of the nymphs on papaya

plants followed by french beans was 44 %, and therefore not much higher than nymphs reared only on papaya plants, but lower, than on french beans alone. No other rearing method resulted in a lower mortality rate lower than 34 %.

When holding density was tested, 5 or 10 nymphs per rearing container did not have a significant effect on the survival of the nymphs.

Relationship between *A.l. lutescens* and its hosts

a. Development of nymphs of *A.l. lutescens* on various hosts, including different varieties a) in the laboratory and b) in the field

Nymphal development and mortality were studied on different hosts in several experiments in the laboratory and field.

These studies showed that kind of host, fruit maturity stage as well as whether the fruit was picked or unpicked, all have a significant influence on the nymphal development of *A.l. lutescens*.

Out of the ten different hosts tested in the laboratory, nymphs only survived to adult on four (papaya plants, cashew plants, french beans and mock orange fruit). In the field the results were similar. Out of six different hosts tested in the field, nymphs only survived to adult on two (mango and cashew growth terminals). This supports the suggestion that even if a wide range of hosts is attacked by *A.l. lutescens*, only a few hosts appear optimal for allowing nymphal development.

There were differences in laboratory and field trials in the survival of nymphs. Growth terminals were more suitable for the nymphal development than fruit.

b. Feeding behaviour studies of *A.l. lutescens* nymphs and adults

In the study on feeding frequency and duration, the feeding activity of individual nymphs or adults was observed on different hosts at 15 minute intervals over an eight hour period on three successive days.

On the hosts tested on which nymphal development progressed furthest, such as papaya, mock orange and beans, feeding frequency was greater and feeding period longer. Nymphs and adults behaved similarly in the feeding frequency and feeding duration tests. Any

significant difference would have shown up on the first day. The results of the experiments of feeding frequency and feeding duration of nymphs therefore support the results of the study on nymphal development.

c. Oviposition rate of female bugs on different hosts

The influence of various hosts on the oviposition rate of *A.l. lutescens* was an additional component used to asses host plant suitability for adult bugs.

The results of all oviposition experiments showed that different hosts and even different host varieties can have a significant influence on the oviposition rate of adult *A.l. lutescens*. The highest oviposition rates were on beans, papaya plants and mock orange, which were also the better hosts for nymphal development in the laboratory.

3. Population studies of *A.l. lutescens* and parasitoids in the field

In order to obtain an understanding of the population dynamics of *A.l. lutescens* on certain hosts, in population numbers and structure over time, studies on the seasonal acceptability of hosts to *A.l. lutescens* were done on papaya plants and mock orange bushes. During the observation period nymphs, adults, eggs and parasitoids were recorded.

In papaya as well as in mock orange *A.l. lutescens* has certain periods in the year where population increases. In papaya, the period is only very short (2 months), but in mock orange, *A.l. lutescens* were present during the whole season. Observations in mock orange bushes showed that the two parasitoids (*Anastatus* sp. and *Ooencyrtus caurus*) are also more active at different times. *Anastatus* were more active at the beginning of the season (August until December), whereas more *O. caurus* were collected early (August), but mainly later on (between February and May), when the number of *Anastatus* had decreased again.

4. Alternative control methods

a. Resistance or tolerance in hosts

Eight papaya varieties and five carambola varieties were examined in detail for varietal differences in the level of bug damage. During this study papaya plants were monitored over a period of about eight months and carambola fruit were exposed to *A.l. lutescens* nymphs for a week.

A significant varietal resistancy could not be proved in papaya plants, but a consistent lower level of damage was present to some degree in the variety PZ90-1XPZ90-1. A significant varietal effect was only found in carambolas where the damage in the variety Thai Knight was the highest.

b. Natural enemies

The three parasitoids discovered in November 1992 (FAY & HUWER, 1993), are considered to be potential control agents against *A.l. lutescens*.

The effect of age of the host egg on the rate of parasitism was examined for *Anastatus* sp. and *Ooencyrtus caurus* in several experiments. All experiments showed that both parasitoids, especially *O. caurus*, are capable of parasitising fruitspotting bug eggs up to a fairly late developmental stage of the embryo, almost until they are fully developed. A significant difference in parasitism of eggs of different age could not be proved for either parasitoid.

c. Neem - a natural insecticide

In this study the effect of neem extracts, as an alternative to conventional chemical control for the bugs, was looked at under several aspects. Neem was tested on eggs, nymphs (nymphal development, repellency effect and toxicity) and adults (oviposition rate, repellency effect and toxicity) mainly under laboratory conditions but also under ambient conditions. The effectiveness of three different neem products was compared as well. The effect of neem on the parasitoids (adult wasps and parasitised eggs were exposed to neem) was also investigated.

7 ZUSAMMENFASSUNG

Amblypelta lutescens lutescens (banana-spotting bug), die zur Familie der Randwanzen (Coreidae) gehört, ist einer der bedeutendsten Schädlinge an Obst und Nüssen in den Tropen und Subtropen Australiens. Sie hat ein sehr breites Wirtsspektrum, und schon kleine

Populationen von Wanzen können große Schäden anrichten. Die Symptome des Wanzenschadens sind verwelkte Triebspitzen, wenn der vegetative Teil der Wirtspflanzen befallen wurde. Werden Früchte geschädigt, so bilden sich an den Saugstellen schwarze Flecken, die durch Pilze und Bakterien verursacht werden, die in das verletzte Pflanzengewebe eindringen. Bis heute ist die einzige Bekämpfungsmethode gegen die Wanzen die Anwendung chemischer Mittel. Endosulfan wird meist wiederholt appliziert, und die Spritzungen sind gewöhnlich prophylaktisch, da es bisher keine Möglichkeiten gibt, das Insekt ausreichend zu überwachen (FAY, 1990). Diese Bekämpfungsmethode kann ökologisch bedenklich sein und sich störend auf andere alternative Bekämpfungsmaßnahmen auswirken, die eventuell in Zukunft in den betroffenen Plantagen angewendet werden.

I. Laborzuchtmethoden

Imagines wurden entweder als einzelne Paare in großen Aufzuchtbehältern oder bis zu zehn Individuen in einem großen Glasbehälter gehalten und ausschließlich mit grünen Bohnen ernährt.

Die Zucht der Larven zunächst an Papayapflanzen und nach der zweiten Woche an grünen Bohnen erscheint als die einfachste und praktischste aller untersuchten Methoden.

Die Mortalitätsrate der Larven an Papayapflanzen, gefolgt von grünen Bohnen, war 44 %, und somit nicht viel höher als bei solchen, die nur an Papayapflanzen aufgezogen wurden, aber niedriger als an grünen Bohnen allein. Eine niedrigere Larvalmortalität als 34 % war mit keiner Zuchtmethode zu erreichen.

Die Haltungsdichte, die bei 5 oder 10 Larven pro Aufzuchtbehälter untersucht wurde, hatte keinen signifikanten Einfluß auf das Überleben der Larven.

II. Beziehung zwischen *A.l. lutescens* und Wirtspflanzen

1. WIRTSPRÄFERENZ:

a. Entwicklung der Larven von *A.l. lutescens* an verschiedenen Wirten und verschiedenen Sorten im Labor und im Freiland

Die Entwicklung und Mortalität der Larven wurde an verschiedenen Wirtspflanzen in mehreren Experimenten in Labor und Freiland untersucht. Die Untersuchungen zeigten, daß die Wirtspflanzenart, das Reifestadium einer Frucht, sowie auch der Umstand, ob es sich

um gepflückte oder ungepflückte Frucht handelt, einen signifikanten Einfluß auf die Larvalentwicklung von *A.l. lutescens* haben.

Bei zehn verschiedenen, im Labor getesteten Wirtspflanzen bzw. Wirtspflanzenfamilien war ein Überleben zum Imaginalstadium nur an vier von ihnen möglich (Papayapflanzen, Cashewpflanzen, grünen Bohnen und Mock-Orange-Früchte). In den Freilandversuchen waren die Ergebnisse ähnlich, d.h. die Larven haben nur an zwei (Mango- und Cashewtriebe) der sechs verschiedenen Wirte bzw. Wirtsteile bis zum Imaginalstadium überlebt. Dies bestätigte die Vermutung, daß ein weites Spektrum an Wirtspflanzen von *A.l. lutescens* befallen wird, aber nur wenige für die Entwicklung der Wanze gut geeignet sind. Triebspitzen eigneten sich besser als Früchte.

Bezüglich der Überlebensrate der Larven gab es keine Unterschiede zwischen Labor- und Halbfreilandversuchen.

b. Untersuchungen des Saugverhaltens von Larven und Imagines

In Versuchen zur Häufigkeit und Dauer der Nahrungsaufnahme wurde die Saugaktivität jeder einzelnen Larve oder Imago in Intervallen von 15 Minuten über acht Stunden an drei aufeinanderfolgenden Tagen an mehreren Wirtspflanzenarten beobachtet.

Bei Wirten, an denen die Larvalentwicklung am schnellsten erfolgte, wie Papayapflanzen, Mock-Orange-Früchten und grünen Bohnen zeigte sich auch eine häufigere und längere Saugtätigkeit. In Experimenten zur Häufigkeit und Dauer der Saugtätigkeit verhielten sich Larven und Imagines ähnlich. Signifikante Unterschiede zwischen den Wirtspflanzenarten traten schon am ersten Tag auf. Die Ergebnisse der Untersuchungen zur Häufigkeit und Dauer der Saugaktivität der Larven bekräftigten somit die Resultate der Untersuchungen zur larvalen Entwicklung.

c. Ovipositionsrate der Weibchen an verschiedenen Wirtspflanzen

Ein Einfluß verschiedener Wirte auf die Ovipositionsrate von *A.l. lutescens* war ein zusätzlicher Aspekt, um die Eignung der Wirtspflanzen für die Imagines beurteilen zu können. Die Ergebnisse aller Experimente zeigten, daß verschiedene Wirtspflanzenarten, sowie auch verschiedene Sorten einen signifikanten Einfluß auf die Ovipositionsrate der Imagines haben können. Die höchsten Ovipositionsraten wurden an grünen Bohnen, Papayapflanzen und

Mock-Orangen verzeichnet, die sich auch im Hinblick auf die Larvalentwicklung im Labor als die besten Wirte erwiesen hatten.

2. POPULATIONSSTUDIEN AN *A.L. LUTESCENS* UND PARASITOIDEN IM FELD

Um die Populationsdynamik von *A.l. lutescens* (im Hinblick auf Populationsstärke und -struktur über einen Zeitraum hinweg) bei bestimmten Wirtspflanzen besser zu verstehen, wurden Untersuchungen über jahreszeitlich bestimmte Akzeptanz von Papayapflanzen und Mock-Orange-Büschen angestellt. Während des Beobachtungszeitraumes wurden Larven, Imagines, Eier und Parasitoide erfaßt.

Bei Papayapflanzen wie auch bei Mock-Orange-Büschen gab es das Jahr über bestimmte Zeiträume, in denen die Population von *A.l. lutescens* zunahm. An Papaya war dieser Zeitraum sehr kurz (2 Monate), bei Mock-Orange-Büschen war *A.l. lutescens* während der ganzen Saison präsent.

Die Beobachtungen in Mock-Orange-Büschen zeigten, daß zwei Parasitoidenarten (*Anastatus* sp. und *Ooencyrtus caurus*) zu verschiedenen Zeitpunkten im Freiland aktiv waren. *Anastatus* sp. war vor allem zu Beginn der Saison (August bis Dezember) aktiv, wohingegen *O. caurus* vorher (August), aber hauptsächlich später (zwischen Februar und Mai) gefunden wurde, wenn die Zahl von *Anastatus* wieder abnahm.

III. Alternative Bekämpfungsmethoden

1. RESISTENZ ODER TOLERANZ DER WIRTSPFLANZEN

Acht Papayasorten und fünf Karambolasorten wurden auf sortenbedingte Unterschiede bezüglich der Schadensintensität untersucht. Im Rahmen der vorliegenden Studie wurden Papayapflanzen über einen Zeitraum von etwa acht Monaten beobachtet, Karambolafrüchte jeweils für eine Woche den Larven von *A.l. lutescens* ausgesetzt.

Eine signifikante sortenbedingte Resistenz war bei Papayapflanzen nicht nachweisbar, aber ein konstant geringerer Schaden war bei der Sorte 'PZ90-1XPZ90-1' zu erkennen. Ein signifikanter Sorteneffekt war nur bei Karambolas zu beobachten, wobei der Schaden bei der Sorte 'Thai Knight' am höchsten war.

2. NATÜRLICHE FEINDE

Drei Parasitoidenarten, die im November 1992 (FAY & HUWER, 1993) entdeckt wurden, können als potentielle Antagonisten zur Bekämpfung von *A.l. lutescens* betrachtet werden.

Der Einfluß des Alters der Wirtseier auf die Parasitierung wurde in mehreren Experimenten mit *Anastatus* sp. und *Ooencyrtus caurus* untersucht. Alle Experimente zeigten, daß beide Parasitoide, besonders *O. caurus* in der Lage sind, die Wanzeneier bis zu einem ziemlich späten Entwicklungsstadium des Embryos zu nutzen, d.h. fast bis zum Ende der Entwicklung. Signifikante Unterschiede bei der Parasitierung unterschiedlich alter Eier konnten für beide Parasitoide nicht nachgewiesen werden.

3. NIEM ALS EINE POTENTIELLE ALTERNATIVE ZU ENDOSULFAN

In der vorliegenden Arbeit wurde der Effekt von Niemextrakten als eine Alternative zur konventionellen chemischen Bekämpfung gegen *A.l. lutescens*, unter verschiedenen Aspekten betrachtet. Hauptsächlich im Labor, aber auch unter freilandähnlichen Bedingungen wurde die Wirkung von Niem auf Eier, Larven (larvale Entwicklung, Repellenteffekt und Toxizität) und Imagines (Ovipositionsrate, Repellenteffekt und Toxizität) untersucht. In mehreren Versuchen wurde die Wirkung von drei verschiedenen Niemprodukten verglichen. Die Untersuchung der Wirkung von Niem auf Eiparasitoide war im Hinblick auf zukünftige IPM-Programme von Interesse.

In Labor- und freilandähnlichen Versuchen wurde eine 100 %-ige Mortalität der Larven mit allen drei getesteten Niemprodukten erreicht.

Die Saugaktivität von Larven und Imagines wie auch die Ovipositionsrate wurden durch eine Behandlung der Nahrung mit Niem verringert, aber signifikante Unterschiede konnten nicht nachgewiesen werden.

In der Regel zeigte das Produkt 'Neem-Azal T/S' von den drei getesteten Produkten die beste Wirkung. Keines der drei Produkte zeigte eine ovizide Wirkung.

Niem hatte zwar keine letale Wirkung auf Imagines des Parasitoiden *Anastatus* sp., doch war eine Repellentwirkung zu beobachten, wobei es bei den getesteten Niemprodukten aber keine signifikanten Unterschiede gab.

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9 APPENDIX

APPENDIX I: HOST RECORDS OF SOME *AMBLYPELTA* SPP.

I	**= *Amblypelta nitida***	**IV**	**= *Amblypelta brevicornis***
II	**= *Amblypelta l. lutescens***	**V**	**= *Amblypelta cocophaga***
III	**= *Amblypelta l. papuensis***	**VI**	**= *Amblypelta theobromae***

+ =	**record**	**min =**	**minor**
F =	**feeding**	**maj =**	**major**
B =	**breeding & feeding**	*** =**	**new record**

HOST	I	II	III	IV	V	VI	Reference
ACTINIDIACEAE							
Actinidia chinensis Planchon (kiwi-fruit)	F,min*						16*
ANACARDIACEAE							
Anacardium occidentale L. (cashew nut)		B,maj					13,16
Mangifera indica L. (mango)	B,maj	B,maj*	+		+		2,3,4,8,16*
Pistachia vera L. (pistachio)		F,min*					16*
Schinus terebinthifolius Raddi	B,min*	F,min*					16*
Spondias mombin L. (yellow mombin)		F,maj.					16*
ANNONACEAE							
Annona muricata L. (soursop)		F,maj*					16*
Annona reticulata L. (custard apple)	B,min	B,maj*					3,4,5,8,16*
Rollinia sp.		B,maj*					16*

HOST	I	II	III	IV	V	VI	Reference
APOCYNACEAE							
Cryptostegia grandiflora (Roxb.) R. Br. (Palay)-rubber vine		+					2,3,5
Plumeria rubra L. (frangipani)		+	+				2,3,14,15,16
ARACEAE							
Anthurium sp.		F,min*					16*
Syngonium sp.		B,min*					18*
ARALIACEAE							
Schefflera actinophylla (Endl.) Harms (umbrella tree)		F,min					5,16
ARECACEAE							
Archontophoenix cunninghamiana (H. Wendl.) H. Wendl. et Drude (Bangalow palm)		B,min*					16*
Cocos nucifera L. (coconut)		F,min	+		+	+	3,10,13,15
Livistona sp. (cabbage palm)		B,min*					16*
ASTERACEAE							
Lactuca sativa L. (lettuce)		B,min*					18*
Xanthium pungens Wallr. (noogoora burr)		+					2,4
Xanthium strumarium L. (noogoora burr)		+					3,15
BOMBACACEAE							
Ceiba pentandra (L.) Gaertn. (kapok)					+		3
Durio zibethinus Murray (durian)		F,min					16*
BROMELIACEAE							
Ananas comosus (L.) Merr. (pineapple)		+					2,3,4

HOST	I	II	III	IV	V	VI	Reference
BURSERACEAE							
Canarium sp. (nali nut)					+		3,10
CAESALPINIACEAE							
Bauhinia galpinii N. E. Br.	B,min*	B,maj					16*
Bauhinia variegata L.	B,min*	B,min*					16*
Cassia fistula L.		F,min*					16*
Ceratonia siliqua L. (carob)		B,min*					16*
Delonix regia (Hook.) Raf. [*Poinciana regia* (flamboyant) in PHILLIPS (1940)] (poinciana)		F,min		F,maj*			3,10,16*
Peltophorum pterocarpum (DC) K. Heyne [*P. ferrugineum* (Decne.) Benth. in BRIMBLECOMBE (1948)]			+				2,15
Senna spectabilis (DC.) Irwin & Barneby		F,min*					16*
CAPRIFOLIACEAE							
Viburnum suspensum Lindl.		B,min*					20*
CARICACEAE							
Carica papaya L. (papaya)	+	B,maj	+		+		2,3,4,5,14,16,
Carica X (? *C. heilbronii* X *C. pentagona*) (babaco)		F,maj*.					16*
CELASTRACEAE							
Denhamia celastroides (F. Muell.) L.W. Jessup	B,min*						16*
CLUSIACEAE							
Garcinia mangostana L. (mangosteen)		F,min*					16*
CONVOLVULACEAE							
Ipomoea batatas (L.) Lam. (sweet potato)			+				15

HOST	I	II	III	IV	V	VI	Reference
Merremia pacifica v. Ooststr.					+		1
Merremia peltata Merrill					+		1
CUCURBITACEAE							
Citrullus sp. (water-melon sp.?)		F,min*			+		3,16*
Cucumis melo L. (melon)					+		10
Sechium edule (Jacq.) Schwartz. (choko)	+	B,min*					4,16*
wild cucumber		+					4
CYATHEACEAE							
Cyathea cooperi (Hook. ex F. Muell.) Domin (tree fern)		F,min*					16*
DIOSCOREACEAE							
Dioscorea sp. (yam)			+				19
EBENACEAE							
Diospyros virginiana L. (persimmon)	F,min*						16*
EUPHORBIACEAE							
Codiaeum variegatum (L.) Blume		+			+		3,4,8,10
Croton sp.		F,min*					16*
Euphorbia pulcherrima Willd. [*Poinsettia pulcherimma* in PHILLIPS (1940)]						+	3,10
Glochidion sp.						+	3,10
Hevea brasiliensis (A. Juss.) Muell. Arg. (rubber)			+			+	3,10,15
Homalanthus populneus (Giesel.) Pax [*Homalanthus populifolius* Graham in PHILLIPS (1940)]						+	3
Jatropha curcas L.					+		3,10
Macaranga aleuritoides F. Muell.					+		1

HOST	I	II	III	IV	V	VI	Reference
Macaranga tanarius (L.) Muell. Arg.		F,min*			+		1,3,10,16*
Mallotus philippensis (Lam.) Muell. Arg. (red kamala)	F,min*						16*
Manihot esculenta Crantz (x) (cassava)		F,min	+		+	+	6,8,10,15,16
Pedilanthus tithymaloides (L.) Poit. (x) (zigzag plant)		B,min					14
FABACEAE							
Erythrina sp. (coral tree)		B,min*					16*
Glycine max (L.) Merrill (soybean)		+					14
Macroptilium atropurpureus (DC.) (Siratro)	B,min*	B,min*					16*
Psophocarpus tetragonolobus (L.) DC. (winged bean)			+		+	+	7
Vigna radiata (L.) R. Wilczek (mung bean)			+				3,15
Vigna unguiculata sesquipedalis (L.) Verdc. (snake bean)			+				19
Vigna unguiculata (L.) Walp. (cowpea)					+		3
JUGLANDACEAE							
Carya illinoensis (Wagenh.) C.Koch (pecan nut)	F,min	F,min*					4,5,8,16*
LAURACEAE							
Actinodaphne solomonensis C.K. Allen					+		4,5,8
Persea americana Mill. (avocado)	B,maj	B,maj*					4,5,8,16*
Cryptocarya laevigata Blume (red-fruited laurel)	F,min*						16*
LECYTHIDACEAE							
Barringtonia edulis Seem.					+		3

HOST	I	II	III	IV	V	VI	Reference
LEEACEAE							
Leea indica (Burm. f.) Merr. [*Leea sambucina* in PHILLIPS (1940)]					+		3,10
LILIACEAE							
Gloriosa superba L. (glory lily)		F,min*					16*
iris lilly (without further particulars)		F,min*					16*
MALPHIGIACEAE							
Malpighia punctifolia L. (acerola)	B,min*	+					16*
MALVACEAE							
Abelmoschus manihot (L.) Medicus (aibika)			+				19
Gossypium sp. (cotton)		+					2,3,4
Hibiscus sp. (Hawaiian hibiscus)		F,min*					16*
Hibiscus tiliaceus L. (cotton tree)		B,maj*					16*
Urena lobata L. (urena burr)			+				3,4
MELASTOMACEAE							
Melastoma malabathricum L.					+		3
MELIACEAE							
Amoora sp.					+		3
Dysoxylum sp.					+		3,10
Melia dubia Cav. (white cedar)		+					3,15
Melia azedarach L. (white cedar)	B,min*.	B,maj.					5,16*
MENISPERMACEAE							
Stephania sp.	B,maj*	B,maj*					16*

HOST	I	II	III	IV	V	VI	Reference
MIMOSACEAE							
Calliandra sp.		F,min*					17*
MORACEAE							
Artocarpus communis Foster & Foster f (breadfruit)				+			19
Artocarpus heterophyllus Lam. (jack-fruit)		F,min*					16*
Ficus carica L. (common fig)	B,min*	+			+		1,3,10,15,16*
Ficus copiosa Steud.					+		3
Ficus leucotricha Miq. (rock fig)		+					14
Ficus racemosa L. (rough-leafed fig)	B,min*	B,min					5,16*
Ficus septica Burm. [*Ficus leucantotoma* in PHILLIPS (1940)]					+		3
Morus nigra L. (mulberry)	B,min*	B,min					4,8,16*
MUSACEAE							
Musa paradisiaca L. (banana)	+	B,min	+				2,3,4,14,16
MYRTACEAE							
Eucalyptus deglupta Blume						+	1,9
Eucalyptus camaldulensis Dehnh. (river gum)		+					14
Feijoa sp. (feijoa)	B,min*						16*
Melaleuca sp. (tea tree)				+			4,8
Myrciaria cauliflora (DC) Berg (jaboticaba)	B,min*						16*
Psidium gaujava L. (guava)	B,maj	B,maj	+				4,5,8,14,16
Psidium cattelianum Sabine (cherry guava)	+						4

HOST	I	II	III	IV	V	VI	Reference
Syzigium spp.	B,min*	B,min*					16*
NYCTAGINACEAE							
Calpidia brunoniana (Endl.) Heimerl [*Pisonia brunoniana* in BRIMBLECOMBE (1948)]		+					2,3,15
OLEACEAE							
Olea europaea L. (olive)				+			4,8
ORCHIDACEAE							
Dendrobium spp. (dendrobium orchids)		F,min*					16*
OXALIDACEAE							
Averrhoa carambola L. (carambola)	B,min*	B,maj*					16*,17*
PANDANACEAE							
Sararanga sp.					+		3
PASSIFLORACEAE							
Passiflora edulis Sims. (passion fruit)	B,min	B,min*					2,3,15,16*
Passiflora quadrangularis L. (granadilla)	+	B,min*			+		2,3,15,16*
Passiflora suberosa L. (corky passion flower)	B,maj*	B,maj.					2,3,5,15,16*
Passiflora subpeltata Ortega (white passion flower)		+					2,3,15
PIPERACEAE							
Piper nigrum L. (pepper)		F,min*.					17*
POACEAE							
Saccharum officinarum L. (sugar cane)					+		3

HOST	I	II	III	IV	V	VI	Reference
POLYPODIACEAE							
Hypolepis tenuifolia (Forst. f.) Bernh.					+		3
PROTEACEAE							
Macadamia integrifolia Maiden & Betche (macadamia nut)	B,maj	B,maj					2,3,4,5,8,16
Macadamia tetraphylla L.A.S. Johns. (macadamia nut)	B,maj	B,maj					5,16
PUNICACEAE							
Punica granatum L. (pomegranate)		B,min*					16*
RHAMNACEAE							
Alphitonia exelsa (Frenzl.) Benth. (soap bush)		F,min					14
Alphitonia petrei Braid and White (soap bush)	B,maj*	B,maj*					16*
ROSACEAE							
Eriobotrya japonica (Thunb.) Lindley (loquat)	B,maj*	B,maj*					16*
Malus sylvestris Mill. (apple)	+						4,8
Prunus domestica L. (plum)	+	+					3,5
Prunus persica vulgaris (L.) Batsch. (peach)	F,min	F,min					3,4,5,16
Prunus persica cv. nectarina (nectarine)	+	+					3,5
Rhaphiolepis indica (L.) Lindl. (Indian hawthorn)	B,min*						16*
Rosa spp. (rose)		B,min*					16, 18*
Rubus indaeus L. (raspberry)		B,min*					16*
Rubus moluccanus L.					+		1

HOST	I	II	III	IV	V	VI	Reference
RUBIACEA							
Coffea sp. (coffee)		F,min*					16*
RUTACEAE							
Casimiroa edulis Llave & Lex. (white sapote)	B,maj*	B,min*					16*
Citrus mayeri Y.Tan. (Meyer lemon)		B,min*					16*
Citrus reticulata Blanco (Imperial mandarine)	F,min*	F,min*					16*
Citrus sinensis (L.) Osbeck (late valencia orange)	F,min*	F,min*			+		10,16*
Citrus sinensis varr. (Naval orange)		F,min*					16*
Clausena brevistyla Oliver	B,min*.	B,min*.					16*
Erimocitrus glauca (Lindl.)	B,min*						16*
Fortunella margarita (Lour.) Swing. (kumquat)		+					4
Geijera parviflora Lindl. (wilga)				+			4,8
Murraya paniculata (L.) Jack. (orange jessamine or mock orange)	B,maj*	B,maj*.					16
SAPINDACEAE							
Alectryon coriaceum Radlk. (beach bird's eye)		B,maj*					16*
Cupaniopsis sp.					+		3
Dimocarpus longan Lour. (longan)	B,maj*	B,maj*					16*
Guioia semiglauca (F. Muell.) Radlk.	+	+					2,3,5,15
Litchi chinensis Sonn. (lychee)	B,maj*	B,maj*					16*
Nephelium lappaceum L. (rambutan)		F,min*					16*
SAPOTACEAE							
Manilkara zapota (L.) van Royen (sapodilla)		F,min*					17*

HOST	I	II	III	IV	V	VI	Reference
Planchonella pohlmanniana (Benth. & Hook. f. es F. Muell.) Burkill (yellow boxwood)		+					3,4
SOLANACEAE							
Capsicum sp. (red chilli)					+		3,10
Cyphomandra crassicaulis (Ortega) Kuntze (tamarillo)		F,min*					17*
STERCULIACEAE							
Ambroma augusta (L.) L. f. (devils cotton)			+				15
Theobroma cacao L. (cocoa)		F,min*	+		+	+	3,6,8,11,17*
THEACEAE							
Camellia japonica L. (camellia)		B,min*					16*
TILIACEAE							
Grewia asiatica L.	B,min*	B,min*					16*
Triumfetta rhomboidea Jacq. [*Triumfetta bartrami* in PHILLIPS (1940)]					+		3
URTICACEAE							
Pipturus argenteus Wedd.					+		1
VERBENACEAE							
Clerodendrum sp.					+		1
VITIACEAE							
Vitis vinifera L. (grape)		B,min*			+		10,16*
XANTHORRHOEACEAE							
Xanthorrhoea sp. (grass tree)	+						4

HOST	I	II	III	IV	V	VI	Reference
ZINGIBERACEAE							
Alpinia sp. (wild ginger)		F,min*					16*

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(ex WAITE & HUWER)

APPENDIX II: CURRENT RECOMMENDATION ON CONTROL OF *AMBLYPELTA* BY THE QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES - AUSTRALIA

Crop	*Amblypelta spp.*	*Amblypelta nitida*	*Amblypelta lutescens lutescens*
Avocado	endosulfan 0.15 l/100 l trichlorfon "Dipterex Liquid" 0.17 l/100 l "Dipterex 500 SL" 0.2 l/100 l	endosulfan 0.15 l/100 l methidathion 0.125 l/100 l trichlorfon 0.2 l/100 l	endosulfan 0.15 l/100 l
Banana	endosulfan 0.15 l/100 l endosulfan + mancozeb + sulphur 13g/2 l		endosulfan 0.15 l/100 l
Cashew		endosulfan 0.2 l/100 l	
Casimiroa (white sapote)	endosulfan 0.2 l/100 l		
Custard apple	endosulfan 0.15 l/100 l	endosulfan 0.15 l/100 l methidathion 65ml/100 l	endosulfan 0.15 l/100 l
Durian	endosulfan 0.2 l/100 l		
Guava	endosulfan 0.2 l/100 l		
Longans	endosulfan 0.2 l/100 l		
Loquat	endosulfan 0.2 l/100 l		
Lychee	endosulfan 0.2l/100l		

Crop	*Amblypelta spp.*	*Amblypelta nitida*	*Amblypelta lutescens lutescens*
Macadamias			acephate 0.66kg/ha or 66g/100 l endosulfan 0.15 l/100 l methidathion 0.125 l/100 l trichlorfon 0.8 l/100 l
Mango		endosulfan 0.2 l/100 l	endosulfan 0.2 l/100 l
Mangosteen	endosulfan 0.2 l/100 l		
Papaya	endosulfan 0.15 l/100 l	endosulfan 0.15 l/100 l trichlorfon "Dipterex Liquid" "Lepidex" 80ml/100 l "Dipterex 500 SL" "Lepidex" 500" 0.1 l/100 l	endosulfan 0.15 l/100 l trichlorfon "Dipterex Liquid" "Lepidex" 80ml/100 l "Dipterex 500 SL" "Lepidex" 500" 0.1 l/100 l
Passionfruit		endosulfan 0.2 l/100 l	
Pecan	endosulfan 0.2 l/100 l		
Persimmon	endosulfan 0.2 l/100 l		
Rambutan	endosulfan 0.2 l/100 l		
Rollinia	endosulfan 0.2 l/100 l		
Sapodilla (chikus)	endosulfan 0.2 l/100 l		

Crop	*Amblypelta spp.*	*Amblypelta nitida*	*Amblypelta lutescens lutescens*
Soursop	endosulfan 0.2 l/100 l		
Stonefruit	endosulfan 0.2 l/100 l		
Tamarillo	endosulfan 0.2 l/100 l		
Yellow mombin (hog plum)	endosulfan 0.2 l/100 l		

Ex (BEAVIS et al.,1991)

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