Factors influencing selection of settling sites within plants and oviposition by greenhouse whitefly (*Trialeurodes vaporariorum* Westwood)

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Joan Elizabeth Breach

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Abstract

Orientation by adult greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) to younger leaves is induced by negative geotaxis and positive phototaxis but there is a minor effect of features of the leaves. The selection of the lower leaf surface is predominantly the result of a preference for being upside-down (ie. a response to gravity) but leaf characteristics also play a role. Negative phototaxis has a minor effect. Adult females lay more eggs on the younger leaves and on the lower leaf surface of some plant species but not others. Leaf hairiness and leaf angle are not significant factors in selection by adults of either 1) younger leaves or 2) the lower leaf surface nor are they significant factors in the number of eggs/female/day laid on either 1) leaves of different ages or 2) the lower or upper leaf surfaces.

Adult survival on sucrose sachets (aqueous sucrose solution sandwiched between two layers of Nescofilm) was optimum for 15-20% sucrose and eggs/female/day laid on the sucrose sachets was independent of sucrose concentration when it was between 10% and 30%. Eggs/female/day reached a maximum after 2-3 days and thereafter dropped sharply. The number of larvae that hatched was independent of sucrose concentration but higher concentrations appear to induce later hatch. Percent egg hatch varied from 40% to 77%. The number of eggs laid on 20% sucrose sachets in complete darkness was nearly twice that of any other light intensity. There was no graded relationship between light intensity and oviposition. More eggs were laid on 15% sucrose sachets in light/dark regimes of 8/16, 4/20 and 0/24 than of 12/12, 16/8 and 24/0 hours. No diurnal fluctuation in egg-laying occurred nor were more eggs laid in either light or dark periods. The sucrose sachet technique is a suitable tool for further studies on greenhouse whitefly behaviour.

The results provide further information for incorporation into integrated pest management research.

Acknowledgements

The final version of this thesis is at last final. The checking has been checked - again. The last mistake been found (or has it?). The protracted process of producing a properly presented thesis is finished. It but remains to acknowledge and thank those who made a contribution towards its completion.

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Greenhouse whiteflies may now rest in peace - on someone else's plants!

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Introduction

Greenhouse whitefly (*Trialeurodes vaporariorum*, Westwood) was selected as the topic for this thesis as it has become an important pest of several greenhouse crops in New Zealand such as tomatoes, beans, cucumbers and chrysanthemums. In other countries eggplants, melons, gherkins and gerberas - all grown in greenhouses are also very susceptible to attack. Plants grown in open ground such as tamarillos and ornamentals such as hibiscus, *Datura* spp. and *Abutilon* spp. are suitable hosts too. In addition weeds such as rauriki (*Sonchus olearaceus*) may be sources of initial infestation for important crops. Therefore, tomato, tobacco (which has been widely used for rearing greenhouse whitefly, *Abutilon* sp., *Datura* sp. and rauriki were selected for this study as representatives of the range of plants attacked. They were all also readily available either as mature plants in the grounds of Massey University or could be grown from seed.

The damage caused by whiteflies can be considerable. They are sap suckers and excrete honeydew on which unsightly sooty mould may grow. If sufficient numbers are present, plant growth may be stunted and crop yield reduced. Also the very presence of the adults and developing immobile stages of greenhouse whitefly may downgrade the aesthetic value of ornamentals both outdoor, such as hibiscus and pot plants, such as impatiens.

Wide usage of chemicals to control greenhouse whitefly has resulted in the development of resistance to some chemicals. Consequently attention has turned to biological control methods and, for tomato, breeding of resistant cultivars. In more recent years integrated pest management programmes have been developed for several crops e.g. tomatoes, cucumbers, chrysanthemums. Work is currently in progress for other crops.

The development of an integrated pest management programme for a greenhouse crop requires research into the interactions of all the components involved in the growing of that

crop.These include all the pests and diseases, potential crop cultivars, as well as environmental factors such as temperature and humidity. An important aspect of this is the interaction between the host plant and each important pest of the crop, for example the plant characteristics which affect the selection of one plant part in preference to another or the factors that affect the number of eggs laid by the adult females. It is in this area that this thesis seeks to add to the knowledge already available. All such information may then be incorporated into a model for that particular crop. As the information is refined and quantified the model can be used to test predictions such as the effect of changes in greenhouse temperature or growing a different cultivar with more hairy leaves.

Resistant plant varieties can be incorporated into integrated pest management programmes. The search for such resistant varieties requires the screening of numerous for the desired traits. Techniques which can do this quickly and accurately are needed. The technique used in this thesis of leaf discs set into holes in water agar could possibly be adapted for use in such a screening process.

Research is sometimes hampered by lack of suitable techniques. For example when leaves are used in experiments changes may take place in the leaves themselves because of the treatments applied and so affect the experimental outcome. Hence sucrose sachets could be useful in experiments to measure oviposition/larviposition or longevity, for work with pesticides, effect of day length, light intensity etc. There are no reports in the literature of the use of sucrose sachets for greenhouse whitefly. This thesis has shown that they provide a suitable tool in greenhouse whitefly research.

It is hoped that the information in this thesis will add to the already large body of knowledge available for the design of integrated pest management programmes and models of greenhouse whitefly behaviour and interactions with its host plants.

Literature Review

Distribution of adult insects within plants

Plant feeding insects are very discerning when selecting not only the plant species but also the precise part of those plants on which they feed and/or oviposit. There are insect species which prefer to feed on leaves e.g. caterpillars of green looper (*Chrysodeixis eriosoma*); stems or branches e.g.lemon tree borer (*Oemona hirta*); flowers e.g. tomato fruitworm (*Heliothis armigera conferta*); roots e.g. carrot rust fly larvae (*Psila rosae*) and fruits e.g. codlin moth (*Laspeyresia pomonella*). Similarly, eggs may be laid on different plant parts depending on the insect species. Some insects are less fussy and will feed and oviposit on more than one plant part e.g. greedy scale (*Hemiberlesia rapax*) feeds on stems, leaves and fruits. However, some are even more fussy and prefer regions within plant parts for example the upper leaf surface (cherry slug (*Caliroa cerasi*)) or the seeds within fruits (codlin moth larvae). However for oviposition codlin moth prefers leaves to fruits.

Further factors add to the complexity of the distribution of individuals of an insect species within a plant. The different life stages, especially those of holometabolous insects, may settle, feed and oviposit in quite different locations on the plant, or one stage (especially the pupa and winged adults) may not be on the plant at all. Adult females of some species lay their eggs on the preferred part of the host plant e.g. white butterfly (*Artogeia rapae*) lays its eggs on the outer leaves of brassicas but others lay their eggs in the vicinity of the host e.g. porina (*Wiseana* spp). Still other species have no choice but to oviposit/larviposit where they feed, because they are immobile e.g. scale insects. Some insects move on and off individual plants throughout the day or over their lifetime e.g. adult grass

grub beetles move in to feed on leaves of trees and shrubs at night and return to the soil during the day. So the distribution of a population of insects within a plant varies widely and has a characteristic pattern for different species.

Location of settling sites within plants

In the context of this thesis 'settle' means remain on the plant part where the insect has alighted. If it rejects the site within a short space of time by flying or walking away then it has not 'settled'. Noldus et al (1986b) found that for adult greenhouse whiteflies this time is about 30 minutes where they have no prior experience of young leaves of suitable host plants.

The process of location of settling sites within plants is likely to be similar to the process of selection of the host plant species itself. Insects would not see the individual plant as a single entity in the way that human beings do, hence homing in on a particular part within the host plant will be just another link or so in the process of feeding/oviposition site selection described by various authors (Thorsteinson, 1960; Saxena, 1969; Lindstedt, 1971). Stinner et al (1983) point out that models of the host plant selection process are complex and that random movement does not explain the observed distribution. However, insects will often first move randomly in order to arrive in the general vicinity of an appropriate host plant before other factors can come into play. This is because the sphere of influence of most factors is relatively small. The major links in the chain of the host plant selection process have already been unravelled (Dethier, 1976) and found to be both physical features of the environment and of the plant as well as chemical substances within or emanating from the plant or pheromones emanating from other individuals of the same insect species.

The factors governing the links in the chain have sometimes been investigated by studying the responses of individual insects to various stimuli. However, Stinner et al (1983) point out that the behaviour of one individual insect may be different from that of a group. One only has to consider the flight patterns of swarms of locusts to realise that some

insect species exhibit group behaviour patterns. Hence it is necessary to study the behaviour of groups of insects as well as that of individuals.

There are a range of factors that may affect the settling site selection process. The chemical factors could be odours which the insect detects from a distance or at the plant surface or non-volatiles again detected at the plant surface or after a test bite or probe. The insect may be attracted, repelled, arrested, stimulated to probe/bite or to oviposit by these chemicals. There has been much argument over the relative importance of secondary plant substances and plant nutrients in host plant selection (Haseman, 1946, 1950; Fraenkel, 1960, 1969; Thorsteinson, 1958, 1960; Beck, 1965; Kennedy, 1965; Jermy, 1966; Schoonhoven, 1968; Saxena, 1969; Dethier, 1970, 1982; Chapman, 1974; Prokopy and Owens, 1978). It appears that both play a role and their relative importance depends on the insect and plant species. In addition some insects are attracted to the opposite sex or to others of the same species by sex or aggregation pheromones so that they are drawn to the plants inhabited by other individuals.

The physical factors can be features of the plant such as leaf hairiness or shape of fruit or colour or the hardness of the fibres around the vascular bundles which prevent penetration to the phloem for sap feeders. The physical factors can also be features of the wider environment. Many insects respond to light, gravity, and/or day length. Prokopy and Owens (1983) considered that the perception of light intensity and colour contrasts, shape and movement perception, and pattern disruption may be as important, or more so, in the process of detection of plant structure within a canopy as the detection of an entire plant from outside the canopy.

The need to locate a host plant varies with the insect species. Some are already on their host plants when the juveniles first emerge and even the adults spend all or almost all of their lives on the same host plant species. Many hemipterous insects, such as greenhouse whitefly, are of this type and tend to spend their whole life cycle not only on the same plant species but also on the same plant individual. For most insects the winged adults, and sometimes the first instars, are the dispersive stages. So, it is the adults of greenhouse whitefly which locate the settling sites within a plant or move to another plant. The newly emerged crawlers have not been observed to move off the leaf on which they emerged.

The flight of hemipterous insects has been described by Southwood (1962) as 'migratory'. That is movement from the current habitat to a new habitat. The migrating insects do not normally respond to stimuli such as food and sex pheromones. He describes the walking movement of adults as 'trivial', that is it has a specific goal such as finding a mate, locating food or seeking shelter. The migratory movement he says occurs at the start of adult life and it is minimal where the habitat is stable and reaches full expression when the habitat is temporary. Hence, although insects such as whiteflies do not need to move very far to find a new habitat, their flight to new settling sites can be described as migratory as defined by Southwood.

Distribution of greenhouse whitefly within a plant.

The distribution of greenhouse whitefly within a plant was observed and recorded many years ago (Hargreaves, 1915). The adults are typically found on the underside of the younger leaves; the eggs are laid on these younger leaves and the immobile juveniles are on progressively older leaves as they develop to adulthood and the leaves mature and approach senescence; the puparia are found on the older leaves. From here the newly emerged adults migrate up the plant to the

younger leaves of the same plant or sideways and upwards to the younger leaves of other plants. Flight will take place above 16°C, at 15°C they walk slowly and no movement occurs below 10°C (Noldus et al, 1985 quoting Weber, 1931). The adults preferentially feed on tertiary veins on the young leaves and on old leaves they prefer the main vein (Noldus et al, 1986b) otherwise they do not appear to prefer a particular area on the leaf surface.

Studies have been carried out on the dispersal of greenhouse whitefly from a point source to surrounding plants. Genchev and Natsoka (1977) found that horizontal migration on tomatoes and cucumbers was relatively slow compared with vertical migration. This they suggested was because adults are 'attracted' upwards towards the young leaves where they feed and oviposit. The whiteflies in the experiment carried out by Noldus et al (1985) with tomatoes in a greenhouse took 3 days to move from the source to settle on average 2.5 leaves from the top of the plants. Xu et al (1988) devised a model for this within plant vertical movement. However, many of the whiteflies will also move horizontally as Noldus et al (1986a) showed in a later experiment and Xu et al (1989) later devised a model for the between plant movement. The distribution within a greenhouse tends to be patchy with groups within patches being highly aggregated (Yamada et al, 1979; Eggenkamp et al, 1982; Xu, 1985; Noldus, 1986c). Dispersal was found to be temperature dependent with higher temperatures resulting in earlier dispersal, more rapid movement and longer distances travelled by van Vianen et al (1988b). The change in the within plant distribution over time as the adults moved up the plants was recorded by Xu et al (1984) and Noldus et al (1985). Van Vianen et al (1988a) showed that feeding site selection involved walking, probing and feeding with increasing time spent on each if the host was satisfactory such as tomato but no feeding occurred and few probes where the plant was an unsatisfactory host such as red ash. However there is little experimental information on

the factors that influence the adults to settle on the lower leaf surface and on the younger leaves.

Various factors have been suggested to explain the upward movement of greenhouse whitefly to the younger leaves. Hussey and Gurney (1959) suggested that it was the result of negative geotaxis and attraction to the colour of the apical leaflets. It has been found that aphids on the vertical stems of plants orientate upwards by light and gravity (Binns, 1978).

Light

Far more evidence is available for a greenhouse whitefly response to light especially to the colour yellow. Hargreaves (1915) thought that whiteflies were neither negatively nor positively phototactic but Åhman and Ekbom (1981) put forward a strong phototaxis and a response to the yellow-green colour of the youngest leaves as the reasons why newly hatched whiteflies move up a plant to settle on the youngest leaves. Light triggers movement off the leaves of origin and lack of light inhibits movement (Noldus et al, 1985). Also whiteflies are more active during the day and tend to settle at night (Ekbom, 1982).

Vaishampayan et al (1975a and 1975b) demonstrated a strong positive response to yellow light in the 520-610 nm range which supports the suggestion of Åhman and Ekbom above. Vaishampayan et al (1975a and 1975b) found that the positive response to hues sharply decreased with darker shades (addition of black to the hue) or less saturated tints (addition of white to the hue) of the same hues and that light intensity affected the response to particular hues. Experiments on the numbers of adults landing on leaves of eggplant, sweet pepper, tomato and cucumber showed that the differences depended on the colour of the leaves (van Lenteren et al, 1977). Verschoor-van der Poel and van Lenteren (1978) found that selection before landing was

influenced by host colour from experiments with both real and artificial leaves. However they do not provide data on the colour of the artificial leaves and it is imprecise for the real leaves.

Within a plant, the range of colour of leaves is usually smaller than between plant species. An exception is poinsettia on which whiteflies select leaves with less chlorophyll and lighter coloured bracts but this selection is not associated with total sugar content nor plant growth habit (Bilderback and Mattson, 1977). This suggests that colour is involved in the orientation process and because the chemical stimuli are satisfactory the whiteflies remain. For plants with far less contrast among leaves the story is different. Hussey and Gurney (1959) offered adults a choice of two leaf ages of tomato in both artificial light and bright sunlight and observed that they selected the younger leaf within 20 minutes but when the whiteflies were prevented from probing by a transparent barrier they did not collect beneath the younger leaf. Noldus et al (1986b) showed that whiteflies do not select leaves of tomatoes of a certain age from a distance in spite of the presence of colour differences.

The response of whiteflies to yellow has been made use of in sticky yellow traps for either monitoring or control in commercial greenhouses. For example see Gillespie and Quiring, 1987; Affeldt et al, 1983; Georgiev, 1984; Mitkov et al, 1984; Veire and Vacante, 1984a and 1984b; Webb et al, 1985; Yano, 1987. The response to light direction from an artificial source has been well documented in the work of various authors on the response to colour. Moericke et al (1966) carried out experiments with whiteflies tethered in flight and found that they fly towards yellow and will stop wing movements if the yellow light strikes the lower part of the eyes. Also, when stimulated by yellow in flight or stationary with wings extended, they adopt what they call a

'fall reflex' position but if the wings are folded over the body the yellow light elicits no response. There is the suggestion of Åhman and Ekbom (1981) of a positive phototaxis for whiteflies and evidence for a response to light direction by alate aphids (Binns, 1978). Whiteflies in flight have a stronger preference for higher light intensities (Macdowall, 1972) in particular if the hue is either 550 nm (blue) or 400 nm (yellow) (Coombe, 1981). Where UV absorbing vinyl film covers a greenhouse there are fewer landings by greenhouse whitefly on cucumbers and tomatoes than under standard vinyl film especially if 380-400 nm is the absorbtion limit but there is no effect on subsequent development (Shinkaji et al, 1983; Nakagaki et al, 1984).

Light may also influence the selection of the lower leaf surface. Coombe (1982) thought that where adults feed is determined by visual stimuli as they walk to the shaded side no matter which side the light (from a xenon arc lamp approximating noon sunlight) shines towards and that this indicated that gravity is not important. However he provides no statistical evidence and there is no indication that heat from the lamp had been eliminated as a cause of the response. He also did not take account of the possibility that both light and gravity could be factors with light overriding the gravity response when light is very bright and directed to the underside of the leaf. Klingauf et al (1978) recognised the importance of light and gravity in selection of the lower leaf surface by the pea aphid (*Acyrthosiphon pisum*) as the alkane fraction of cuticle wax in *Vicia faba* and *Brassica n. napus* caused the aphid to move from upper to lower surface only when the leaf was in a natural position. If light is a factor in both selection of the younger leaves and the lower leaf surface there is an apparent contradiction in whitefly response to light: a positive phototaxis to induce movement upwards to the younger leaves and a negative phototaxis to induce movement away from light to the shaded lower side of the leaf. It may be that whitefly adults respond positively

to light when in flight and negatively when walking or when they have received stimuli to settle.

Plant chemicals

In the experiments of Hussey and Gurney (1959), mentioned above, if the whiteflies were unable to probe because of an artificial barrier they did not congregate below the leaf discs. This suggests that some cues to induce settling come from plants after landing. Noldus et al (1986b) confirmed that adults can distinguish young from old leaves rapidly. If they have experience of young leaves first they need only 3 probes of about 2 minutes each before choosing to depart from old leaves and if they have no experience of young leaves they need 6 probes of about 3 minutes each before departing. The stylets penetrate to the phloem and the stylet path was thought to be intercellular for both larvae and adults (Hargreaves, 1915; van der Kamp and van Lenteren, 1981). The work of Janssen et al (1988; 1989) confirmed that the path is almost completely intercellular before the phloem is reached in about half an hour. Rejection of the plant occurs after a few minutes by which time the stylets will have penetrated to just below the epidermis and sampled the apoplast close to the leaf surface and it is the chemical properties of this which play an important role in host plant selection or rejection. There are sensilla on the labium which suggest a chemosensory or a mechano-chemosensory function (Walker and Gordh, 1989). Noldus et al (1986b) conclude from their study of probing times that searching is random. The tobacco whitefly (*Bemisia tabaci*) will probe almost any substance on which it alights - even yellow plastic mulch (Berlinger, 1986). Thus greenhouse whitefly does not have to feed in order to select/reject a plant and the chemicals involved in the process are therefore likely to be secondary plant substances rather than nutrients.

Studies of the nutrient status of plants do not give a true analysis of what phloem feeding insects are receiving (van

Emden, 1966). However the nutrient status of the whole plant or plant parts has been found to correlate well with selection by some insects e.g. nitrogen content of *Artemisia ludovici* and phloem and seed feeding insects (Strauss, 1987), high nitrogen and low potassium content of turnip and the aphid *Myzus persicae* and higher nitrogen in cotton and the tobacco whitefly *Bemisia tabaci* (Berlinger, 1986), the higher nitrogen content of younger tomato leaves and greenhouse whitefly (Noldus, 1986b). Prokopy and Owens (1983) suggested that a higher than average nitrogen content in young than in mature leaves may confer a yellow-green appearance which may be the actual stimulus for the choice.

Tobacco whitefly prefers to settle and survives better in vitro at pH 6.0-7.25 in both choice and no choice tests. Late in the season of cotton production the pH of the preferred old leaves is 6.8 and the less preferred young is 5.9 so pH may be important in selection of settling sites for tobacco whitefly (Berlinger et al, 1983). Generally the pH of plant sap varies 5.0-6.5 depending on the plant species and also changes with plant age (Caldwell, 1956 in Berlinger, 1983). The effect of pH on greenhouse whitefly plant part selection has not been investigated.

Odour plays an important role in host plant selection for some insects but this does not appear to be so for greenhouse whitefly. Vaishampayan et al (1975b) showed that volatiles from bean leaves did not elicit a response. However they did not repeat their experiment with any other plants and do not indicate the age of the leaves. No experiments have been reported that investigate whether there is a difference in volatiles emanating from younger and older leaves and whether these have an effect on selection within a host plant but this could still be the case for certain plants. It may be that odours from non-host plants are repellant to greenhouse whitefly. However Berlinger (1986) found no response to olfactory stimuli in the tobacco whitefly. Odour is not

likely to have any effect on selection of the younger leaves by greenhouse whitefly.

The aphid *Hyadaphis erysimi* is incited to probe by water vapour after landing (Nault and Styer, 1972) and Mound (1965; in Berlinger, 1986) thought that *Bemisia* stays on hairy leaves because the micro climate is more favourable and Vet (1980) quotes from Eisjakers (1969) that greenhouse whitefly covered smaller distances when the RH was higher and from Weber (1931) who found that up to 50% of greenhouse whitefly larvae died at 25-30°C when humidity was high and that 80% RH was optimal.

Physical features of leaves

It has been observed that when a leaf is turned over any whiteflies present on the lower surface walk over to the other side (Hargreaves, 1915; Coombe, 1982). Hargreaves suggested several reasons for the preference for the lower surface: (1) the cuticle is thinner and the vascular bundles are closer to the surface, (2) phototaxis: he observed that they had no preference for either surface when the leaves were vertical, (3) the position of the anus and character of the excreta mean they would be engulfed in their own honeydew if they settled on the upper surface, (4) they sought protection from precipitation.

Van Lenteren et al (1977) and van der Kamp and van Lenteren (1981) measured the distance between the surface and the vascular bundles for eggplant, cucumber, tomato and sweet pepper and the length of the stylets of all whitefly stages and found that this was not a limiting factor, nor was cuticle toughness. No sclerenchyma or xylem bundles prevented access to the phloem on these plants.

A leaf physical factor that has been implicated in host plant selection is the type and density of the leaf hairs. Luckwill (1943) describes 7 types of leaf hair on the genus

Lycopersicon (tomato). They are:

I. Slender hairs 1.5-2.5 mm long with a small glandular vesicle at the tip.

II. Slender hairs 0.2-1.0 mm long with no vesicle at the tip and a 4-5 cell base.

III. Slender hairs 0.4-1.0 mm long with no vesicle at the tip and a 1 cell base.

IV. Slender hairs 0.2-0.4 mm long with a vesicle at the tip. Only present in *L. Hirsutum.*

V. Short hairs 0.1-0.3 mm long with a pointed tip sometimes curved.

VI. Glandular hairs 0.1-0.5 mm long with a glandular head of 2-4 cells.

VII. Small glandular hairs 0.05-0.10 mm long with a head of 4-8 cells.

The aphid *Myzus persicae* and 5 species of thrips can become impaled on the spines of beans and tomatoes (McKinney, 1938). *Aphis craccivora* and *Myzus persicae* are sometimes caught in the glandular hairs which are either broken by the insects or by plant rub, rain or handling (Johnson,1955). Some tomato varieties resistant to mites were found to have denser hairs on the lower and upper leaf surface but this was not the only factor conferring resistant qualities (Stoner et al, 1968). Gentile et al (1968) found that two accessions of *Lycopersicon hirsutum* were resistant to whiteflies and had more glandular hairs. However de Ponti et al (1975) did not find that glandular hairs or other morphological features on *L. hirsutum* and *L. hirsutum glabratum* were responsible for the observed resistance and assumed it was due to internal factors such as sap chemicals. In contrast *Solanum pennellii* will trap whiteflies in sticky glandular hairs. Van der Kamp and van Lenteren (1981) considered that it is unlikely that the pattern and distribution of leaf hairs influenced suitability of eggplant, tomato cucumber and sweet pepper for greenhouse whitefly. However Georgiev and Sotirova (1986) found that the degree of resistance of tomatoes to greenhouse

whitefly could be correlated with the leaf hairs of types b and c and they were able to produce resistant hybrids with such leaf hairs. It is not clear from the abstract (the paper is written in Bulgarian) what these hair types are as they do not correspond to those described by Luckwill (1943). Then again Malausa (1988) found no relationship between resistance and hairiness in eggplants. Berlinger (1986) notes that Rossetto et al (1977) found that on soybean cultivars tobacco whitefly laid more eggs on young than mature leaves of the same plant despite there being a higher hair density on the young leaves. Very high densities of leaf hairs may well physically prevent whiteflies from reaching the leaf surface with their ovipositors.

Because greenhouse whitefly prefers the underside of leaves it may possibly prefer leaves which tend to be horizontal rather than more vertical. There is no indication in the literature that leaf angle to the horizontal has an effect on plant part selection for greenhouse whitefly. However, Nair and Daniel (1983) found that there were twice as many adult tobacco whitefly on cassava varieties with erect leaf orientation than those with horizontal or downward orientation.

Aggregation and Pheromones

Lloyd (1922) described greenhouse whitefly as "distinctly gregarious". It may be that the adults congregate on the underside of young leaves in part because a few individuals arrive and settle and others are attracted to them. Åhman and Ekbom (1981) set up an experiment which showed that groups which are all female or mixed sexes tended to aggregate and all male groups tended to disperse. However the number they used in any one run of the test was small - 4 individuals. Xu (1985) in his study of the dynamics of within-leaf spatial distribution patterns found that adults are highly aggregated due to the pairing and feeding near main veins to form groups which in turn tend to be aggregated. Van Vianen et al (1988b)

showed that adults whiteflies were not attracted to plants already infested with adults or larvae but may be arrested on plants already infested with larvae. Neither Xu nor Åhman and Ekbom nor van Vianen et al mention the possibility of an aggregation pheromone but Åhman and Ekbom suggest that a sex pheromone is involved in mate finding. Li and Maschwitz (1983) extracted a sex pheromone from greenhouse whitefly and showed that it would attract males at short range and induced resting behaviour but van Vianen et al (1988b) regard their evidence for the action of a sex pheromone as inconclusive.

Oviposition within plants

If the adults of an insect species are already settled and feeding at a particular site within a plant then eggs will normally also be laid at this site. For holometabolous insects the oviposition site selected by the adult female is often quite different from her own feeding site. Therefore the process of oviposition site selection and the factors that stimulate the female to lay eggs may also be quite different for these two situations. It could be assumed that, where the oviposition and feeding sites are the same, the factors that are most conducive to optimum oviposition are also present at this site. This may not necessarily be so.

A range of factors affect oviposition by insects giving rise to considerable variation in number of eggs laid per female over her lifetime and oviposition rates both between and within species. Greenhouse whitefly is no exception to this.

Oviposition by greenhouse whitefly

The number of eggs laid per female per day by greenhouse whitefly is dependent on a whole raft of factors such as the plant species (O'Reilly, 1974; van Lenteren et al, 1977; Sas et al, 1978), the previous nutrition of the female (van Boxtel et al, 1978; Hussey and Gurney, 1959); temperature

(Hussey and Gurney, 1957) and whitefly density which, if it is above 1 pair of whiteflies per square centimetre, induces a reduction in fecundity (Xu et al, 1984). Eggs per female per day can therefore vary widely: 3 (Lloyd, 1922), 5 (Speyer, 1929), 4.2-10.8 depending on temperature (Hussey and Gurney, 1957), 5.2 (Tong, 1977), 5-10 (van de Merendonk and van Lenteren, 1978). Even when parameters are kept as uniform as possible there is considerable variation in the number of eggs per female per day. Tong (1977) records figures between 2.22 and 7.49 on tomato and Collman and All (1980) a range of 0 to 9.3 on excised bean leaves. The duration of the egg stage also varies. Hargreaves (1915) observed that the eggs remained cream coloured for 2-4 days and 10-13 days elapsed before they hatched. Others record the duration of the egg stage as: 11-16 days (Trehan, 1941), 13-16 days with a maximum of 117 days (Lloyd, 1922), 8 days and 21 at low temperature (Speyer, 1929), 8 days (van Lenteren et al, 1977). Percent egg hatch has been recorded as 95.9 on eggplant, 93 on cucumber, 91.9 on tomato, 87.7 on sweet pepper (van de Merendonk and van Lenteren, 1978) and arcsin % egg hatch as 66.83 on tobacco, 72.09 on cucumber and 77.30 on tomato (O'Reilly, 1974). Egg-laying starts almost immediately after emergence and increases to a maximum, which depends on the plant species, then fluctuates around this level before gradually declining (Sas et al, 1978; van Boxtel et al, 1978). Whiteflies will continue to produce fertile eggs throughout their lives even without repeated matings (Åhman and Ekbom, 1981). The total life cycle during a year can be as short as 3 weeks (Tauber and Helgesen, 1974) or as long as 13 weeks (Hargreaves, 1915) but 7 weeks (Curry and Pimental, 1971a) would be a more usual maximum time. The length of the life cycle depends mainly on temperature which is the most important factor influencing the development of whitefly populations (Xu et al, 1984).

Light

Light also has an effect on oviposition. Trehan (1941) found

that greenhouse whitefly laid more eggs under yellow light than any other except colourless (white). However although he measured the intensities of the colours he did not separate the effects of colour and intensity nor mention the name of the plant he used. Hussey and Gurney (1959) found that low light resulted in low egg production on excised tomato leaflets but when a range of intensities was tried no consistent pattern emerged. They also found that there was no significant difference among eggs/female/day with light/dark regimes between 0/24 and 20/4 hours on excised tomato leaflets but they do not indicate the duration of the experiment. Oviposition continues at night (van Evert and Schutte, 1983).

Plant chemicals

Nutrient status also affects larviposition/oviposition e.g. the fecundity of the aphids *Brevicoryne brassicae* and *Myzus persicae* is proportional to the total soluble nitrogen within leaves of brussels sprouts of the same age but not between leaves of different ages (van Emden and Bashford, 1969); the reproductive capability of the pea aphid (*Macrosiphum pisi*) is reduced by deficiencies of nitrogen, phosphorus, potassium, calcium or magnesium in pea plants (Barker and Tauber, 1951). There is a high correlation between nitrogen content of leaves and the density of *Bemisia tabaci* on cotton (Joyce, 1958). Detached tomato leaves from plants grown in aerated nutrient solutions with varying levels of nitrogen show no difference in oviposition rate by greenhouse whitefly but for phosphorus there were significantly fewer eggs/female/day and lower fecundity only where adult females were reared on phosphorus deficient plants and then allowed to lay eggs throughout the rest of their lives on leaves of plants grown at three phosphorus levels. This phenomenon may in part explain why whiteflies that are reared on a relatively poor host then transferred to a good host lay fewer eggs and have a shorter life-span (van Boxtel et al, 1978). However those transferred from a poor host to the same

host do better on it than those that were reared on better hosts.

Just because whitefly adults select the younger leaves on which to feed and then lay eggs it does not mean that they will necessarily lay more eggs on the younger leaves. For tomato, fecundity declines with leaf age (Hussey and Gurney, 1959). A similar effect occurs for cabbage whitefly (*Aleyrodes brassicae*) on mustard, broccoli and turnip (Iheagwam, 1980), cotton whitefly (*Bemisia gossypiperda*) (Trehan, 1944 in Iheagwam, 1980) and viburnum whitefly (*Aleurotrachelus jelinekii*) (Southwood and Reader, 1976 in Iheagwam, 1980). The effect may be due to changes in the metabolism of the plant as the leaves age (Hussey and Gurney, 1959) especially changes in the total protein and amino acids (van Emden and Bashford, 1969).

Physical features of leaves

The nature of the cuticle may also affect the ability of whiteflies to lay eggs as the stalk is inserted into the leaf surface but not into stomata, as is the case for some other whiteflies (Paulson and Beardsley, 1985). Because eggs take up water from leaf tissue (Byrne et al, 1990) they may dehydrate and not hatch if not anchored into leaf tissue.

Longevity of adult greenhouse whitefly

The longevity of adult females will affect the total number of eggs laid throughout her life. Adult longevity in greenhouse whitefly is highly variable: some may die within 24 hours after emergence and others live for 3 weeks or more on excised bean leaves at 27° C and 74% RH (Collman and All, 1980). These authors found that 34.1% of females and 41.4% of males died within four days of eclosion and that females lived longer than males.

Summary

The evidence discussed above points to possible negative geotaxis, positive phototaxis and movement towards leaves with more yellow in their hue as the orientation factors in selection of the younger leaves. After landing on leaves the final selection takes place, with chemicals from a test probe playing an important role. Aggregation due to aggregation or sex pheromones may play a role but leaf hairiness is probably not a factor.

The foregoing review and discussion indicates that the factors involved in the selection of the lower leaf surface are probably negative phototaxis, possibly geotaxis so that adults are upside-down and possibly an aggregation effect but there is no evidence for the influence of physical or chemical features of the leaf. However this latter possibility cannot be completely discounted.

There is evidence for much variation in eggs/female/day under uniform conditions and that whiteflies lay more eggs with higher temperatures; more preferred host plants; younger leaves; yellow or white light. Where the phosphorus content of leaves on which the female parent was reared is lower oviposition is reduced. With low light intensities fewer eggs are laid and light/dark regimes between 0/24 and 20/4 hours make no difference to the number of eggs laid. Eggs are laid in the dark as well as the light.

Thesis objectives

The experiments that follow sought to fill in some of the gaps in the information on the effects and relative importance of the factors that affect the selection of the younger leaves and the lower leaf surface. Some of the factors that affect oviposition will also be considered as

they are conveniently studied along with the factors that affect settling site selection.

The objectives of this thesis were to determine, firstly, the effects and relative importance of geotaxis, phototaxis and characteristics of the leaves on the selection of the younger leaves. Secondly, the effects and relative importance of gravity, light/shade and characteristics of leaves on the selection of the lower leaf surface. In addition the leaf hair density was checked for correlation with selection of younger leaves and lower leaf surface, and nitrogen, phosphorus and potassium content of leaves for correlation with leaf age.

The effects on oviposition of leaf age, leaf surface, the nitrogen, phosphorus and potassium content of leaves, leaf hair density were examined mainly in conjunction with the above experimental work. The effect on oviposition of light intensity and a range of light/dark regimes was determined using an artificial substrate for egg-laying so that any effects of these factors with experiments on leaves could be eliminated.

Experiments

Statistical Analysis of Experiments

In the past many experiments with count data have been analyzed with analyses of variance usually after the data had been tranformed. With the advent of computer analysis it is now possible to use the more statistically correct discrete multivariate analysis. However some authors have persisted in using analyses of variance for count data. This situation has been reported in the paper by Stanek et al (1987) and I quote:

> "Many observations in entomlogical studies are discrete or categorical in nature. Measurements are often made of the frequency of occurrence of particular behaviours or morphological characters in different species or populations. Discrete measures are also encountered in studies of trap effectiveness and in evaluating both insect resistance to insecticides and plant resistance to insects. In toxicological studies, the discrete measure for an insect is often 'dead' or 'alive' (a binary response), and intermediate responses do not exist. Although entomologists have long been aware of and applied the analysis of variance and other multivariate methods to continuous data, the more recently developed techniques of discrete multivariate analysis (e.g. Bishop et al, 1975, Forthofer and Lehnen, 1981) have not been generally used. Instead, categorical data have either been analyzed by continuous-data methods (with violation of assumptions of normality and homoscedasticity), or statistical treatments have been limited to simple two-way contingency tables using χ^2 tests or nonparametric methods."

Therefore, throughout this thesis contingency tables with a loglinear analysis have been used for all count data and analyses of variance restricted to the non-count data.

1. Factors influencing selection of settling sites within a plant

The experiments discussed in this section were designed to investigate the effects of gravity, light and leaf characteristics on the settling sites of adult whiteflies within host plants. Three forms of plant material were used: intact plants, excised leaflets and leaf discs set into holes in water agar. Two aspects of settling sites were studied: factors affecting the selection of the lower leaf surface and factors affecting the selection of the younger leaves.

A. Selection of lower or upper leaf surface.

It is well-known that adult whiteflies settle almost entirely on the lower leaf surface. Coombe (1982) thought that this was not likely to be a gravity response as he found that shining a light onto whiteflies on the lower surface of a leaf caused most of them to walk over the leaf margin to the upper surface. Differences in the lower and upper surfaces of the leaf itself (either external and/or internal) could also influence the ultimate settling site, for example leaf hairs, or fibres around the phloem making penetration of the mouthparts to the phloem from the upper leaf surface more difficult. Hence, the three factors which could be involved in the observed preference for lower leaf surface are:

1. **Gravity** response. That is whiteflies prefer to settle in an upside-down position and settling on the lower leaf surface will normally facilitate this.

2. Negative **phototaxis** (when walking). That is whiteflies walk from the higher light intensity on the upper leaf

surface to settle in the lower light intensity of the lower leaf surface.

3. **Leaf surface characteristics.** That is differences in external or internal leaf structure between lower and upper leaf surfaces which induce more whiteflies to settle on the lower surface.

B. Selection of younger or older leaves.

It is also well-known that adult whiteflies prefer to settle on the younger leaves. It has been observed that whiteflies in flight tend to move upwards. This may be either a negative geotactic and/or a positive phototactic response. This orientation in flight will, for most plants, naturally lead whiteflies to the younger leaves which are higher up the plant than the older leaves from which they emerged from pupae. There is also the possibility that there are characteristics of leaves of different ages which either induce take-offs to flight (from older leaves) and/or induce settling (on younger leaves). Such characteristics could be physical e.g. hairiness of leaves, or chemical e.g. nutrient content or presence/absence of secondary plant substances. Hence, the factors possibly involved in the selection of the younger leaves are:

1. Negative **geotaxis** (when in flight).
2. Positive **phototaxis** (when in flight).
3. **Leaf age** characteristics.

The effects and relative importance of these factors are addressed in the experiments in Sections 1-1 to 1-3.

1-1 Gravity, light direction, and leaf characteristics and selection of lower leaf surface and younger leaves of intact plants.

The two experiments discussed in this section were designed to investigate the effects of gravity, light (direction or intensity i.e shade or direct light) and leaf characteristics on the settling sites of adult whiteflies within host plants.

These experiments were designed to indicate whether all or any of the factors below influence the selection of the lower leaf surface and the youngest leaves.

A. Selection of lower or upper leaf surface.

1. **Gravity** response.
2. Negative **phototaxis** (when walking).
3. **Leaf surface characteristics.**

B. Selection of younger or older leaves.

1. Negative **geotaxis** (when in flight).
2. Positive **phototaxis** (when in flight).
3. **Leaf age** characteristics.

To facilitate discussion in the remainder of this section the six factors outlined above will be referred to by the words in bold type.

Materials and Method

Two similar experiments (Experiments 1-1/1 and 1-1/2) were carried out using tomato plants (*Lycopersicon esculentum* cv. Virosa) approximately 50 cm tall. There were four

plants each under a different orientation/light regime which were:

1. Upside-down and light from above.
2. Natural orientation and light from above.
3. Natural orientation and light from below.
4. Upside-down and light from below.

The plants for the orientation/light regimes 1 and 2 were placed in one cage and the plants for the orientation/light regimes 3 and 4 were placed in another cage. Both cages were placed in a glasshouse. Approximately 400 adult whiteflies were introduced into each cage and the number of individuals present on the upper and lower surfaces of each leaf were counted 2 and 24 hours later. The experiments were not continued any longer than 24 hours as firstly, the leaflets of the upside-down plants were already curling around towards the light and secondly, it was difficult to water the upside-down plants.

The 10 cm pots in which the plants were grown were covered with black polythene to eliminate any effects of pot colour. The leaves of the plants which were upside-down were wired into a horizontal position. The leaves were numbered consecutively up the stem with 1 being the oldest leaf. Leaves 11, 12 and 13 were very immature, leaves 1 to 8 or 9 were fully expanded and leaves 8 or 9 to 10 were intermediate.

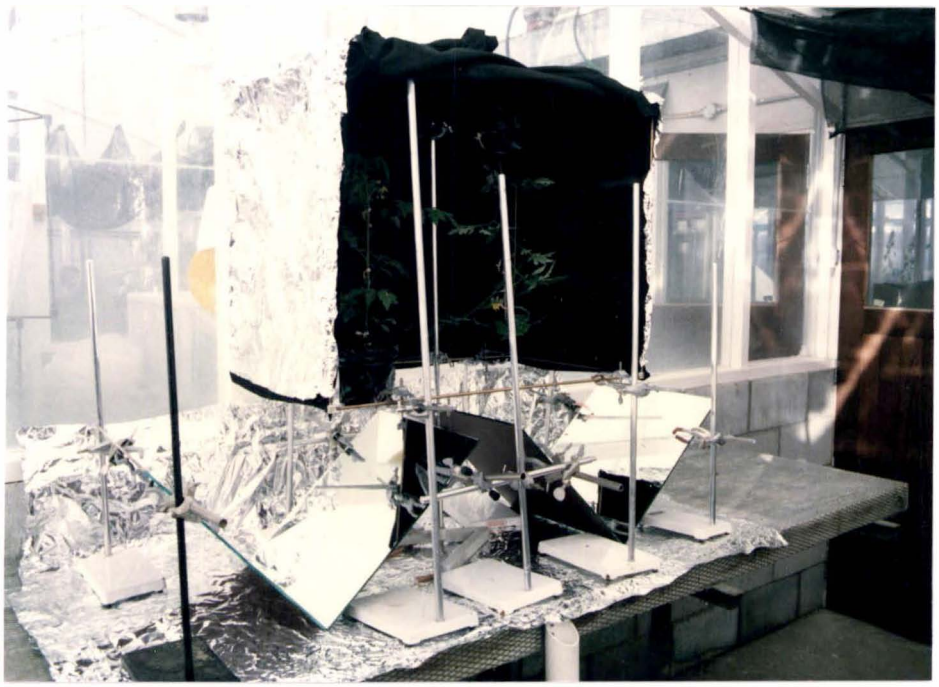
The cages were 5.5 X 60 X 45 cm, covered with black cloth on the inside and black polythene on the outside on all but one 75.5 X 45 cm face which for the first cage faced up and for the second cage faced down. Over one vertical (75.5 X 60 cm) face the cloth formed a flap 'door' to give ready access for counting the whiteflies. The cage with light from below had the top and sides, other than the one with the flap, covered with aluminium foil to help prevent the temperature rising

Photograph 1-1/1

Tomato plants in cage for Experiments 1-1/1 and 1-1/2.
Light from above plants. Plant 1 left, plant 2 right.

Photograph 1-1/2

Tomato plants in cage for Experiments 1-1/1 and 1-1/2.
Light from below plants. Plant 3 left, plant 4 right.



reduce the number of whiteflies flying out immediately after release.

The results of parts A (selection of lower or upper leaf surface) and B (selection of younger or older leaves) had to be analyzed separately as the factors are confounded - for example, it is impossible to say whether the presence of whiteflies on the lower surface of the youngest leaves is due to the gravity effect causing them to go to the down side or to fly against gravity to the youngest leaf.

The results for A. (selection of lower or upper leaf surface) were analyzed using contingency tables with a loglinear model for the three factors discussed above and also the factors 'time' (2 and 24 hours) and 'experiment' (1-1/1 and 1-1/2) (Bishop et al, 1975). Counts for surfaces were summed across ages. The models of best fit were determined. For each model the terms were further analyzed to determine which pairs of factor combinations were significantly different from each other.

The counts for the leaf ages for B. (selection of youngest or oldest leaves) were divided into three groups: 'youngest', 'middle aged' and 'oldest'. Then the numbers of whiteflies on the youngest and oldest were compared to determine whether there were more whiteflies at one or other end of the plants. Which leaf ages are included in each group is arbitrary. The leaf ages were allocated to the groups for oldest and youngest leaves so that the natural case (plant number 2 - plant right way up and light from above) had significantly more whiteflies on the younger than the older leaves which is as observed in the field. The middle group of leaf ages was omitted and an analysis using contingency tables with a loglinear model was carried out (Bishop et al, 1975). Hence, a reasonable basis for comparison of the number of whiteflies on youngest and oldest leaves was provided.

Results and Discussion

A. Selection of lower or upper leaf surface

A summary of the counts of adults on the two leaf surfaces for the two experiments at 2 and 24 hours are presented in Fig. 1-1/1. The significant differences for gravity, phototaxis and leaf surface are indicated in the figure and those for times and experiments are in Appendix Table A1-1/1.

Analysis for the factors gravity, phototaxis, leaf surface, experiment and time showed that there were four 3 way and one 4 way interactions. As at least some of these included 'experiment' and 'time' then the experiments did not yield the same results and there were changes in the results from 2 to 24 hours. Because of this and the fact that the experiments were not carried out under identical conditions it was decided to analyze the two experiments separately.

The analysis showed that there were: For Experiment 1-1/1 three 3 way interactions each involving time. For Experiment 1-1/2 one 3 way and three 2 way interactions. The figures for these are in Tables 1-1/2 to 1-1/5.

The results show that, usually at both 2 and 24 hours, whiteflies prefer to be:

1. '**Down**' rather than 'up' whether they are in 'shade' or 'light' (Tables 1-1/2 iii, 1-1/4 iii and 1-1/5 ii) and also whether they are on the 'lower' or the 'upper' leaf surface (Tables 1-1/2 ii, 1-1/3 ii and 1-1/4 ii).
2. **In 'shade'** rather than 'light' whether they are 'down' or 'up' (Table 1-1/2 iii and 1-1/5 ii), when they are 'up' only (Table 1-1/4 iii) and also whether they are on the 'lower' or 'upper' leaf surface

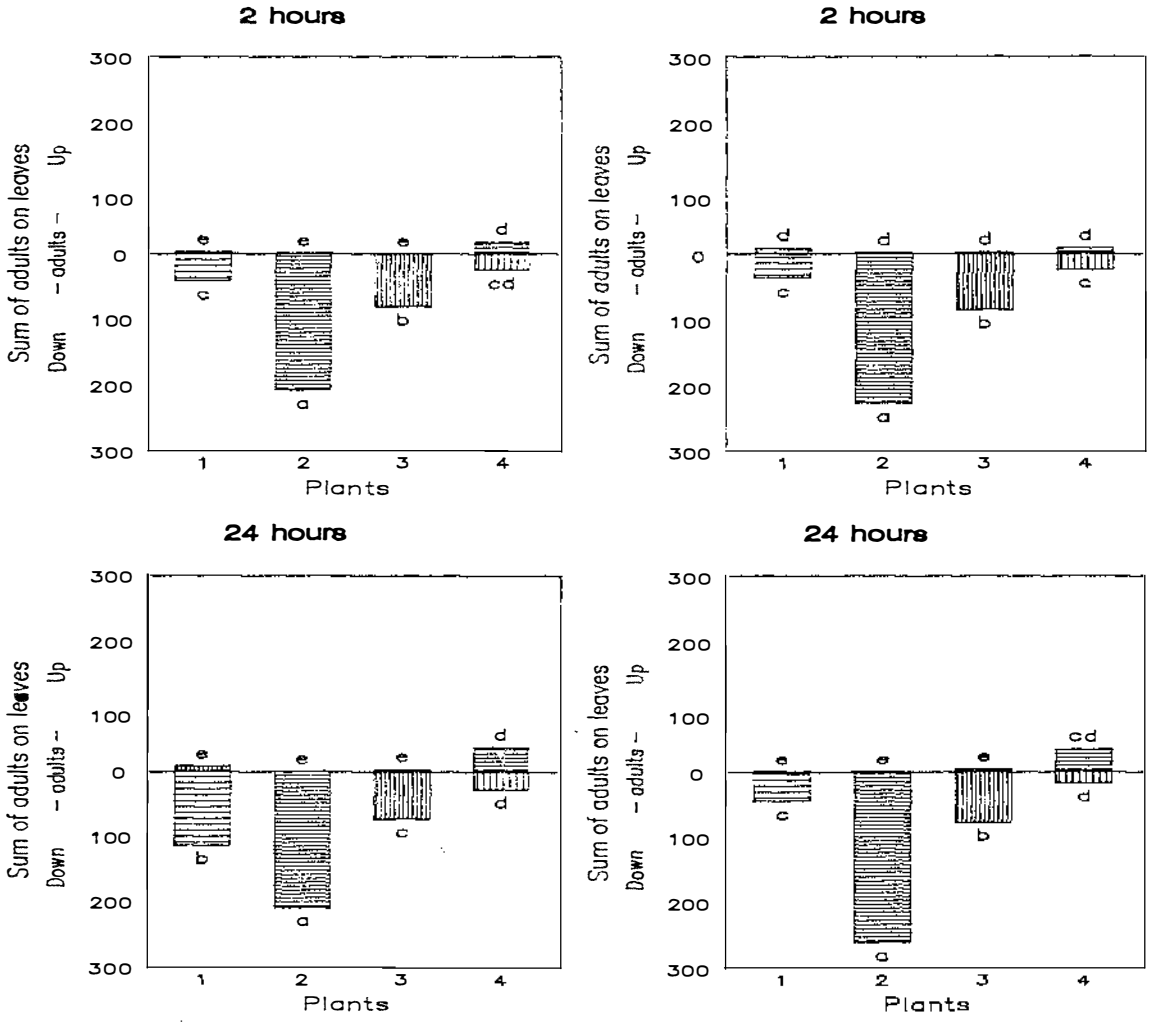
Fig. 1-1/1

Adult preference for lower or upper leaf surface of intact plants under 4 orientation/light regimes.

Tomato cv. Virosa

i. Experiment 1-1/1

ii. Experiment 1-1/2



Within each graph bars with the same letter are not significantly different (P>0.01). For significant differences between times and between experiments see Appendix Table A1-1/1.

For the orientation of plants 1, 2, 3 and 4 and the light direction see page 37 and the photographs on pages 40 and 41.

Table 1-1/2

Experiment 1-1/1 at 2 hours.

i. Sum of adults in shade or light and on lower or upper leaf surface.

	Shade	Light
Lower	226 a	84 b
Upper	42 c	27 c

ii. Sum of adults upside-down or right way up and on lower or upper leaf surface.

	Down	Up
Lower	289 a	21 c
Upper	68 b	1 d

iii. Sum of adults in shade or light and upside-down or right way up.

	Shade	Light
Down	250 a	107 b
Up	18 c	4 d

Figures with the same letter are not significantly different ($P>0.01$).

Table 1-1/3

Experiment 1-1/1 at 24 hours.

i. Sum of adults in shade or light.

Shade	Light
363 a	232 b

ii. Sum of adults upside-down or right way up and on lower or upper leaf surface.

	Down	Up
Lower	282 a	45 c
Upper	141 b	3 d

Figures with the same letter are not significantly different ($P>0.01$).

Table 1-1/4

Experiment 1-1/2 at 2 hours.

i. Sum of adults in shade or light and on lower or upper leaf surface.

	Shade	Light
Lower	236 a	95 b
Upper	63 b	27 c

ii. Sum of adults upside-down or right way up and on lower or upper leaf surface.

	Down	Up
Lower	314 a	17 c
Upper	63 b	3 d

iii. Sum of adults in shade or light and upside-down or right way up.

	Shade	Light
Down	266 a	111 b
Up	10 c	10 c

Figures with the same letter are not significantly different ($P>0.01$).

Table 1-1/5

Experiment 1-1/2 at 24 hours.

i. Sum of adults on lower or upper leaf surface.

Lower	Upper
373 a	63 b

ii. Sum of adults upside-down or right way up and in shade or light.

	Down	Up
Shade	306 a	38 c
Light	95 b	0 d

Figures with the same letter are not significantly different (P>0.01).

(Table 1-1/2 i and 1-1/3 i) when they are on the 'lower' leaf surface only (Table 1-1/2 i).

3. **On the 'lower' leaf surface** whether they are in the 'shade' or in the 'light' (Tables 1-1/2 i and 1-1/4 i) and whether they are 'down' or 'up' (Tables 1-1/2 ii, 1-1/3 ii and 1-1/4 ii).

These results can also be seen in Fig. 1-1/1.

Relative importance of gravity, phototaxis and leaf surface characteristics

The results show the following:

1. **'Down' has more effect than 'shade'**. This is seen in Tables 1-1/2 iii, 1-1/4 iii and 1-1/5 ii where there are significantly ($P<0.01$) more whiteflies in the treatment 'down' and 'light' than in the treatment 'up' and 'shade'.
2. **'Down' has more effect than 'lower' leaf surface.** This is seen in Tables 1-1/2 ii, 1-1/3 ii and 1-1/4 ii where there are significantly ($P<0.01$) more whiteflies in the treatment 'down' and 'upper' than in the treatment 'up' and 'lower'.
3. **'Lower' leaf surface has more effect than 'shade'.** This is seen in Table 1-1/2 i where there are significantly ($P<0.01$) more whiteflies in the treatment 'lower' and 'light' than in the treatment 'upper' and 'shade' but not for Experiment 1-1/2 (Table 1-1/4 i).

Hence, the order of importance of the above factors is: 'down' > 'lower leaf surface' and 'shade'; 'lower' leaf surface slightly > 'shade'. Therefore adult whiteflies go to the lower leaf surface of plants primarily because they prefer to be upside-down and secondarily (at least in the case of tomato) because of characteristics of the lower leaf surface and their preference for shade rather than the

brighter light on the upper leaf surface when settled on a plant.

Changes with time

Whiteflies settled within 2 hours and there were few changes by 24 hours (Appendix Table A1-1/1). There were three significant ($P<0.01$) changes. One, ('up', 'light', 'lower') had too few numbers and only occurred with one experiment, so no conclusions can be drawn. The other two both involve 'Shade' (with 'down' and 'upper' and with 'up' and 'lower'). This could reflect a time delay in the effects of 'shade'. Consider all treatments involving 'shade'. The treatment 'shade', 'down' and 'lower' would be very much dominated by the effect of gravity ('down') so that the light effect could be overridden. The 'shade', 'up', 'upper' treatment has too few numbers to draw satisfactory conclusions. The other two show an increase in numbers with time in at least one experiment. However, if time is required for light to take effect then the treatments with 'light' should go down in numbers, which they have not. This hypothesis could be explored further with higher numbers of whiteflies so that if an effect is present it would be detected.

The changes with time could also reflect the movement of whiteflies from elsewhere in the cages rather than from one treatment to another.

Differences in light intensity

Differences in light intensity between cages with light from above and light from below the plants may have had some effect on the results. If the light intensities were the same and if a greater difference in the light intensity between 'shade' and 'light' induces more whiteflies to be in the shade then one would expect the 'up' and 'shade' treatment to have higher numbers and the 'down' and 'light' treatment to

have lower numbers than in these experiments since for these cases both plants are in the lower light intensity. However, it is not possible to determine this from these experiments.

B. Selection of youngest or oldest leaves

A summary of the counts of adults on the three leaf age groups for the two experiments at 2 and 24 hours are presented in Fig. 1-1/2. The significant differences between the oldest and youngest age groups for gravity, phototaxis and leaf surface are indicated in Fig. 1-1/2 and in Appendix Table A1-1/2.

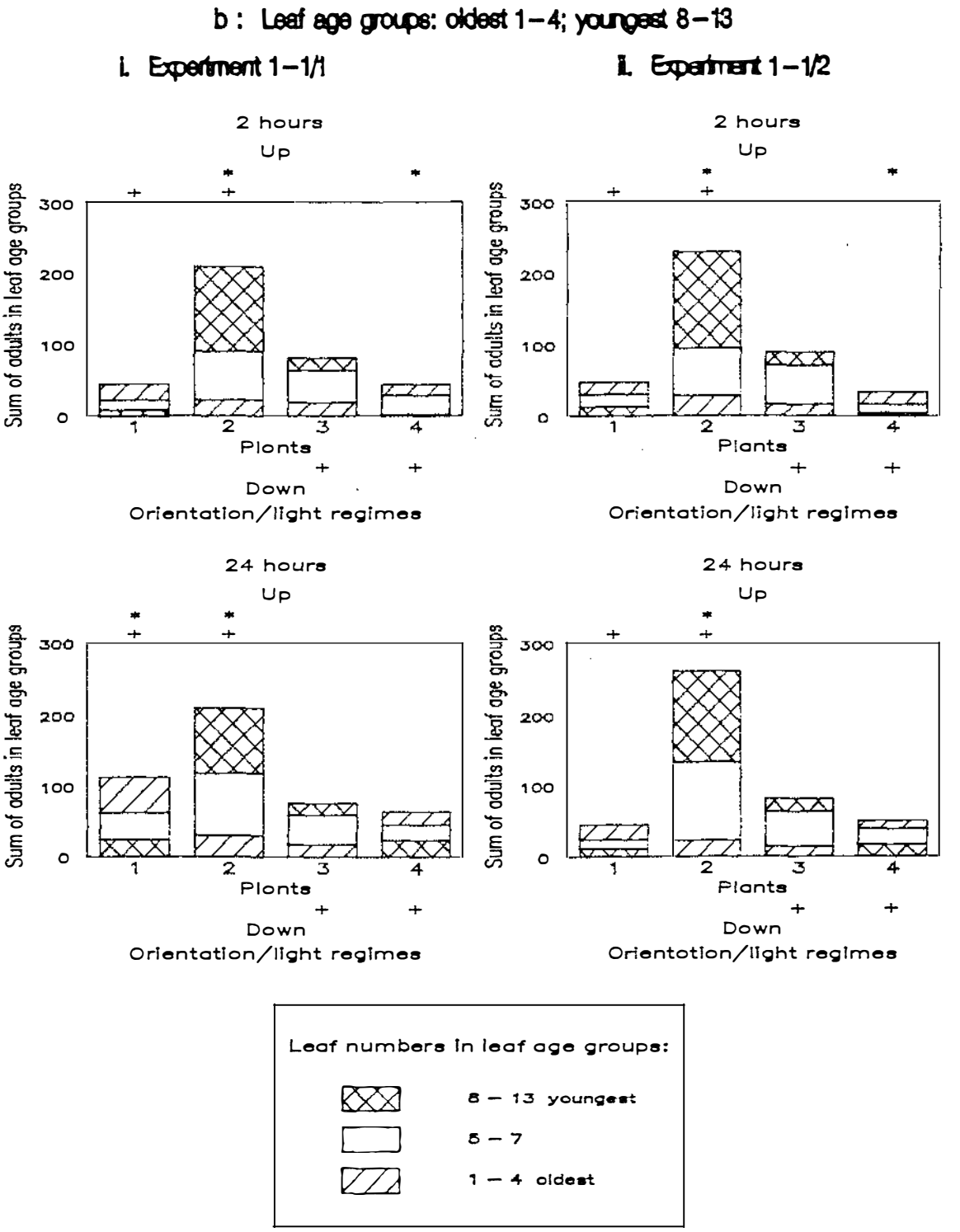
For whiteflies to congregate on the younger leaves they must either (1) exhibit negative geotaxis in flight or (2) exhibit positive phototaxis in flight or (3) move randomly and settle when they locate the preferred younger leaves or (4) any combination of these three factors. Table 1-1/6 summarises the possible effects of each of these factors on the distribution of whiteflies with leaf age for each of the plants used in these experiments.

Two hypotheses will now be considered. Table 1-1/6 should be referred to throughout this discussion.

Hypothesis 1: One of the factors is the sole factor.

1. **Geotaxis.** Negative geotaxis is not the sole factor causing whiteflies to congregate on the younger leaves as there are not consistently more whiteflies at the 'up' end of the plants.
2. **Phototaxis.** Positive phototaxis is not the sole factor as whiteflies are not consistently at the end nearest the light source.

Fig. 1-1/2 continued.



* Numbers are significantly different (P<0.01) at this end of the plant.
\+ This end of the plant was nearest the light.
For significant differences between times and between experiments see Appendix Table A1-1/2.

Table 1-1/6

Direction of whitefly response to gravity, light and leaf age.

	Gravity direction			
	Older to younger	Younger to older	Younger to older	Older to younger
	Light direction			
	Leaves nearest light source			
	Older	Younger	Older	Younger
	Plant number			
	1	2	3	4
	Youngest leaves			
		Both Expts. 2 & 24 hrs *		
Negative geotaxis	↓	↑	↑	↓
Positive phototaxis	↓	↑	↓	↑
Selection of younger leaves	↑	↑	↑	↑
	* 24 hrs Expt. 1-1/1			* 2 hrs Both Expts. b. only
	Oldest leaves			

* significantly more ($P<0.01$) whiteflies at this end of the plant as indicated. Shorter arrows indicate lower light intensity.

3. **Leaf age.** Each gravity/light direction combination does not consistently have more whiteflies on the younger leaves. Hence, the reason for whiteflies congregating on the younger leaves in the natural situation is not due entirely to leaf age characteristics.

Hypothesis 2: At least one of the factors has no effect.

1. **Geotaxis.** If geotaxis has no effect then the results for plants 1 and 3 and for plants 2 and 4 should be similar but they were not. This is because the other factors both act in the same direction within each pair of plants.

   Some of these differences may be due to the greater light intensity for plants 1 and 2. However, for plant 4 gravity is the only factor that would be inducing the whiteflies to be on the oldest leaves where in fact they were at 2 hours. Hence, it can be concluded that gravity does have an effect.

   The difference between plants 1 and 3 could be explained by either (1) no gravity effect and the stronger light for plant 1 resulting in more whiteflies on the older leaves for Experiment 1-1/1 at 24 hours (but this is not so for the other experiment) or (2) a gravity effect plus the stronger light effect resulting in more on the older leaves. Hence, no conclusion can be drawn about whether gravity has an effect or not from the results for plants 1 and 3.

2. **Phototaxis.** If phototaxis has no effect then the results for plants 2 and 3 and for plants 1 and 4 should be the same but they were not. Here there is no complication of differences in intensity for gravity or leaf ages as there was with phototaxis. Hence, phototaxis does have an effect on selection of younger leaves.

3. **Leaf age characteristics.** If leaf age characteristics have no effect then the results for plants 1 and 2 and for plants 3 and 4 should be the same but the whiteflies would be at opposite ends of the plants within each pair. This is so for plants 1 and 2 at 24 hours for Experiment 1-1/1 only and for plants 3 and 4 at 24 hours. There is no complication of differences in light intensity here. The results are not consistent across both experiments but they do point towards a small effect of leaf age characteristics.

It can be concluded from the arguments for hypotheses 1 and 2 that negative geotaxis, positive phototaxis and leaf age characteristics all have some effect on selection of the youngest leaves.

It remains to discuss the relative importance of the three factors and how rapidly their effects become apparent.

Relative importance of geotaxis, phototaxis and leaf age characteristics

Consider Table 1-1/6 again. For plant 2 all three factors are inducing the whiteflies to congregate on the younger leaves so no conclusion can be drawn about their relative importance. For the other three plants there are opposing effects among the three factors.

For plant 3 it appears that the positive phototactic effect is approximately opposite and equal to the combined effects of negative geotaxis and leaf age characteristics.

For plant 4 it appears that by 24 hours the negative geotactic effect is approximately opposite and equal to the combined effects of positive phototaxis and leaf age characteristics but only for one of the leaf age groups selected. This seeming contradiction to the plant 3 case in

regard to the contribution of leaf age characteristics can be explained by assuming that the contribution is relatively small in comparison with that of the other two factors. This is consistent with the conclusion from 3 in the hypothesis 2 section.

However, the results for plant 1 do not entirely support this as the combined effects of negative geotaxis and positive phototaxis overcome the leaf age effects only for Experiment 1-1/1 by 24 hours. Maybe this is because of the greater light intensity for plant 1 compared with plants 3 and 4.

As for plants 3 and 4, there are equal numbers of whiteflies at each end of the plants at 24 hours and assuming leaf age characteristics have a small effect, the negative geotactic effect and the positive phototactic effect must be approximately equal. Now compare the results for plant 2 with plants 3 and 4. The changes in the direction of the factors are: plant 3 only phototaxis and plant 4 only geotaxis is reversed. For plant 4 this has resulted in more whiteflies being at the opposite (oldest leaf) end of the plant at 2 hours only but for plant 3 the numbers at each end are equal. Hence, this suggests that gravity has more effect initially and the phototaxis ultimately has an equal effect by 24 hours.

It can be concluded that negative geotaxis, positive phototaxis and leaf age characteristics all have an effect on selection of the younger leaves. It is not clear from these experiments which has the greater effect out of negative geotaxis and positive phototaxis but each has a greater effect than leaf age characteristics.

Differences between experiments

Although there were differences between experiments for A (selection of lower or upper leaf surface) the conclusions for this section were consistent for both experiments.

For B (selection of youngest or oldest leaves) the only difference between experiments is for plant 1 where there are significantly more whiteflies on the oldest leaves at 24 hours for Experiment 1-1/1 but not for Experiment 1-1/2. There is no clear explanation for this difference. There could well be differences in the light received by the whiteflies over the duration of the experiments. However, it might be expected that this would show up between the experiments in the other light direction also. The explanation may be that there were insufficient whiteflies for the effect to show up. Compare the 112 whiteflies for Experiment 1-1/1 with the 45 for Experiment 1-1/2 on plant 1 (Appendix Table A1-1/2).

Other factors affecting the results of these experiments

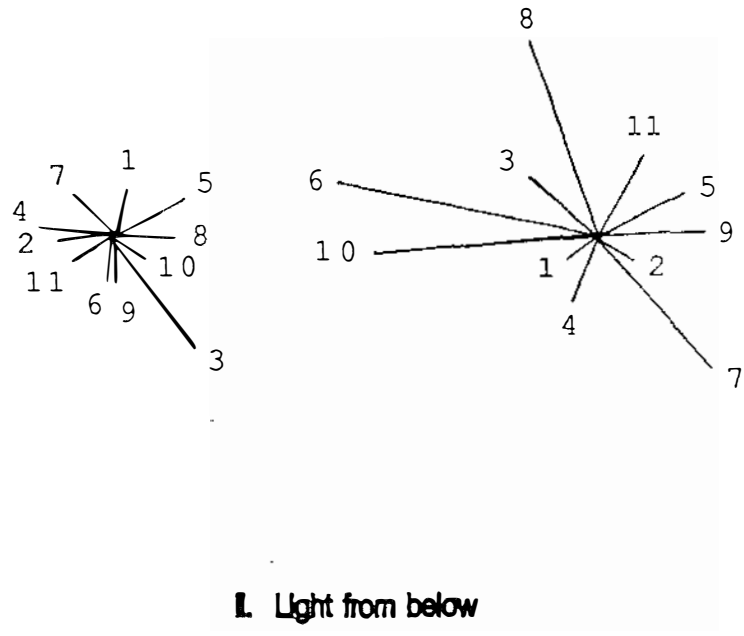
Size of the leaflets. The selection of younger leaves may be affected by the size of the leaflets. Smaller leaflets may have fewer whiteflies present because there is less physical room rather than because of other factors inherent in the leaves but this is unlikely as none of the leaflets were as crowded as leaves can become in the field. Alternatively, the smaller leaflets may be harder for whiteflies to locate.

Method of introduction of whiteflies. Because whiteflies tend to stay at the sites where they first land it might be thought that there could be more whiteflies present on the leaves nearest the introduction points or where the whiteflies have moved sideways to the other plant in the

Fig. 1-1/3
Plan of leaf arrangement for plants in Experiment 1-1/2.

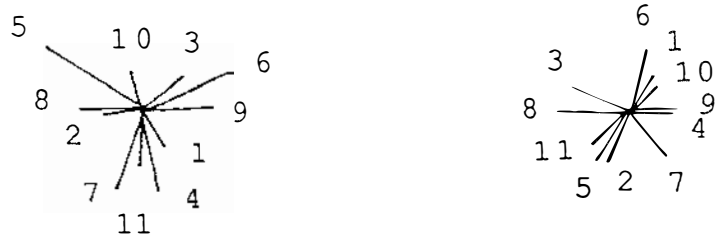
I. Light from above

Plant 1 on left, plant 2 on right.



II. Light from below

Plant 3 on left, plant 4 on right.



The numbers are the leaf ages in order up the stem. 1: oldest.
The length of the lines is proportional to the number of adults present at 24 hours.

cage that there could be more whiteflies on the side nearest the other plant. Therefore a plan of the leaf arrangement was drawn up for Experiment 1-1/2 (Fig. 1-1/3). Care was taken in Experiment 1-1/2 to introduce the whiteflies close to the main stem to avoid this problem and Fig. 1-1/3 does not show a particularly uneven distribution around the plants except for plant 1 where there is some indication that the whiteflies may have moved from plant 1 to the nearest leaves of plant 2.

Movement of whiteflies from plant to plant. This may have occurred as suggested above. However, if the total whiteflies on the plants is considered (see Appendix Table A1-1/2) and plants 1 and 2 and also plants 3 and 4 is compared, in no case is the increase in numbers on one plant from 2 to 24 hours close to the decrease in numbers on the other plant. In most cases numbers increased on both plants. However, it is worth noting the large differences in total numbers on plants within cages and also between plant 2 and all the others.

Temperature differences. The temperature differences (see Table 1-1/1) between the two cages and the two experiments could have had an effect on results. The cooler minimum temperatures in Experiment 1-1/2 could have induced less movement and maybe slowed down the phototactic effect. Hence, a greater difference from 2 to 24 hours would be expected between Experiments 1-1/1 and 1-1/2. This is so for the 'down', 'shade', 'upper' treatment for leaf surface selection (Appendix Table A1-1/1 b) but not for any other treatment.

Summary

These experiments show that greenhouse whitefly selects the lower leaf surface of tomato primarily because it prefers to be upside-down (gravity response), secondarily, because of a preference for some characteristic/s of the lower leaf

surface and thirdly because it prefers to be in the shade (negative phototactic response).

These experiments also show that greenhouse whitefly selects the youngest leaves of tomato mainly because of a combined negative geotactic and positive phototactic response in flight. Characteristics of leaf ages have only a minor effect.

1-2 Gravity, light direction, and leaf characteristics and selection of lower leaf surface of excised leaflets.

In Section 1-1, using intact tomato plants, the selection of settling sites did not take place under completely standard conditions of light and temperature nor were the number of whiteflies standardised. Also no account was taken of the possible effect of aggregation of whiteflies. Therefore the experiment in this section was carried out to address these shortcomings.

Leaf age was not incorporated and only leaf surface and the following factors were investigated:

1. **Gravity** response.
2. Negative **phototaxis** (when walking).
3. **Leaf surface characteristics.**
4. **Aggregation** of whiteflies.

Excised leaves or leaflets have been used in experiments by others: tomato and greenhouse whitefly (Hussey and Gurney, 1959), field beans and 3 aphid species (Müller, 1968), *Solanum* spp and green peach aphid (Sams et al, 1975), citrus and citrus blackfly (Cherry et al, 1978), tomato and greenhouse whitefly (Noldus et al, 1986b) and lemon and bayberry whitefly (Walker, 1987). Although there is some possibility of changes in the metabolic processes within the excised leaflets over time, the technique has proved to be satisfactory for examining host plant selection and oviposition. Hence its use in this experiment.

Materials and Method

Experiment 1-2.

A single excised leaflet of tomato (*Lycopersicon esculentum*) cv. Virosa was inserted into vermiculite and water in a vial within a transparent cage (10 cm long, 5 cm diameter). Two facing rows of four cages were placed in a box. See Photograph 1-2.

Each leaflet was then subjected to one level of each of the following factors:

1. Orientation:
   - Lower surface up.
   - Lower surface down.
   - Left edge down.
   - Right edge down.
2. Light direction:
   - Lower surface towards light source.
   - Lower surface away from light source.
   - Left edge towards light source.
   - Right edge towards light source.
3. Presence/absence of whiteflies at start:
   - Whiteflies present only on lower surface.
   - Whiteflies present only on upper surface.

The box was then placed with the open end facing a light source which was either shining from above, below, the right or the left side of the growth cabinet where the experiment was carried out. Seventy-five female whiteflies were placed in each cage and allowed to settle over night. The numbers on each leaflet surface were counted in the morning and again 12 hours later.

This arrangement was designed to examine the relative importance of the following factors affecting whitefly selection of settling sites:

Photograph 1-2

Tomato leaflets in cages for Experiment 1-2.

1. **Gravity response**: whether whiteflies prefer to be
   Down i.e. upside-down (horizontal) or
   Up i.e. right way up (horizontal) or
   become evenly distributed on both surfaces i.e.
   Vertical - leaflet with left edge down or
   Vertical - leaflet with right edge down.
2. **Phototaxis**: whether whiteflies move to be either
   In the light or
   On the shady side of a leaflet or
   become evenly distributed on both surfaces when:
      Light is towards the right edge of the leaflet or
      Light is towards the left edge of the leaflet.
3. **Leaf surface**: whether whiteflies settle on
   Lower leaf surface or
   Upper leaf surface.
4. **Aggregation**: whether whiteflies move to where other whiteflies are:
   Present on the leaflet surface or
   Absent from the leaflet surface.

There were 16 runs, 4 for each of the 4 positions of the light source. For each run of the experiment the eight leaflets were arranged as follows:

1. Upper surface towards the light and whiteflies absent at start.
2. Upper surface towards the light and whiteflies present at start.
3. Upper surface in shade and whiteflies absent at start.
4. Upper surface in shade and whiteflies present at start.
5. Left edge down and whiteflies absent at start.
6. Left edge down and whiteflies present at start.
7. Right edge down and

whiteflies absent at start.

8. Right edge down and
whiteflies present at start.

It was found that all the edge combinations had to be allocated to the same side of the box otherwise when light was directed from the left or right side of the growth cabinet identical combinations of phototaxis and gravity factors were created instead of right and left combinations. The order of the runs was randomised and the arrangement of the leaflets on each side of the box was re-randomised for each run.

There were 64 treatments altogether: 4 'gravity' levels X 4 'light' levels X 2 'leaf surface' levels X 2 'present/absent' levels.

All runs of the experiment were carried out in a growth cabinet at 20+/-1 C. The humidity could not be controlled and fluctuated considerably throughout the runs of the experiment from about 40 to 100% RH.

A cool light source was used with the ends of both fibre optic arms tied together 21 cm from the plane of the leaflets. The light intensity, which was set to the maximum possible, was measured with a quantum sensor and found to be about:

400 $\mu E/m^2/s$ at the centre of the plane of the leaflets;
340 $\mu E/m^2/s$ through the acetate;
20 $\mu E/m^2/s$ through the leaflets and acetate.

Fig. 1-2/1 shows the spectral quality of the light source. Figure 1 on the left is from Morgan et al (1985).

The vials with the leaflets in the cages were inserted into holes in polystyrene at opposite ends of the cardboard box. The cages were held in place by lengths of florist's wire above and below each set of four cages and by appropriately

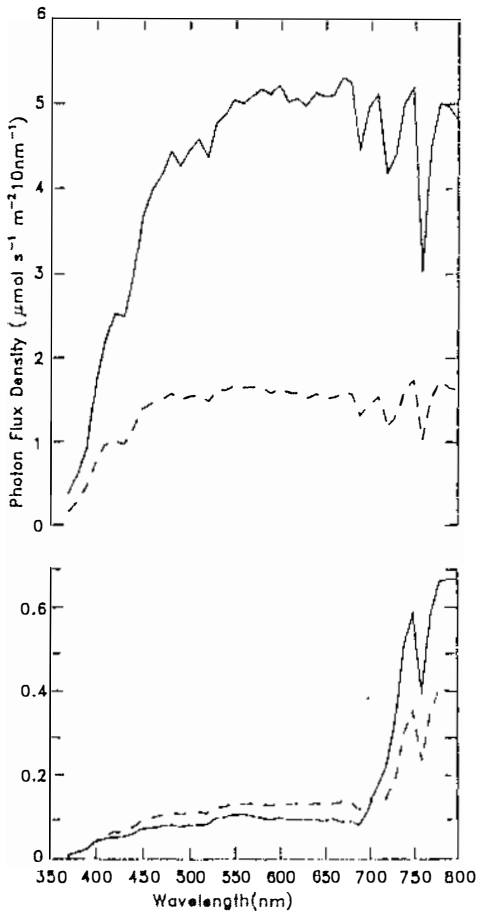
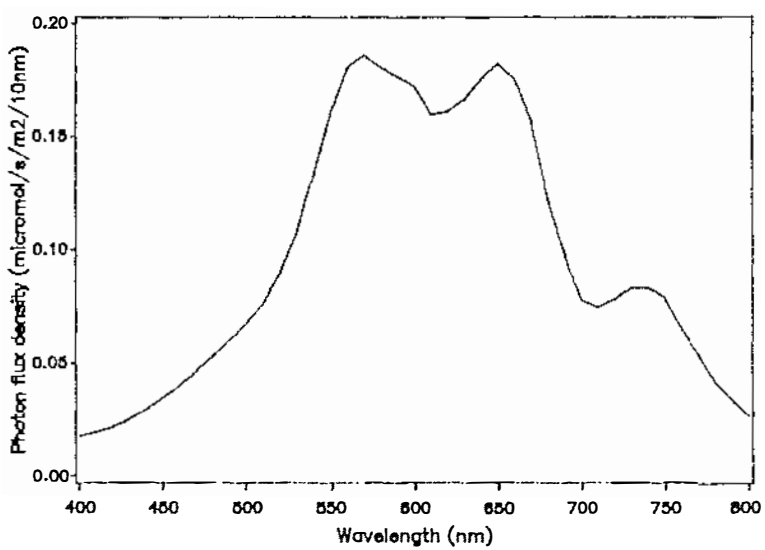


Figure 1. Spectral photon flux density for daylight (upper) and shadelight (lower) at ground level within the medium stocking plantation of *Pinus radiata*, during either clear sky (——) or overcast sky (- - - -) conditions. The PPFD values for each scan were: daylight, clear—1400 μmol s^{-1} m^{-2}; daylight, overcast—450 μmol s^{-1} m^{-2}; shadelight, clear—27 μmol s^{-1} m^{-2}; shadelight, overcast—35 μmol s^{-1} m^{-2}.

Fig. 1—2/1

Spectral photon flux density for cool light source.



Graphs on left are from Morgan et al (1985).
PPFD: photosynthetic photon flux densities.

shaped partitions of cardboard in the centre. The whole box was lined with black paper. The base of the box could slide out so that the number of whiteflies on the leaf surface on that side could be counted easily. See Photograph 1-2.

The cages were made from Mylar overhead projector acetate. They were attached to the vials by a sleeve of terylene sheer held in place by rubber bands. The open ends of the cages were closed by a piece of terylene sheer. The vials were prepared by filling them with vermiculite and water then carefully removing the air bubbles to prevent airlocks and consequent wilting of the leaflets. The tops of the vials were sealed with Nescofilm and a rubber band. The leaflets were held in one plane by attaching the tips with cellotape to a length of florist's wire inserted into each vial. The leaflets were just fully mature and selected for uniformity of size. Left and right leaflet edges were defined as being on the left and right respectively when the leaflet upper surface was viewed from the petiole of the leaf.

The day before the start of each run female whiteflies 2-10 days old were anaesthetized and 75 were placed in each cage. All leaflets at this stage were arranged in a horizontal plane. Over night in complete darkness the whiteflies settled predominantly on the 'down' surface of the leaflets. The next day at the start of the experiment the number of whiteflies on each surface of each leaflet were counted and then the leaflets were turned as appropriate to give the planned orientation to light and gravity for that run.

When the experiment was designed it was anticipated that it would be analyzed using analysis of variance. Hence, a balanced design was devised but the factors could not be fully randomised. However, after the results were obtained it became clear that a loglinear approach was a far more appropriate method of analysis though it was also realised that the experimental design was not ideal for loglinear

analysis. It would have been more appropriate to have had more whiteflies per cage and fewer replicates of the same conditions.

The counts at the start and at the end of the experiment were analyzed and the models of best fit found using contingency tables and a loglinear model for the factors described above (Bishop et al 1975). Further analysis was carried out to determine which pairs of factor combinations were significantly different from each other.

Results and Discussion

The results of the counts at 0 and 12 hours are presented in Fig. 1-2/2. Each pair of bars (above and below the centre line) in Fig. 1-2/2 represents 4 treatments: the two leaf surfaces of the same leaflets are one each side of the centre line and the two present/absent levels are represented as stacks in each bar with 'absent' being blank and the 'present' level having the appropriate fill for both present/absent levels for that bar. Of course any one 'present' level must be paired with an 'absent' level on the other side of the centre line for the same leaflet.

The 4 light directions and the 8 leaflets of each run have been regrouped so that the 16 orientation/light regimes are in four groups of four to facilitate clear expression of the main results. The four groups are all the combinations of:

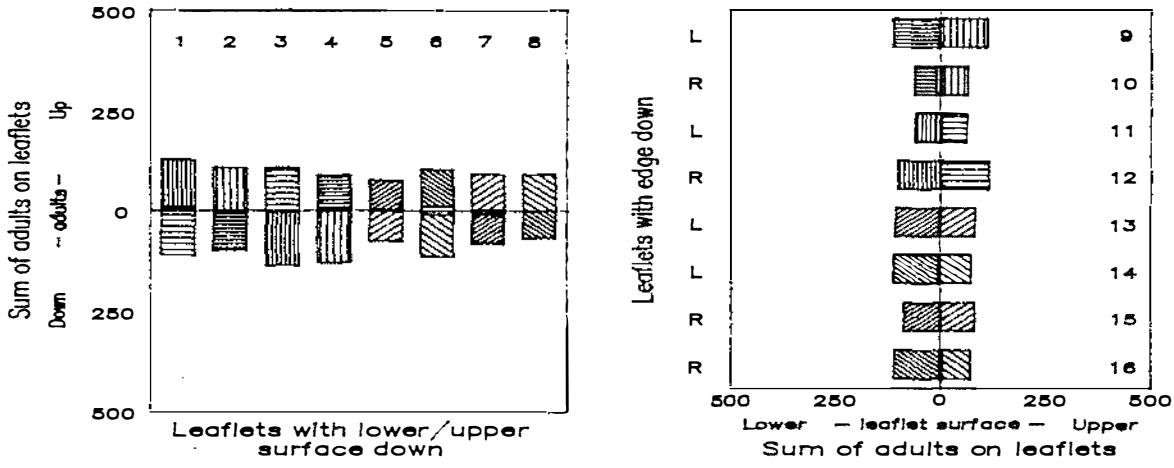
A. Down, up orientation and in shade, in light regimes. This equates with the combinations of Section 1-1. See Fig. 1-2/2 paired bars numbered 1 to 4 and compare with Fig. 1-1/1 where plants 1 to 4 correspond to the bars 1 to 4.
B. Down, up orientations and light from side (left or right). Here the light on each leaf surface is the same so in effect differences in light have been eliminated. See Fig. 1-2/2 paired bars numbered 5 to 8.

Fig. 1–2/2

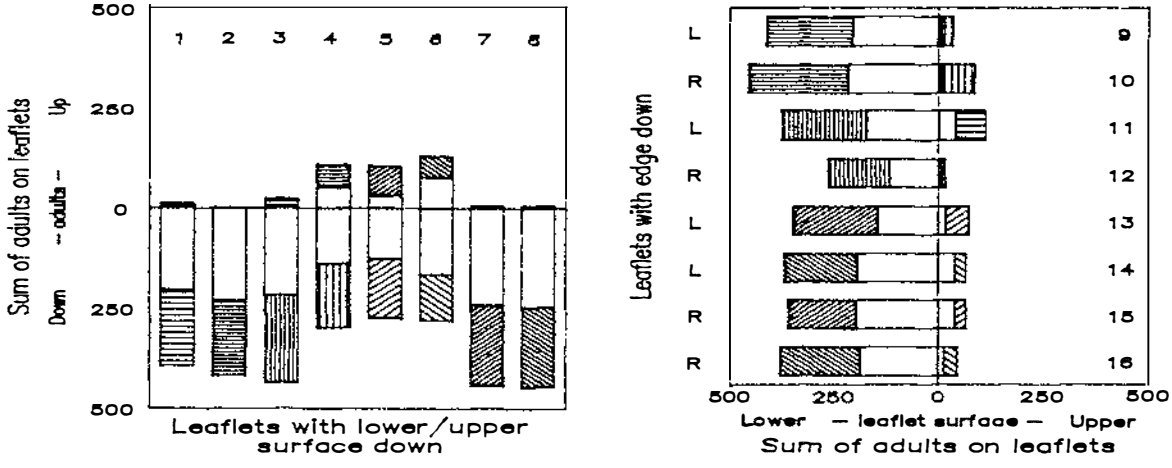
Adult preference for lower or upper leaf surface of excised leaflets under 16 orientation/light regimes.

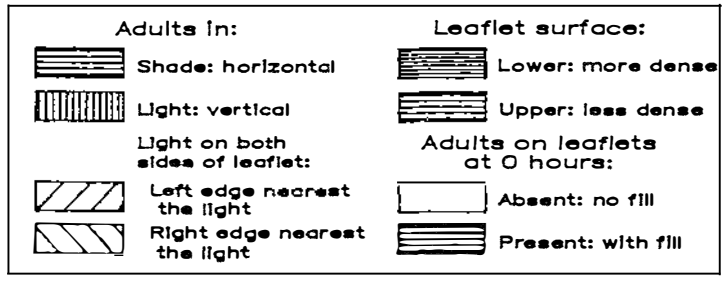
Tomato cv. Virosa

I. 0 hours



II. 12 hours





Numbers 1—16 are the positions of the leaflets in relation to light and gravity.
L: left edge, R: right edge of leaflet down.
For significant differences see Appendix Table A1—2/1.

C. Vertical orientation (left and right leaflet edges down) and in shade and in light regimes. Here the whiteflies are in effect half way between up and down so the gravity effect is the same on both sides of the leaflet and therefore should not influence the results. See Fig. 1-2/2 paired bars numbered 9 to 12.

D. Vertical orientation (left and right leaflet edges down) and light from the side (left or right). Here both gravity and light are the same on each side of the leaflets so only the differences in leaf surface characteristics should influence the results. See Fig. 1-2/2 paired bars numbered 13 to 16.

The analysis for the factors gravity, phototaxis, leaf surface and presence/absence for each time showed that there was a 4 way interaction for each time. Therefore levels of the different factors were compared within groups A, B, C and D defined above. The results and the significant differences are recorded in Appendix Table A1-2/1 and Table 1-2/1. It should be noted that in these tables the paired values for lower and upper leaf surfaces are not necessarily from the same leaflet. The numbers in brackets within each table correspond to the numbers allocated to the paired bars in Fig. 1-2/2.

Total whiteflies on the leaflet in each cage

For the comparisons in the analysis to be valid there must be equal numbers of whiteflies on the leaflets in each category being compared since most comparisons do not involve a choice test. These totals are in Table 1-2/1. They have been summed across the four replicates for each combination of the four factors for each group A, B, C and D. At 12 hours only group B shows any significant ($P<0.01$) differences among the treatment totals. The highest two values (242 and 252) are significantly different from the lowest two values (180 and 192). If these were adjusted up/down as appropriate to remove the differences in the totals for group B then in the body of

Table 1-2/1 continued.

Sum of adults	0 hours		12 hours		0 hours	12 hours
	Lower surface (same leaflet)	Upper surface (same leaflet)	Lower surface (same leaflet)	Upper surface (same leaflet)	Total	Total
C **Left edge down, In shade**						
On lwr (9)	112	0	206	7	112 a	213 a
On upr (9)	1	113	205	28	114 a	233 a
Right edge down, In shade						
On lwr (10)	53	2	238	7	55 c	245 a
On upr (10)	9	65	216	9	74 bc	225 a
Left edge down, In light						
On lwr (11)	51	4	202	40	55 c	242 a
On upr (11)	10	60	172	72	70 bc	244 a
Right edge down, In light						
On lwr (12)	103	1	147	71	104 ab	218 a
On upr (12)	0	115	116	80	115 a	196 a
D **Left edge down, Left edge to light**						
On lwr (13)	105	1	202	17	106 a	219 a
On upr (13)	3	83	146	57	86 ab	203 a
Left edge down, Right edge to light						
On lwr (14)	108	0	174	40	108 a	214 a
On upr (14)	4	75	193	27	79 ab	220 a
Right edge down, left edge to light						
On lwr (15)	88	0	163	39	88 ab	202 a
On upr (15)	1	82	196	28	83 ab	224 a
Right edge down, Right edge to light						
On lwr (16)	110	5	191	15	115 a	206 a
On upr (16)	1	68	185	32	69 b	217 a

Figures with the same letter within each column of totals for each group A, B, C and D are not significantly different (P>0.01).
Figures in brackets are the leaflet (treatment) numbers and correspond with those in Fig. 1-2/2.
lwr: lower; upr: upper.

the table 242 and 247 would be reduced and 30, 150, 76 and 116 would be increased. Now consider Appendix Table A1-2/1a group B. These adjustments would possibly remove the significant differences for 116/164 and 76/30. Small changes would be unlikely to change the non significance of the other pairs of numbers affected. Similarly in Appendix Table A1-2/1b the adjustments would possibly remove the significant difference for 201/150 but probably not any of the other pairs of numbers affected. Again in Appendix Table A1-2/1c no changes would be likely. Also consider Table 1-2/2. The changes would not alter the overall conclusions but could remove the significant ($P<0.01$) differences within the two groups 'up'/'lower' and 'down'/'upper'.

Consider the totals for 0 hours in Appendix Table A1-2/1a. There are significant ($P<0.01$) differences in all four of the groups A, B, C and D. In a similar way to that described above the numbers can be adjusted up/down as appropriate and checked for the effects in the tables. It was found that probably some of the significant ($P<0.01$) differences would disappear and no new ones would be created.

Hence, the fact that the totals in each category are not always equal may account for some of the abberant significant differences.

Gravity and phototaxis response. Appendix Table A1-2/1c. At the start of the experiment there were no significant differences ($P<0.01$) among the gravity and phototaxis levels in groups A or B within levels of the factors 'present' or 'absent' or within either lower or upper leaf surfaces. However, at 12 hours it can be seen that whiteflies prefer to be:

1. **'Down' rather than 'up'** (group B - light is the same on both sides of the leaflet) and this is so whether they are in 'shade' or 'light' (group A) and also (for groups A and B) whether they are on the lower or

Table 1-2/2

Group B at 12 hours

	Down	Up
Lower		
'Present'		
Side (L)	201 ab	76 e
Side (R)	199 ab	53 ef
'Absent'		
Side (L)	242 a	30 f
Side (R)	247 a	76 e
Total	**889**	**235**
Upper		
'Present'		
Side (L)	150 cd	2 g
Side (R)	116 d	5 g
'Absent'		
Side (L)	124 cd	4 g
Side (R)	164 bc	1 g
Total	**554**	**12**

Figures with the same letter within the whole table are not significantly different (P>0.01).

the upper leaf surface or whether they are 'present' or 'absent' at the start.

2. **In 'shade' or 'light' equally** where they are also:
   On the lower leaf surface (group C - gravity effect is the same on both sides of the leaflet) or
   'Down' (group A)
   whether 'present' or 'absent' except where the right edge is down, and when on the upper surface and 'absent' at the start. This could be a reflection of the total number of whiteflies on the leaflets as opposed to elsewhere - leaflets 4 have 187 and leaflets 1 have 212.

In contrast to this whiteflies prefer to be:

In 'shade' rather than light where they are also

On the upper leaf surface (group C) or

'Up' (group A)

whether 'present' or 'absent' except where they are 'up' and on the upper surface and 'absent' at the start (group A). However the numbers are very small (6 and 1).

Leaf surface response (Appendix Table A1-2/1b)

At the start of the experiment about two thirds of the leaf surface pairs are not significantly different. The remainder show no pattern and are more either a reflection of differences in the total number on the leaflet surfaces (for example leaflets 10 and 12 have 118 (53 + 65) and 218 (115 + 103) respectively); hence the difference between 10 and 12 in group C or a reflection of very small numbers as is the case for all in the 'absent' category.

At 12 hours it can be seen that whiteflies prefer to be:

On the lower leaf surface no matter what the level of the other factors with the exceptions, in group A, where two have very small numbers and the third is the much preferred case of 'down' and in the 'shade'. This appears to have masked the preference for the lower leaf surface.

Aggregation of whiteflies (Appendix Table A1-2/1a)

At the start of the experiment there are consistently significantly more whiteflies in the 'present' than the 'absent' category for all groups A to D as intended.

At 12 hours whiteflies have no preference for:

'present' or 'absent' levels -

for most gravity/phototaxis levels. Otherwise they prefer to move to where whiteflies are:

already present. There is one exception in group B. There is no pattern among the gravity/phototaxis levels where this preference occurs. However, see the later discussion of the relative importance of 'shade' and 'present'.

Hence, the aggregation factor, if it is operating at all, is very weak. This does not confirm the results of Åhman and Ekbom (1981) who reported an aggregation effect. It does not contradict the results of Xu (1985) and Noldus (1986c) as the aggregation they observed is due to feeding preferences and not necessarily preferences for association with other indidviduals.

Relative importance of gravity, phototaxis, leaf surface characteristics and aggregation

The results show the following:

1. **'Down' has more effect than 'shade'.** This is seen in Appendix Table A1-2/1c group A where there are significantly more whiteflies in the categories 'down' and 'light' (lower: 219, 217; upper: 191, 161) than in the categories 'up' and 'shade' (lower: 59, 50; upper: 18, 6) for both leaf surfaces.
2. **'Lower' has more effect than 'shade'.** This is seen in Table 1-2/3a which is group C at 12 hours from Appendix Table A1-2/1 with significant differences recorded across all levels of all the factors. Here the numbers in the 'lower' and 'light' categories all (except one - 116) are significantly greater than all those in the 'upper' and 'shade' categories.
3. **'Down' has more effect than 'lower'.** This is seen in Table 1-2/2 which is group B at 12 hours from Appendix Table A1-2/1 with significant differences recorded across all levels of all factors. Here the numbers in the 'down' and 'upper' categories are

Table 1-2/3a

Group C at 12 hours

	Lower	Upper
Shade		
'Present'		
Vert. (L)	206 ab	72 f
Vert. (R)	238 a	80 ef
'Absent'		
Vert. (L)	205 ab	40 g
Vert. (R)	216 ab	71 f
Total	**865**	**263**
Light		
'Present'		
Vert. (L)	202 ab	28 g
Vert. (R)	147 cd	9 h
'Absent'		
Vert. (L)	172 bc	7 h
Vert. (R)	116 de	7 h
Total	**637**	**51**

Figures with the same letter throughout the whole table are not significantly different (P>0.01).

significantly (P<0.01) greater than all those in the 'up' and 'lower' categories.

4. **'Shade' has more effect than 'present'**. This is seen in Table 1-2/3b which is Table 1-2/3a rearranged. For the subtotals, there are significantly (P<0.01) more in the 'shade', 'absent' categories than the 'present', 'light' categories. Also there are more in the 'present' than 'absent' categories only where the other factors are the least preferred ones i.e. in the 'upper' and 'light' category. This indicates that aggregation does have an effect but that it is masked

Table 1-2/3b

Group C at 12 hours

	Shade	Light
'Present'		
Lower		
Vert. (L)	206 a	202 a
Vert. (R)	238 a	147 a
Subtotal	**444** v	**349** w
Upper		
Vert. (L)	72 a	28 a
Vert. (R)	80 a	9 b
Subtotal	**152** x	**37** y
Total	**596** p	**386** r
'Absent'		
Lower		
Vert. (L)	205 a	172 a
Vert. (R)	216 a	116 b
Subtotal	**421** v	**288** w
Upper		
Vert. (L)	40 b	7 a
Vert. (R)	71 a	7 a
Subtotal	**111** x	**14** z
Total	**532** q	**302** s

Figures with the same letter throughout the whole table are not significantly different (P>0.01).

by the preferred levels of the other factors i.e. 'down', 'lower' and 'shade'.

Hence, whiteflies select the lower leaf surface primarily because they prefer to be upside-down, secondarily because of a preference for some characteristic/s of the lower leaf surface and thirdly because they prefer shade rather than

light. This agrees with the conclusions from Section 1-1. In addition there appears to be a minor aggregation effect which has less effect than any one of the other three factors.

1-3 Leaf characteristics, leaf age, and leaf angle and selection of settling sites on leaf discs set into water agar.

The technique used in this section of leaf discs set into holes in water agar has the advantages that the whitefly response occurs under closely controlled conditions and that the plant material does not have to be specially grown for the experiments. It has been used to keep leaf material from dehydrating in studies in plant pathology (Spiers, 1981). It was found by Müller (1966) that when leaf discs floating in water of diameters, 22, 16 and 10.5 mm were used for rearing the bean aphid (*Aphis fabae*) the adults were smaller as the diameter decreased.

Selection of both leaf surface and leaf age were considered. In the first part (1) leaf surface selection was investigated for 4 plant species. In the second part (2) leaf age selection was added for one plant species and the influence of leaf hair density and type considered. In the third part (3) the angle of inclination of leaf material and leaf age was evaluated.

Hence, in this section the following factors were investigated:

A. Selection of lower or upper leaf surface.

1. **Leaf surface characteristics**
   - leaf hair density and type
   - internal structure of leaf
2. **Leaf angle** of inclination

B. Selection of younger or older leaves.

1. **Leaf age** characteristics
   - leaf hair density and type
   - nitrogen, phosphorus and potassium content of leaves

(1) Leaf surface selection for four plant species

The experiments in this section measured leaf surface selection only. The collective characteristics of the leaf surface and particularly the internal leaf structure were investigated for their influence on the selection of the lower leaf surface of 4 plant species.

Materials and Method

Two leaf discs, one with lower and the other with upper surface down, were presented to whiteflies in a cage and the number of adults on each leaf surface was counted at intervals over 24 hours.

Four experiments were carried out with 4 species of plants:

Experiment 1-3/1: Tomato (*Lycopersicon esculentum*) cv. Virosa.
Experiment 1-3/2: Tobacco (*Nicotiana tabacum*) cv. White Burley.
Experiment 1-3/3: *Abutilon* sp.
Experiment 1-3/4: *Datura* sp.

Ten identical cages were set up for each experiment except Experiment 1-3/1: Tomato where six cages were set up because insufficient whiteflies were available. The cages were placed in two rows in a growth cabinet at 20+/-1 C and 12/12 hour light/dark regime.

The leaves for *Abutilon* and *Datura* were selected from plants growing outside, those for tomato from plants grown in a greenhouse in 10 cm pots especially for this experiment and those for tobacco from plants grown for the whitefly colony (See Appendix 1 for details regarding the rearing system).

The two leaf discs each 1.5 cm diameter were cut from leaves of the same age, approaching full maturity. Wherever possible the pair of discs was cut from the same leaf or leaflet. They were then inserted into two holes in 2 percent water agar in a petri dish. The petri dish was inverted over the open end of the cage in a horizontal position. The cage stood on the other half of the petri dish and had a black filter paper placed under it. The cage was made from a Mylar overhead projector acetate sheet formed into a cylinder. A similar cage for Experiment 1-3/5 is seen in Photograph 1-3/1.

Adult whiteflies 1-9 days old were anaesthetized with carbon dioxide and 50 females for each cage were counted and allowed to recover before being transferred to the cages. The number of adults present on each leaf disc was counted every 15 minutes for the first 2 hours, every half hour for the next 2 hours and at 5, 6 and 24 hours. The number of eggs laid on each disc was counted at 24 hours.

The results were analyzed using contingency tables analysis and the loglinear model of best fit for each time for the factors leaf surface (lower and upper) and replicate (cages 1 to 6 or 10) was determined (Bishop et al, 1975). Also the hypothesis that there is no difference between the number of adults on the lower and upper leaf surface was tested for each time using the binomial probability distribution.

Results and Discussion

The results for selection of leaf surface by adults are summarised in Fig. 1-3/1 and the significant differences ($P<0.01$) are recorded in Appendix Table A1-3/1. The

Photograph 1-3/1

Cage with leaf discs set into holes
in water agar for Experiment 1-3/5.

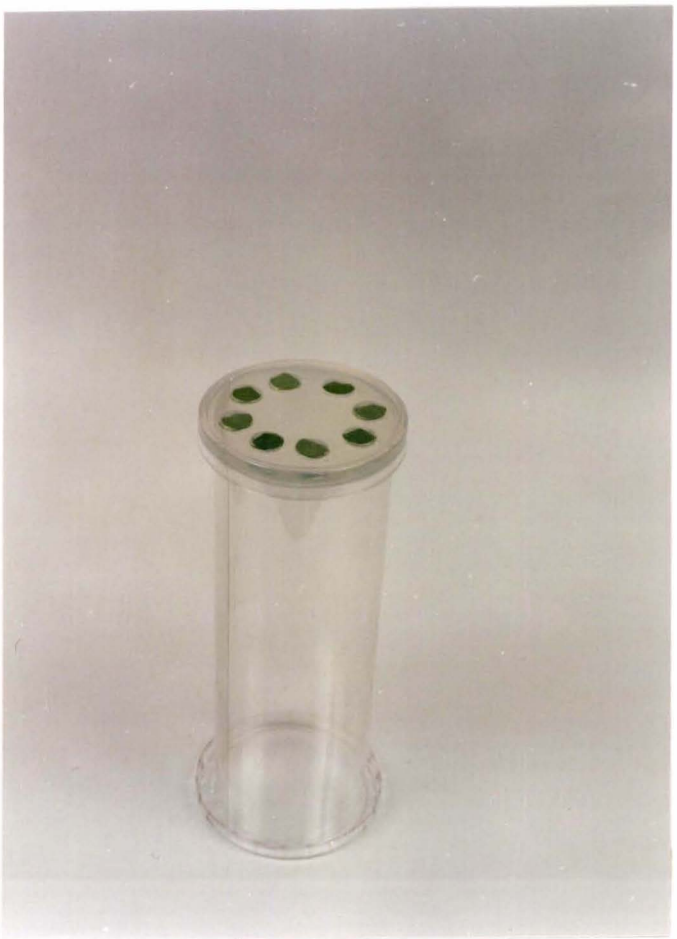
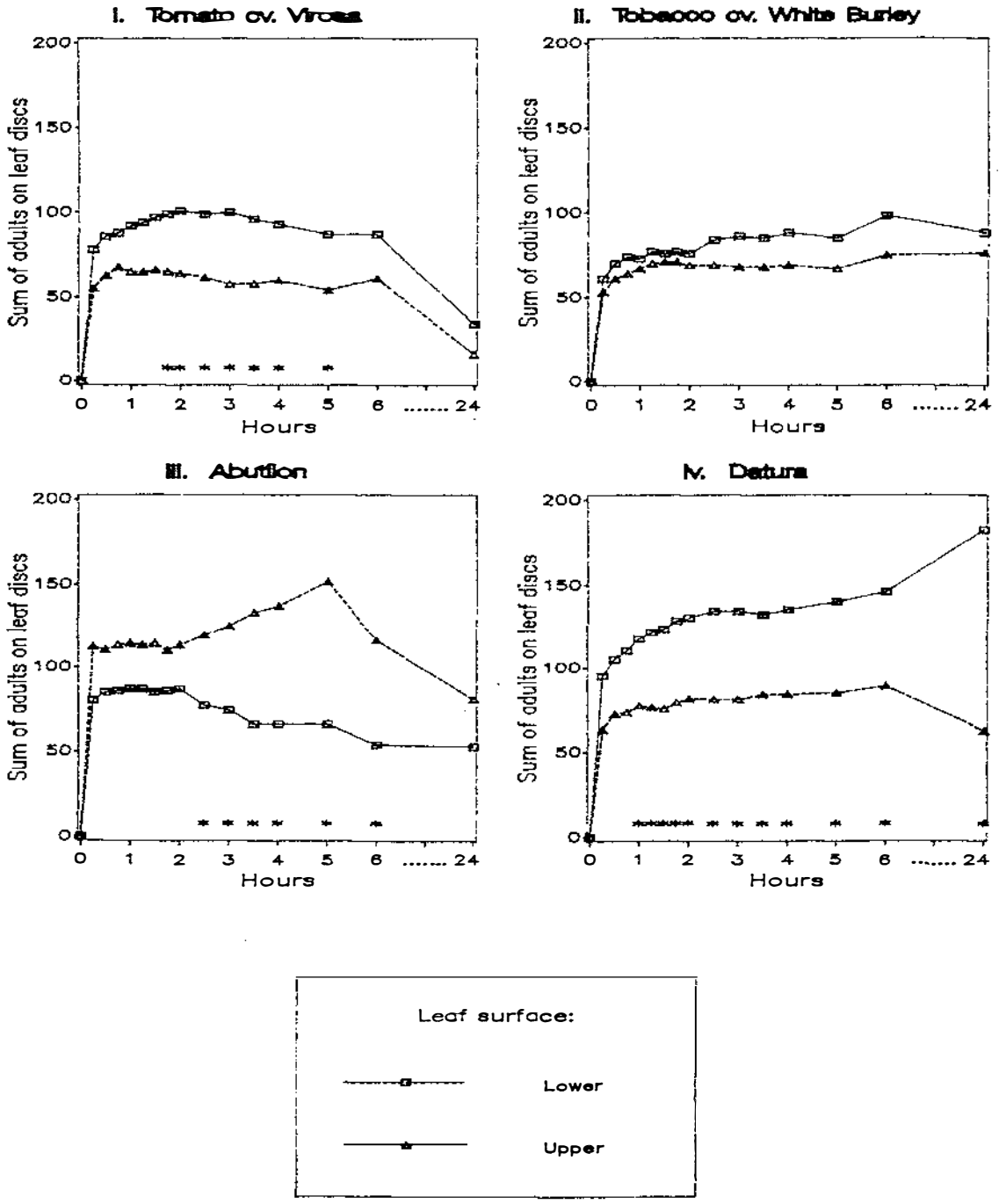


Fig. 1–3/1
Adult preference for lower or upper surface of leaf discs – choice test.



* Adult numbers on lower and upper leaf surfaces are significantly different ($P<0.01$) at these times. See Appendix Table A1–3/1.

oviposition results are presented and discussed in Section 2-1 (3) (See Fig. 2-1/4).

The results show that whiteflies prefer:

1. The lower leaf surface of tomato and *Datura*.
2. The upper leaf surface of *Abutilon*.
3. Neither surface of tobacco.

In no case is the preference very marked. Hence, characteristics of the leaves do not have a strong influence on the selection of the lower leaf surface by greenhouse whitefly.

Selection takes place after some time, *Datura* taking the shortest and *Abutilon* the longest, but this may be a reflection of the total number of whiteflies on the leaf discs rather than a time delay in the choice becoming final. Numbers need to reach a critical level before small differences such as these become apparent. Observation of the percentages on the leaf discs supports this as they change little throughout the experiments with the exception of *Abutilon*.

These experiments were not designed to investigate what factors of leaves might be influencing the selection of leaf surface. This is considered in more detail in the Discussion Section. However, at this point it is worth noting that *Abutilon* has dense stellate hairs on the lower but not the upper leaf surface and this may have influenced the selection of the upper leaf surface. Tomato, *Datura* and tobacco are all in the Solanaceae family and have several hair types from glandular to short or long and pointed. They are more dense on the lower leaf surface so cannot have a marked influence on leaf surface selection. The types of leaf hair on tomato are discussed in the literature review on page 24.

Variation among replicates.

There was some variation among replicates for *Abutilon* and some possible causes are:

1. **Whitefly age.** Whiteflies which were very young may have been less active and so may have taken longer to reach the leaf discs or may not have reached them at all. It is possible that some replicates had more younger whiteflies than others as for some replicates whiteflies were collected from younger leaves where they are likely to be older and others from older leaves where they are likely to be younger.

2. **Aggregation.** Whiteflies may have tended to move to discs where whiteflies were already present because of the attraction of an aggregation pheromone. The presence of such a pheromone is supported by the work of Åhman and Ekbom (1981) who showed that females(males absent)tend to aggregate. However, Experiment 1-2 indicated that aggregation has very little affect on the selection of leaf surface.

3. **Effects of anaesthetization.** It was observed that whiteflies that had not had as long to recover from the anaesthetization were less active. Duration of anaesthetization may also reduce activity.

The whitefly age differences and effects of anaesthetization discussed above imply that the number of whiteflies on discs should increase over time but there is no evidence of increases in numbers on the discs within a replicate over time except where the numbers are very small over the first 3-5 hours. Most of the selection appears to take place during the first fifteen minutes.

(2) Leaf surface and leaf age selection

The experiment in this section involved leaf surface and leaf age selection for one plant species. The collective characteristics of the leaf surface and of leaf age (particularly the density of leaf hairs and hair type) were investigated for their influence on the selection of the lower leaf surface and the younger leaves.

Materials and Method

Experiment 1-3/5

Leaf discs set in water agar were used for this experiment and the method was similar to that for Experiments 1-3/1 to 1-3/4.

The following changes were made:

1. One plant species was used: tomato cv Virosa.
2. Eight leaf discs were randomly allocated to holes arranged in a circle in the water agar. A pair of leaf discs for each of four leaf ages was cut and for each pair of discs one had the lower and the other the upper leaf surface exposed.
3. Eight cages were set up in a row along the front of a growth cabinet.
4. The first dark period commenced one hour after the start.
5. One hundred whiteflies were introduced into each cage.
6. Counts of adults were made immediately then at 0.5, 1.0, 1.3, 13.5, 24.0, 37.5 hours.
7. Counts were also made of the number of leaf hairs in three main categories:

   glandular hairs (Types VI and VII)
   long hairs (Type I)

short hairs (Types II, III and V).
A description of these types of hairs is on page 24.

At the same time in the same growth cabinet another experiment was set up to investigate oviposition on lower and upper leaf surfaces and four leaf ages of intact tomato cv. Virosa plants. This experiment will be described in Section 2-1 (3).

The plants used were grown in 10 cm pots until about 60 cm tall. Four plants were selected and from each plant the four leaf ages were selected as follows:

Leaf age 4 was the youngest leaf from which two leaf discs could be cut from one of the larger leaflets.

Leaf ages 3, 2 and 1 were the next but one leaves down the stem in order.

Next a leaflet pair was selected within each leaf age. Then from each leaflet within the pair two discs were cut one to have the upper and the other the lower surface exposed for whitefly selection. Hence, each leaflet pair yielded two replicates. If the leaflet was not large enough to have two discs cut out then one disc was cut from each leaflet and another leaflet pair from the same leaf was selected from which to cut the two leaf discs for the other replicate.

The loglinear model of best fit included the added leaf age factor and, for each term of the model, the hypothesis that there is no difference between any pair of counts within any leaf age and leaf surface category (as appropriate) was tested (Bishop et al, 1975).

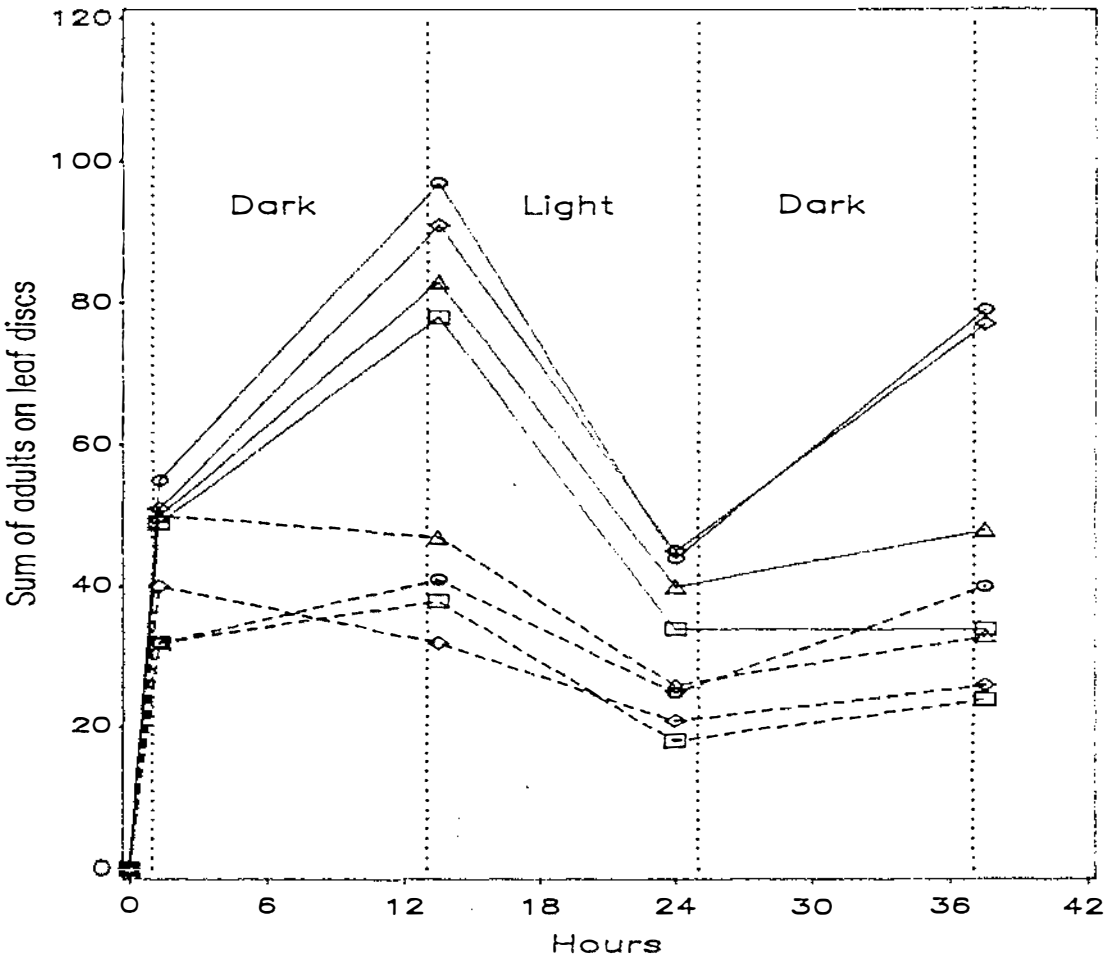
Results

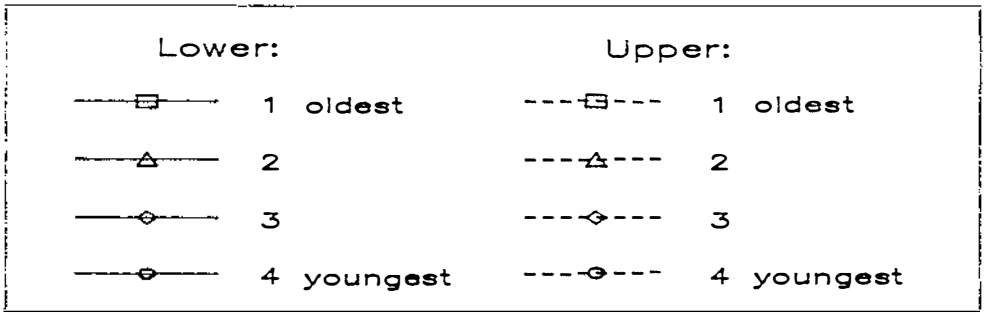
The results are illustrated in Fig. 1-3/2 and the significant differences recorded in Appendix Table A1-3/2.

Fig. 1-3/2

Adult preference for lower or upper surface and four leaf ages of leaf discs -- choice test.

Tomato cv. Virosa





There are some significant differences (P<0.01) between lower and upper leaf surfaces of the same leaf age but no significant differences (P>0.01) between any leaf ages for either lower or upper leaf surface at any time except 37.5 hours. See Appendix Table A1-3/2 1. for details.

The leaf hair densities and types are recorded in Fig. 2-1/2 i and Appendix Table A1-3/2 ii. They did not show any relationship with adult selection of leaf age or leaf surface.

The results show that there is no interaction between leaf surface and leaf age and that whiteflies prefer:

1. The lower leaf surface. However, the relative proportion on each leaf surface does not approach the natural situation where virtually all whiteflies are on the lower leaf surface.
2. Leaves of different ages equally.
3. Light rather than dark periods to search for suitable settling sites. Fig. 1-3/2 shows a pattern of more whiteflies being present on the leaf discs after the dark periods and fewer after the light periods. This pattern of activity is supported by the work of Ekbom (1982) who found that whiteflies are more active during the day than at night.

Hence, the characteristics of the leaves themselves do not play a major role in the selection of the lower leaf surface nor in the selection of the younger leaves. This confirms the results of Experiments 1-1/1, 1-1/2 and 1-2.

(3) Leaf angle and leaf age selection

The experiments in this section investigate the angle of inclination of leaves in association with leaf age for its influence on the selection of settling sites by adult greenhouse whiteflies for three plant species.

The angle of inclination of leaves varies considerably. Some plants have leaves which are nearly vertical (e.g. many monocotyledons) but most are closer to the horizontal. The angle of inclination of leaves of any one species may not only reflect a natural tendency to be at a particular angle but may have been influenced by several environmental factors also. The leaves may orientate themselves towards the light and their angle of inclination may change during the day as they follow the movement of the sun. Also many leaves, especially soft large ones and those with naturally wavy laminas, do not have the whole leaf blade at the same angle. Leaves of different ages on the same plant may be at different angles for example young tobacco leaves are almost vertical and older leaves curve up until they are horizontal then down from the centre to the apex of the leaf.

The first series of experiments (A) in this section was designed to investigate whether greenhouse whiteflies have a preference for horizontal over inclined leaves and whether leaf age influences this choice. The second series of experiments (B) was designed to investigate the influence of the area of leaf discs as perceived by whiteflies as they approach them.

A. Materials and Method

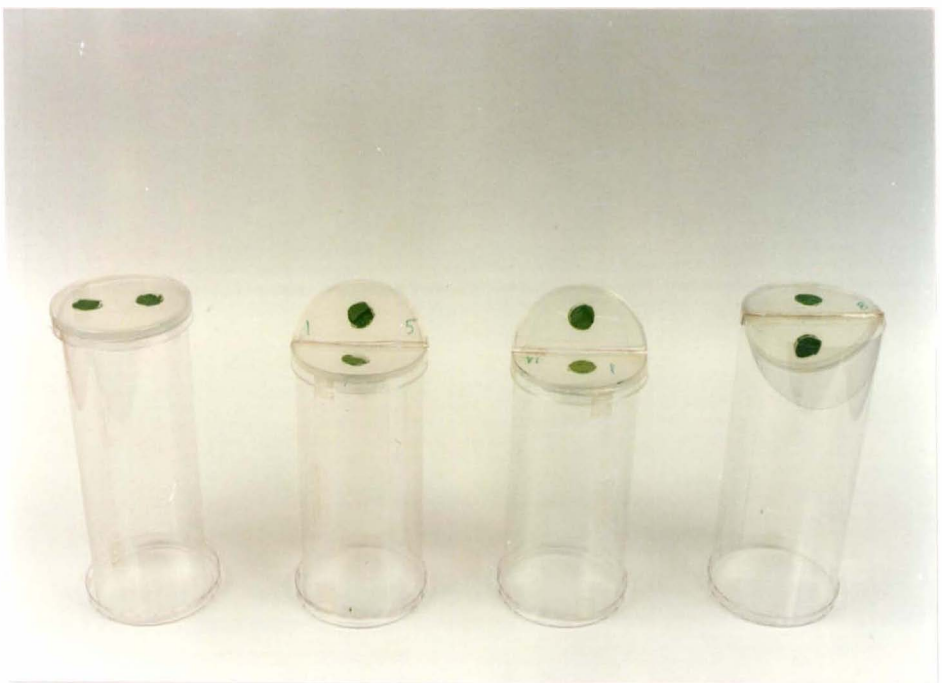
Leaf discs set in water agar were used for this experiment and the method was similar to that for Experiments 1-3/1 to 1-3/4.

The following changes were made:

1. Three plant species were used and each experiment was repeated as indicated below:
   Experiment 1-3/6: (4 runs)
   Tomato cv. Virosa (*Lycopersicon esculentum*).
   Experiment 1-3/7: (1 run)
   Tobacco 'White Burley' (*Nicotiana tabacum*).
   Experiment 1-3/8: (4 runs)
   Rauriki (*Sonchus olearaceus*).
2. The discs all had the lower surface exposed for adult selection.
3. One of the two discs in each cage was horizontal and the other at one of the angles 0°, 45°, 60° and 90°. The petri dishes for the angles 45°, 60° and 90° were cut in half. One half containing one leaf disc was inclined and the other half petri dish with the other leaf disc was horizontal. Whole petri dishes were used for the 0° angle. The discs for the 45° and 60° angles were above and the 90° angle discs below their corresponding horizontal discs. All cylinders were constructed so that gaps between petri dish halves and between petri dishes and cylinder were reasonably well sealed with pieces of acetate cut to fit so preventing whiteflies from escaping (See Photograph 1-3/2).
4. The leaf age of the pair of discs was either the youngest leaf from which two leaf discs could be cut (younger) or just fully mature (mature).
5. Eight cages were set up for each run. Two cages for each of the four angles were used. Of these two, one had the younger and the other the mature leaf age.

Photograph 1-3/2

Cages with leaf discs set into holes in water agar for Experiments 1-3/1 to 1-3/3.
Angles from left to right: 0°, 45°, 60° and 90°.



6. Fifty female whiteflies approximately 2-10 days old were placed in each cage.
7. The number on each leaf disc was counted at 0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.5, 3, 3.5, 4, 5, 6 and 24 hours for tobacco but for tomato and rauriki the counts at times 1.25, 1.75, 2.5 and 3.5 were omitted.

Eggs laid on the leaf discs were counted at the end of each run of the experiments.

The results were analyzed using a contingency table and the loglinear model of best fit for each plant species and time for the factors angle, disc (horizontal or inclined), leaf age and replicate (cages 1 to 8) was determined (Bishop et al, 1975). The egg counts are discussed in Section 2-1 (3).

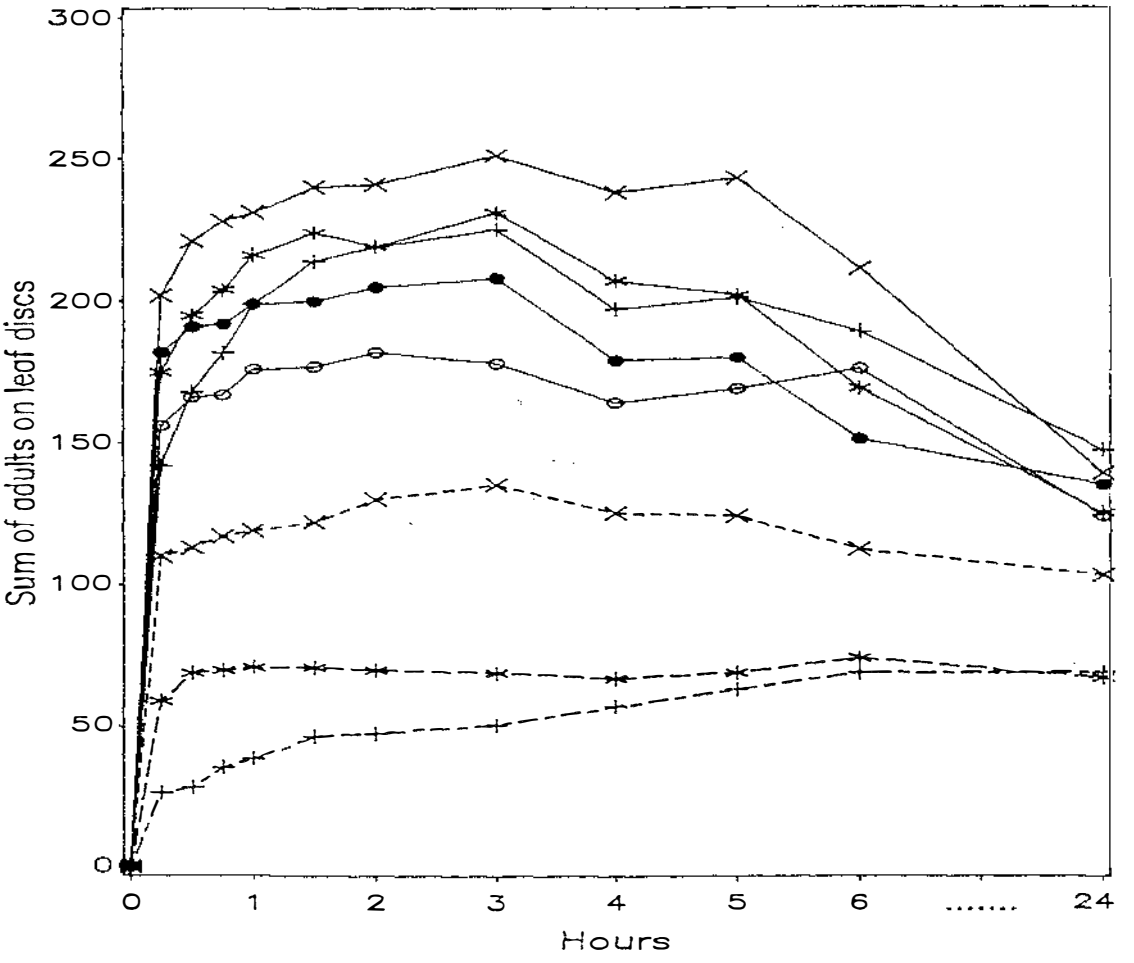
A. Results and Discussion

Figs. 1-3/3 and 1-3/4 summarise the results for this part. The analysis showed that throughout the experiments for both tomato and rauriki there was an interaction between 'disc' (horizontal/inclined) and 'angle'. Apart from two minor abberations (discussed under "Leaf age, leaf angle and whitefly selection" below) these were the only significant differences for tomato and rauriki. For tobacco there was an interaction between 'disc' and 'angle' only from 3 hours until the end of the experiment. Before this time there was a significant difference between horizontal and inclined discs. In addition there was an interaction between 'leaf age' and 'angle' throughout the experiment. There is one minor abberation to these generalisations at 6 hours where the result was the same as for the early part of the experiment.

There were a few missing values in the results because some leaf discs wilted during the experiment. In these cases both discs from the same cage were then omitted from subsequent counts. The missing values make no difference to the analysis where inclined and horizontal leaf discs are compared as the same number of missing values are in the horizontal and inclined categories. See Appendix Tables A1-3/3 i. a. and iii. a. However where angles were compared the missing values will affect the analysis. In spite of this the general trend can still be seen in the earlier count times of the experiments. See Appendix Tables A1-3/3 i. b. and iii. b.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

i. Tomato cv. Virosa

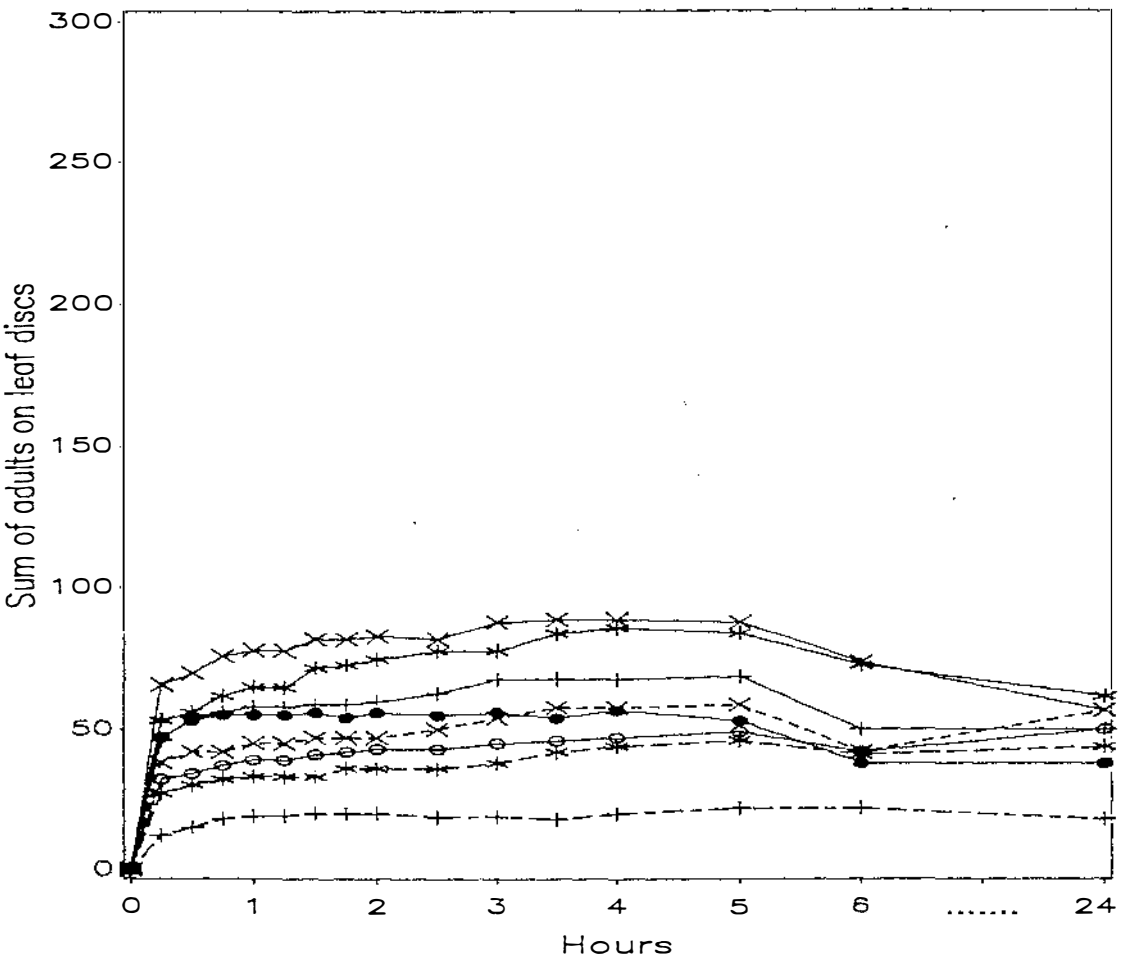


Inclined disc at:		Horizontal disc with:	
—o—	0 deg.	—●—	0 deg. inclined disc
- - -×- - -	45 deg.	—×—	45 deg. inclned disc
– – *– –	60 deg.	—*—	60 deg. inclined disc
- - -+- - -	90 deg.	—+—	90 deg. inclined disc

For significant differences see Appendix Table A1–3/3 i.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

ii. Tobacco cv. White Burley

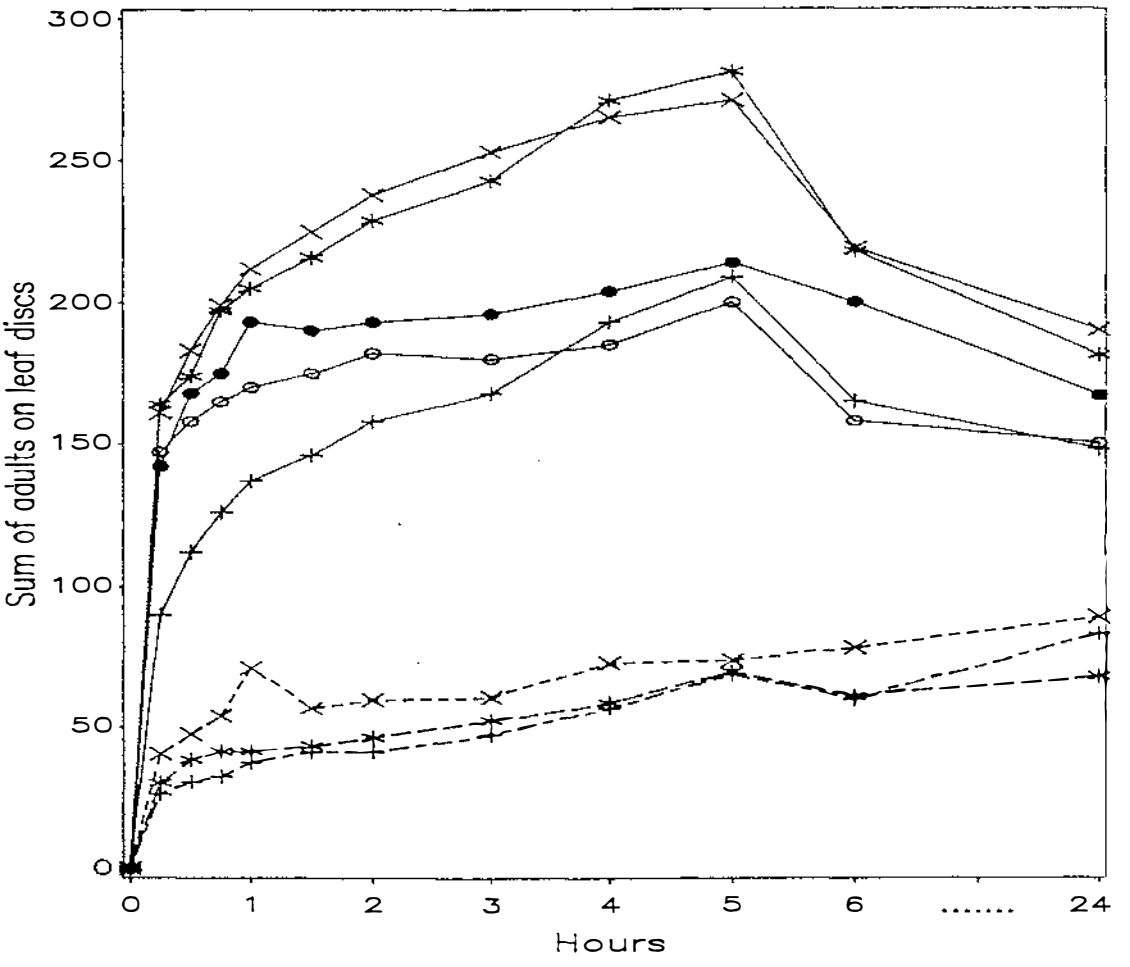


Inclined disc at:		Horizontal disc with:	
—o—	0 deg.	—●—	0 deg. inclined disc
---×---	45 deg.	—×—	45 deg. inclined disc
—–*––	60 deg.	—*—	60 deg. inclined disc
---+---	90 deg.	—+—	90 deg. inclined disc

For significant differences see Appendix Table A1–3/3 ii.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

I. Paurikl

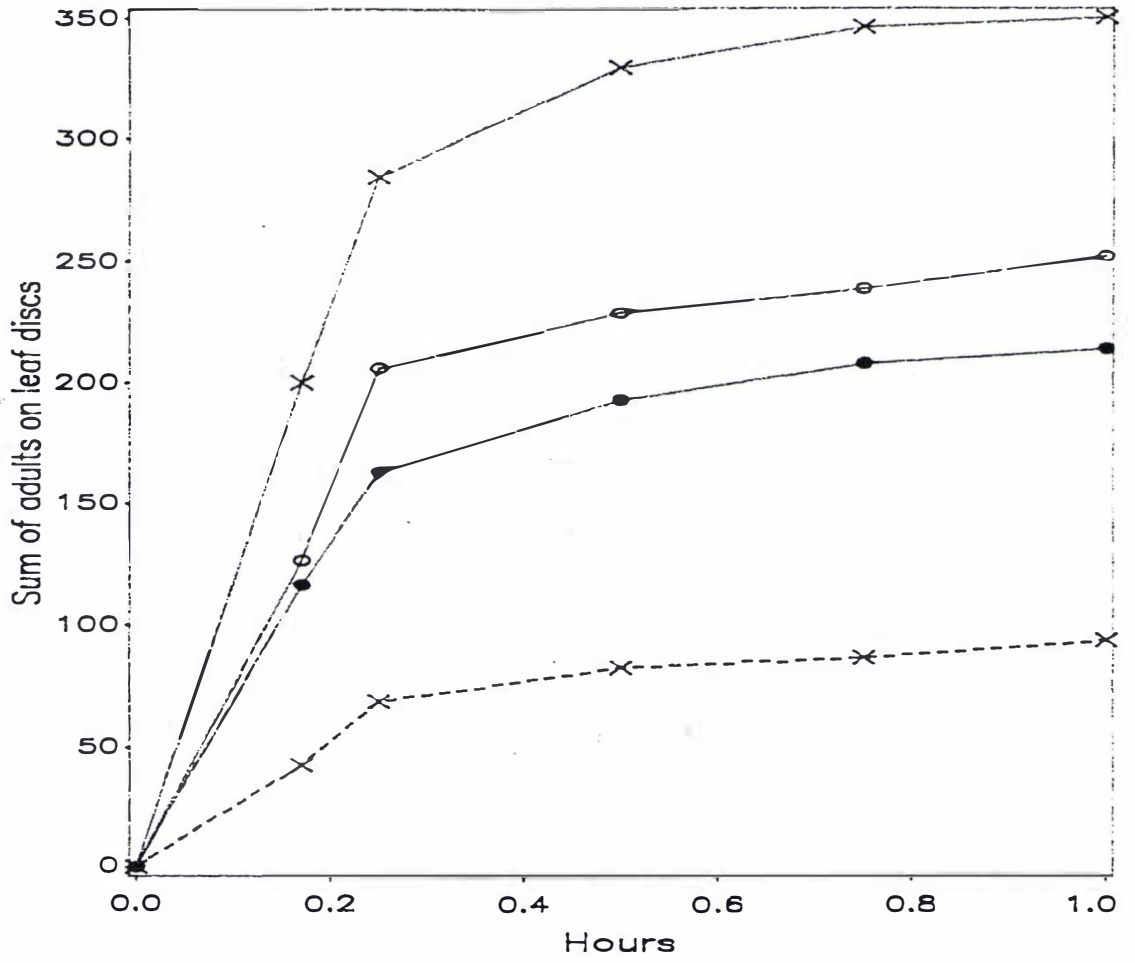


Inclined disc at:		Horizontal disc with:	
—o—	0 deg.	—●—	0 deg. inclined disc
---×---	45 deg.	—×—	45 deg. inclned disc
– –*– –	60 deg.	—*—	60 deg. inclined disc
– –+– –	90 deg.	—+—	90 deg. inclined disc

For significant differences see Appendix Table A1–3/3 iii.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

Iv. Tomato cv. Virosa – 45 deg. Projected equal disc area

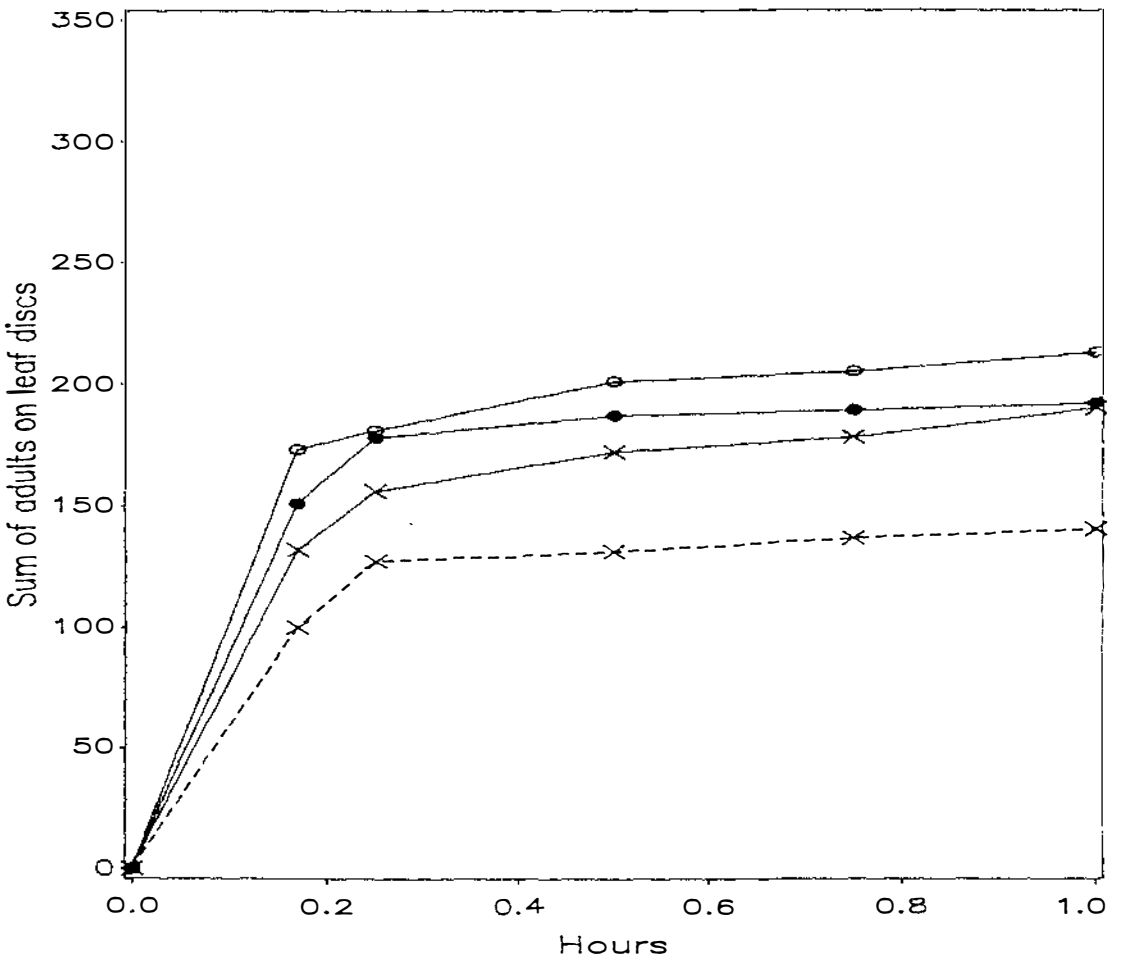


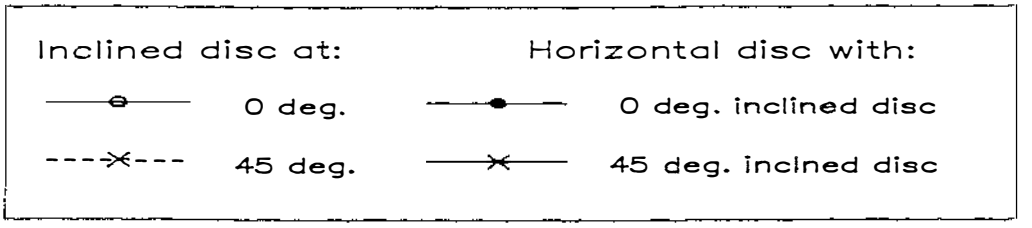
Inclined disc at:		Horizontal disc with:	
—o—	0 deg.	—●—	0 deg. inclined disc
---×---	45 deg.	—×—	45 deg. inclined disc

For significant differences see Appendix Table A1–3/3 Iv.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

v. Rauriki – 45 deg. Projected equal disc area

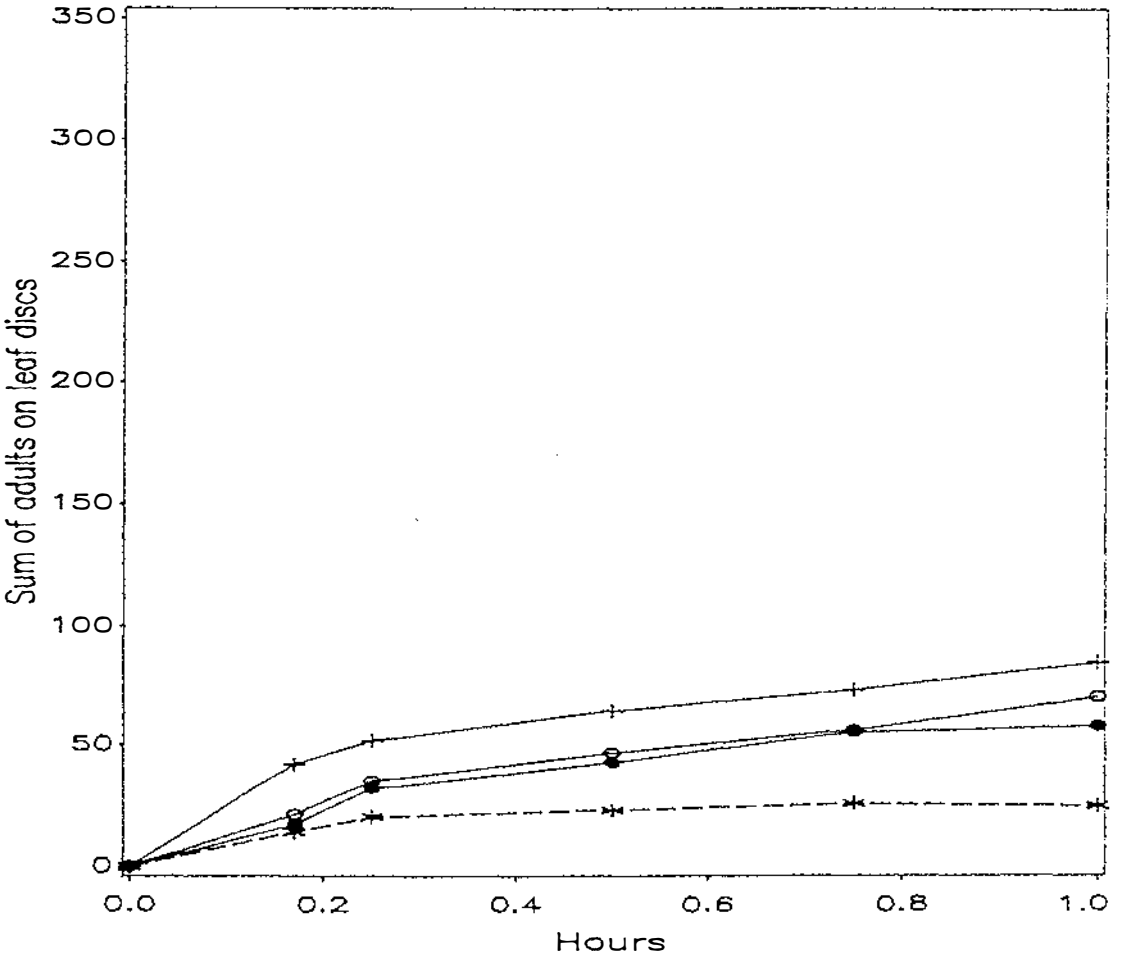




For significant differences see Appendix Table A1–3/3 v.

Fig. 1–3/3
Adult preference for leaf discs at angles 0, 45, 60 or 90 degrees.

vi. Rauriki – 60 deg. Projected equal disc area



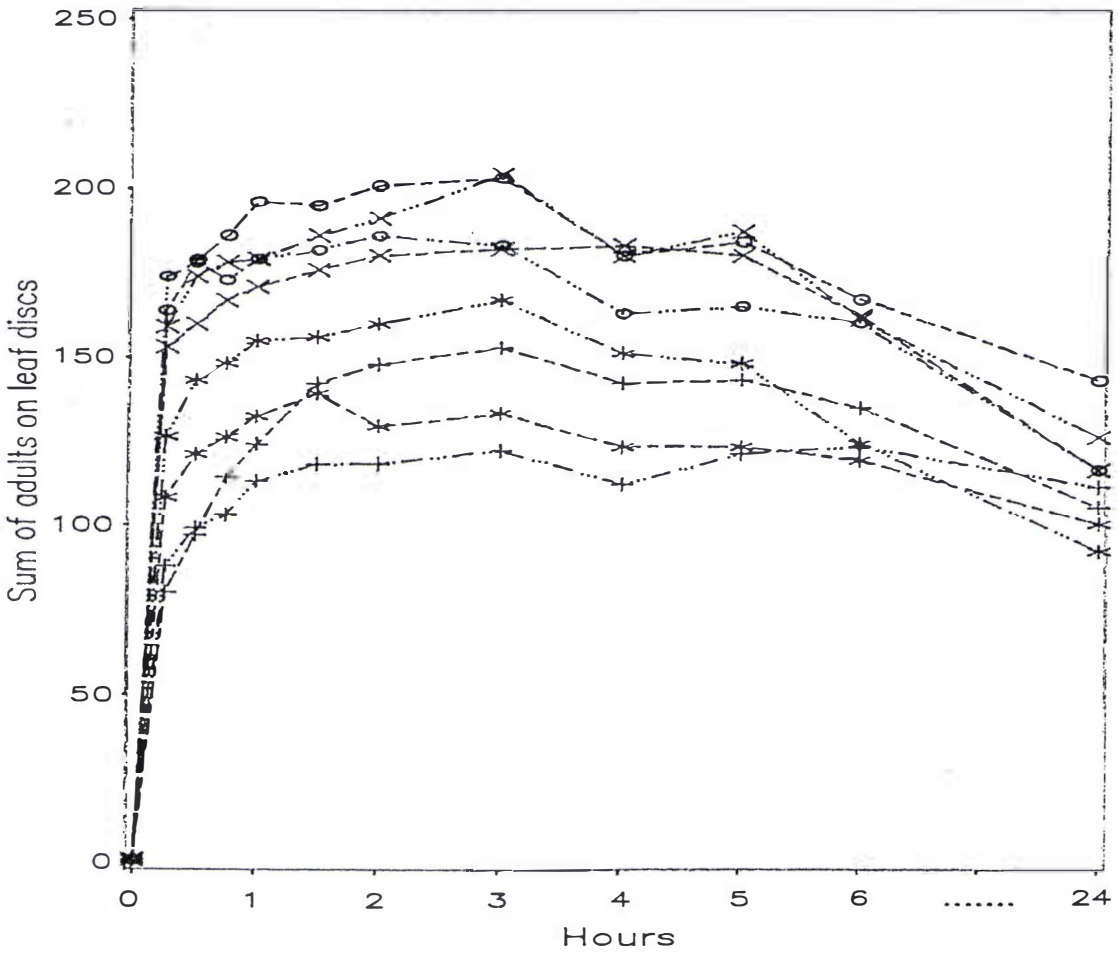
Inclined disc at:		Horizontal disc with:	
—o—	0 deg.	—●—	0 deg. inclined disc
---×---	45 deg.	—×—	45 deg. inclined disc

For significant differences see Appendix Table A1–3/3 vi.

Fig. 1–3/4

Adult preference for younger or mature leaf discs inclined at 0, 45, 60 or 90 degrees.

I. Tomato cv. Virosa



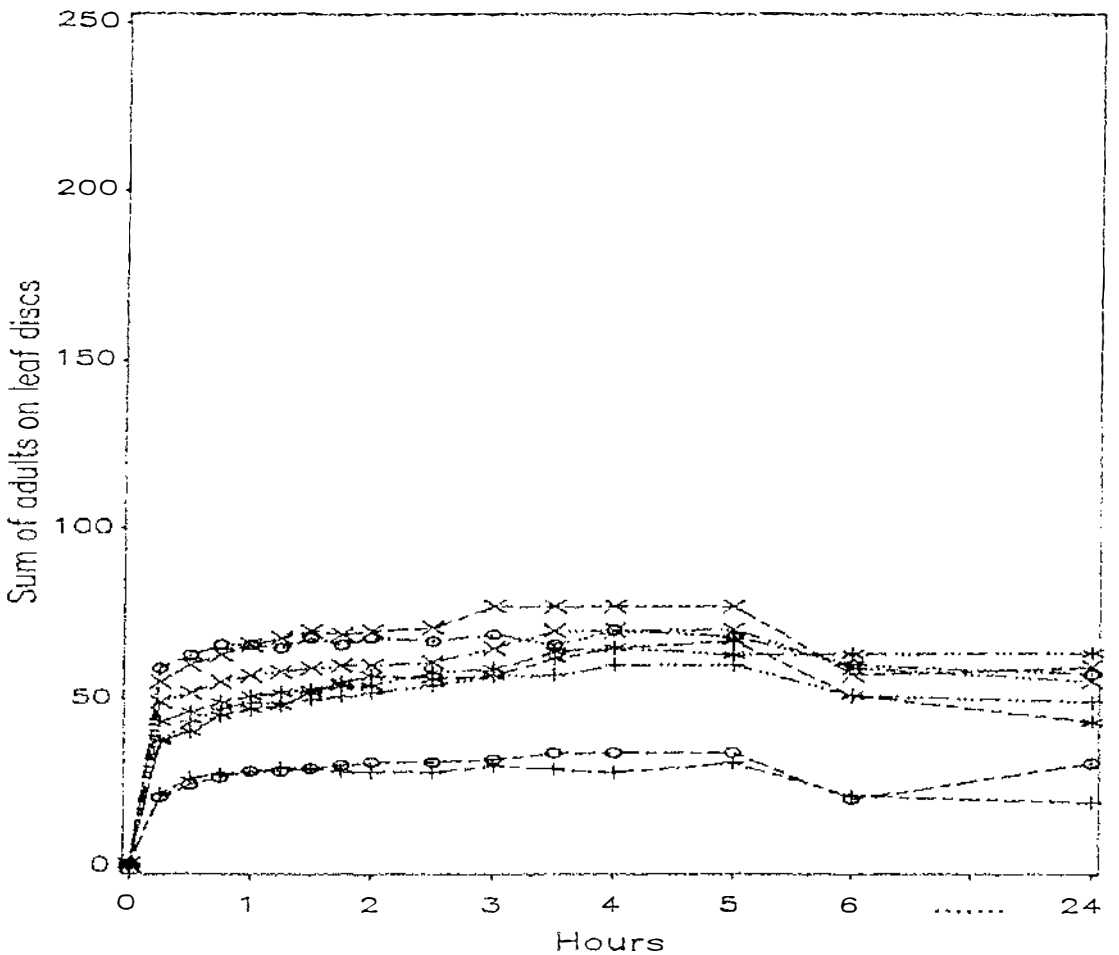
Mature disc at:		Younger disc at:	
---o---	0 deg.	···-o-···	0 deg.
---x---	45 deg.	···-x-···	45 deg.
---*---	60 deg.	···-*-···	60 deg.
---+---	90 deg.	···-+-···	90 deg.

For significant differences see Appendix Table A1–3/4 I.

Fig. 1–3/4

Adult preference for younger or mature leaf discs inclined at 0, 45, 60 or 90 degrees.

ii. Tobacco cv. White Burley



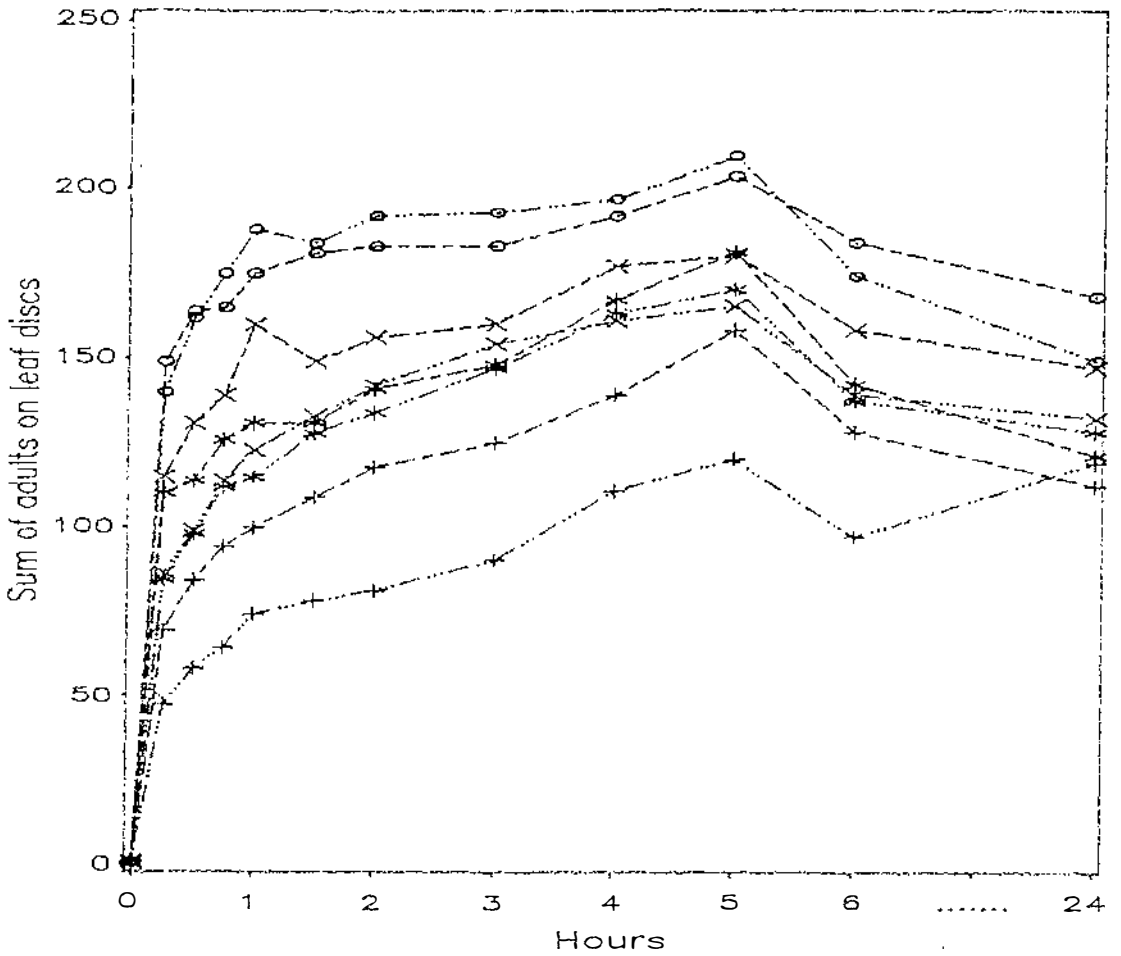
Mature disc at:		Younger disc at:	
---o---	0 deg.	···o···	0 deg.
---×---	45 deg.	···×···	45 deg.
---*---	60 deg.	···*···	60 deg.
---+---	90 deg.	···+···	90 deg.

For significant differences see Appendix Table A1–3/4 ii.

Fig. 1–3/4

Adult preference for younger or mature leaf discs inclined at 0, 45, 60 or 90 degrees.

iii. Raunki



Mature disc at:		Younger disc at:	
---o---	0 deg.	···-o-···	0 deg.
---×---	45 deg.	···-×-···	45 deg.
---*---	60 deg.	···-*-···	60 deg.
---+---	90 deg.	···-+-···	90 deg.

For significant differences see Appendix Table A1–3/4 iii.

Leaf angle and whitefly selection

Although the results may seem to indicate that tomato and rauriki show the same trends a closer inspection of Appendix Table A1-3/3 shows that this is not so. For tomato the number of whiteflies on the inclined disc decreased as the angle increased. This was more pronounced in the early than the latter part of the experiment.

For rauriki the number of whiteflies on the inclined disc was the same for all angles greater than 0° almost throughout the experiment and the 0° inclined disc had significantly more whiteflies than any of the other angles.

Because the total number of whiteflies on leaf discs is not the same in all instances it may be thought that these generalisations are not valid. However, the percentages on leaf discs support the above conclusions for tomato and rauriki. See Appendix Tables A1-3/3 i. b and A1-3/3 iii. b.

For tobacco almost throughout the experiment there were significantly more whiteflies on the 0° (inclined) than the 90° leaf disc but this is not so for any of the other angles.

Hence, whiteflies do not consistently show a decrease in preference for leaves as the leaf angle increases.

Leaf age, leaf angle and whitefly selection

For tomato and rauriki leaf age had no effect on whitefly selection except for two abberant results (mentioned above). They are:

1. Tomato shows an 'age' by 'angle' interaction at 3 hours which has no obvious biological explanation (see Appendix Table A1-3/4 i.).

2. Rauriki shows a significantly greater number on the mature leaf discs at 0.25 hours (see Appendix Table A1-3/4 iii.).

For tobacco there were significantly ($P<0.01$) more whiteflies on the younger leaf discs throughout the experiment for cages with a 0° inclined disc and from 1.75 hours to the end for cages with a 90° inclined disc. For cages with 45° or 60° inclined discs there was no significant difference between younger and mature leaf ages. See Appendix Table A1-3/4 ii. The preferential selection of the younger leaf discs at 90° may in part explain the selection of the younger leaves on the plant as these tend to be upright. However, whiteflies will also congregate on the older leaves which tend to be more horizontal and since 0° has yielded a similar result to that for 90° the argument is contradicted: the whiteflies would need to have been in greater numbers on the mature leaf at 0° for the argument to follow.

Other factors that may have influenced the results

Where a greater number of whiteflies have selected the horizontal leaf disc the reason may be that they are able to perceive a larger area for the horizontal than the inclined leaf disc as they fly upwards from below. To check this Experiments 1-3/9 to 1-3/11 were carried out. Here each disc had the same projected area onto a horizontal plane.

The cages for the 45° and 60° angles had the inclined disc above the horizontal disc whereas the cage for 90° had the inclined disc below the horizontal disc. So as whiteflies may tend to reach the lower disc first it may have the greater number of whiteflies and this disc is the horizontal one for 45° and 60° and the inclined one for 90°. However, the inclined disc for 90° is far less visible from below. It

would be difficult to devise a system where the horizontal disc was below the inclined disc for 90°.

Some of the angle - leaf age effects could be due to the younger leaf discs being less flat and whiteflies therefore being able to find a position on the disc where they would be virtually horizontal no matter the angle. It was also sometimes difficult to ensure that discs were not a little wrinkled in fitting them into the slightly smaller hole in the agar especially as all the plants have soft leaves.

No clear conclusion can be drawn on whether whitefly preference for leaves decreases as the angle of the leaf to the horizontal increases. The results were not consistent among the plant species: tomato, tobacco and rauriki. Only whiteflies on tomato showed decreasing preference with increase in leaf angle.

There is no clear evidence of a correlation between preference for particular angles and leaf age.

B. Materials and Method

Leaf discs set in water agar were used in this part and the method was similar to that for part A.

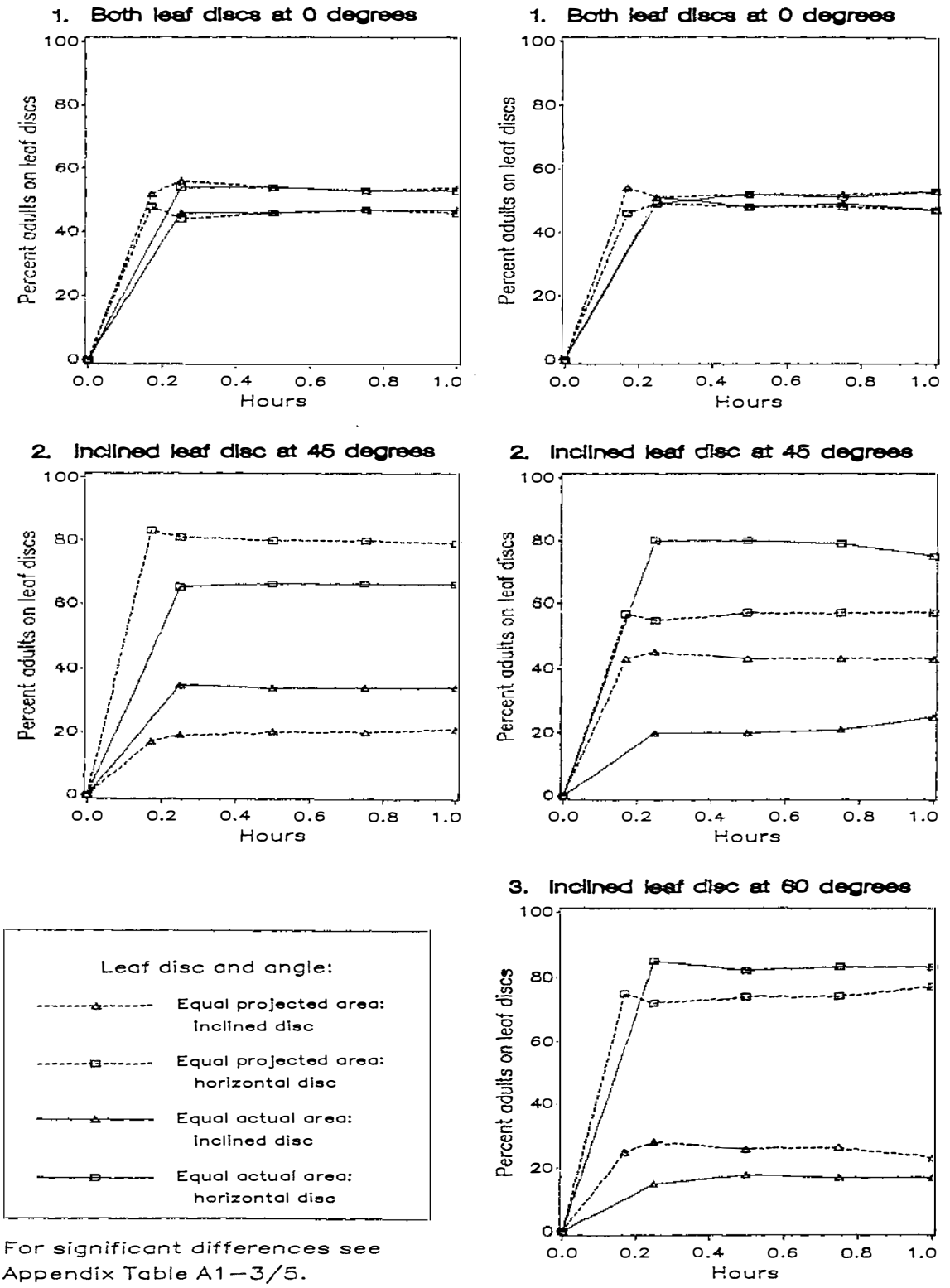
The following changes were made:

1. Three plant species were used and each experiment was repeated as indicated below:
   Experiment 1-3/9: Tomato at 45° (2 runs).
   Experiment 1-3/10: Rauriki at 45° (2 runs).
   Experiment 1-3/11: Rauriki at 60° (1 run).
2. Only two angles were used: 0° and either 45° or 60° as indicated above.
3. Only mature leaves were used.

Fig. 1–3/5
Adult preference for leaf discs of equal actual or equal projected area.

i. Tomato cv. Virosa

ii. Rauriki



For significant differences see Appendix Table A1–3/5.

greater number on the horizontal disc for the equal actual area but not for the equal projected area. For the 60° angle there was a greater number on the horizontal disc for both actual and projected area cases.

For the horizontal disc the counts for the two angles were generally the same for both actual and projected area cases. But for the inclined disc there were generally more whiteflies with the 0° angle.

The total whiteflies on the leaf discs was greater for the 0° than for other angle/s for the actual area and projected area 45° case but not the 60° case. Where the totals are not the same comparisons among angles may not be strictly valid.

The percentages on the two discs in Appendix Table A1-3/5 ii. show for actual and projected areas: no difference for the 0° angle, a greater proportion on the horizontal disc for the actual area for both 45° and 60° angles.

For tomato comparison of Appendix Table A1-3/5 i. shows that there were no differences in the results for actual and projected area cases.

The percentages on the two discs in Appendix Table A1-3/5 show for actual and projected areas: no difference for the 0° angle, proportionally fewer whiteflies on the horizontal disc for the actual area case at the 45° angle.

Discussion of Sections A and B

Choice between horizontal and inclined discs

From the results for rauriki, tomato and tobacco (Appendix Table A1-3/3 iii. to vi.) it can be seen that whiteflies prefer to be horizontal rather than at an angle between 45°

and 90°. The comparisons with equal projected areas (Appendix Table A1-3/5) shows that the lesser number on the inclined disc cannot be attributed to the smaller perceived area of that disc for tomato and rauriki at 60°. But for rauriki at 45° there was no significant difference between horizontal and inclined discs in the projected area case. This greater number on the horizontal disc was due only in part, if at all, to its greater perceived area. Differences in the vertical distance to the two leaf discs or visibility of one disc from the other may affect the selection or reselection of discs. Consider the 45° and 60° angles: whiteflies have a greater vertical distance to travel to reach the inclined disc so may tend to reach the horizontal disc first and settle there. Also the inclined disc is not directly visible (whiteflies may be able to see it through the agar and petri dish) from the horizontal disc so if whiteflies move off the horizontal disc they may not locate the inclined disc very easily. Now consider the 90° angle. The horizontal disc was above the inclined disc and each disc was visible from the other. There is no evidence from these experiments that these factors have a substantial or even a minor effect. Whether these factors have a significant effect could be tested by comparing counts of whiteflies on the inclined disc below with above the horizontal disc. Hence, it can be concluded that whiteflies tend to select a horizontal rather than an inclined leaf disc but this is not completely consistent.

Angle

The differences in the total numbers of whiteflies on leaf discs may well have skewed the comparisons among the angles within horizontal or inclined disc categories. However, it appears that there is not a consistent inverse correlation between numbers of whiteflies and angle. For example there was no difference among the angles 45°, 60° and 90° (rauriki, Appendix Table A1-3/3 vi. b) or there was no difference among

the angles 0°, 45° and 60° (tobacco, Appendix Table A1-3/4 ii. b), or there was a gradual decrease in numbers from angle 0° to 90° (tomato, Appendix Table A1-3/4 i. b). Thus no clear conclusion can be drawn from these experiments on whether whiteflies have a decreasing preference for increasing angles.

Leaf age.

Leaf age has little or no effect on selection of the horizontal rather than the inclined disc or on the numbers at the different angles. For rauriki there was only a greater number on the younger leaf disc at 0.25 hours.

Leaf age has little effect on the number of whiteflies at the various angles, there only being a difference for tomato at 3 hours. Some of the angle - leaf age effects could be due to the younger leaf discs being less flat and whiteflies therefore would be able to find a position on the disc where they would be virtually horizontal no matter the angle. It was also sometimes difficult to ensure that discs were not a little wrinkled in fitting them into the slightly smaller hole in the agar especially as all the plants have soft leaves.

For tobacco there were more whiteflies on the younger leaf disc in the early and later parts of the experiment. Rauriki had more whiteflies on the younger leaf age only at 0.25 hours. This could be due to differences in colour of the two leaf ages for it is well known that whiteflies preferentially select surfaces with a predominance of yellow and tend to avoid those with a predominance of blue (Vaishampayan, 1975a, 1975b; Trehan, 1941). However, no marked differences in leaf colour were observed when the experiments were set up.

Equal projected disc area

Using equal projected areas for the horizontal and inclined leaf discs did not remove the significant difference between horizontal and inclined leaf discs nor between angles. This, therefore, confirms that whiteflies prefer to be horizontal rather than at an angle between 45° and 90°. However, the percentage on the horizontal compared with the inclined disc in the same cage was somewhat reduced compared with the equal actual area case (see Appendix Table A1-3/5).

2 Factors influencing oviposition

Oviposition and leaf surface, leaf age, leaf angle, light intensity and light/dark regimes.

While adult whiteflies may prefer to settle on the lower leaf surface of younger leaves this does not necessarily mean that the females will lay more eggs under these conditions. The preference of adult insects for the lower leaf surface and younger leaves may indicate that they can detect differences in leaf surfaces and leaf ages. Another way that would indicate their ability to detect such differences is if their oviposition on the two leaf surface and leaves of varying ages differed. If differences are detected the question then arises as to which characteristic/s of the leaves give/s rise to the variation in oviposition.

It is well known that nutritional differences affect fecundity (see literature review) so if the nitrogen, phosphorus and potassium content of leaves can be correlated with oviposition on those leaves then it would suggest that the nutrient status of leaves affects the fecundity of whiteflies.

It has also been suggested that insects can have physical difficulty in laying eggs on very hairy leaves and that this will give rise to fewer eggs being laid on very hairy leaves so if leaf hairiness can be correlated with oviposition this would suggest that whiteflies may have difficulty laying eggs on hairy leaf surfaces. Some insects such as aphids can also become stuck in exudate from glandular leaf hairs or impaled on other types (see literature review). This may be the case with whiteflies for some plant species but it does not appear to be a problem on tomato varieties commonly grown commercially.

Therefore, the first part of this section (2-1) explores the relative egg-laying capacity of female whiteflies on the two leaf surfaces and on differing leaf ages and also on leaf discs at varying angles. The effect of leaf hairs and the nitrogen, potassium and phosphorus contents of leaves were also considered.

In the second part of this section (2-2) two questions are addressed: 'Does light intensity affect oviposition or are any differences in oviposition on lower (shady side) and upper (lighter side) leaf surfaces due entirely to leaf characteristics?' and 'Do differences in light/dark regimes (day length in the field) affect oviposition or is the slowing of the life cycle in winter due entirely to other factors such as temperature?'. The effects of light intensity and light/dark regimes on oviposition with the leaf characteristic factors removed were investigated.
In order to eliminate the effects of the leaves themselves sucrose sachets were used as the oviposition substrate in the experiments in this section. Therefore, the first task was to find the optimum sucrose solution to use in the sachets. This is considered in the first part (1) of Section 2-2.

2-1 Oviposition on leaves.

The first part (1) of this section addresses three questions: 'Is the technique using leaf discs set into holes in water agar a satisfactory method for examining oviposition by greenhouse whitefly?' and 'Do whiteflies lay more eggs on younger leaves?' and 'Do whiteflies lay more eggs in different places within a leaf?' The second part (2) considers oviposition using intact plants on the two leaf surfaces and 4 leaf ages under the same conditions i.e. with both surfaces down. The third part (3) evaluates oviposition on leaf discs: lower and upper leaf surface, leaf

age and leaf angle. These are the results from the Experiments 1-3/1 to 1-3/8 in Section 1-3.

(1) Oviposition on leaf discs versus intact leaves of 4 leaf ages.

Because it can be difficult to standardise all the variables in experiments using intact plants therefore the technique using leaf discs set into holes in water agar was used. For example it is not possible to standardise comparisons across leaf ages on whole plants because factors such as leaf size and the distance from a light source are not the same.

This series of experiments was designed to investigate differences in oviposition by greenhouse whitefly on leaf discs compared with intact leaves in order to justify the use of leaf discs in other experimental work. The effects of leaf age and of position within a leaf on oviposition were also investigated.

Materials and Method

Whiteflies were caged on the lower leaf surface of either intact plants or leaf discs inserted into 2% water agar and the eggs laid over two days counted. Four leaf ages and either 2 or 3 positions within the leaf were used. The experiments were carried out in a growth cabinet at 20+/-1° C.

Two plant species were used:

Experiment 2-1/1:

Tomato (*Lycopersicon esculentum*) cv. Moneymaker

Experiment 2-1/2:

Tobacco (*Nicotiana tabacum*) cv. White Burley

All plants were grown from seed and the seedlings transplanted into 10 cm pots. Plants of similar size were selected for each experiment.

The four leaf ages were selected as follows:

For tomato leaf age number 4 was the youngest leaf from which leaf discs could be cut and leaf ages 3, 2 and 1 were the next leaves in order down the stem.

For tobacco leaf age number 4 was the youngest leaf from which three leaf discs could be cut from one side and leaf ages 3, 2 and 1 were the next leaves in order down the stem. For two of the tobacco plants it was not possible to include the fourth leaf age as there was limited space in the growth cabinet.

Position within a leaf was selected as follows:

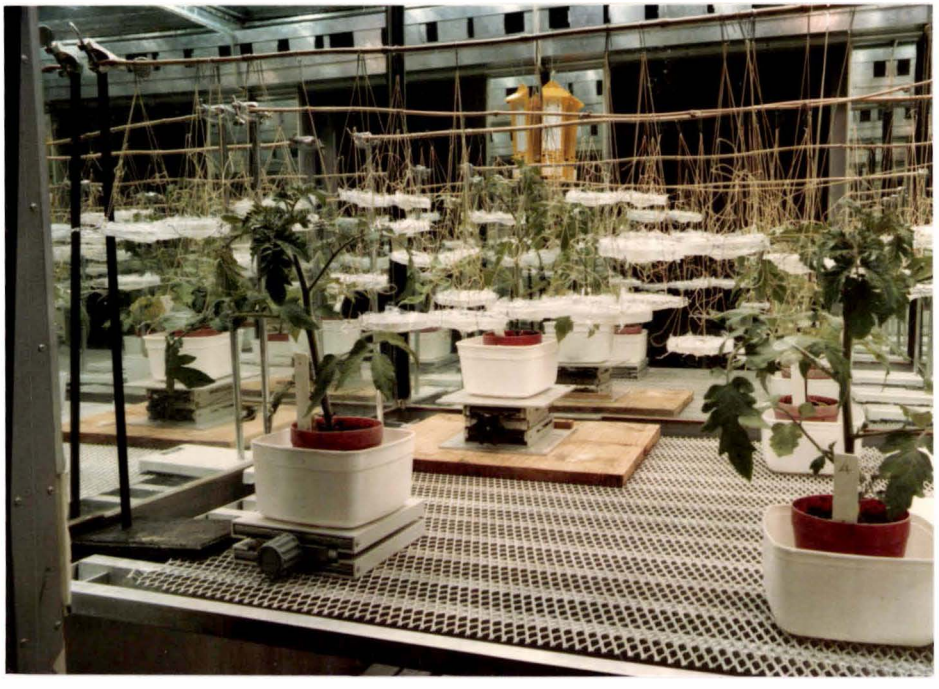
For tomato (2 positions) position 1 was the leaflet pair nearest the leaf apex and position 2 the next leaflet pair towards the leaf base. One leaflet from each pair was randomly selected and a leaf disc cut from it. The other of the pair was used as the corresponding intact leaflet. See Photographs 2-1/1 to 2-1/3.

For tobacco (3 positions) position 1 was nearest the apex and position 3 nearest the petiole. All leaf discs were taken from the same side of the leaf to prevent any possible interference with water or nutrient transport within the intact side of the leaves. Again the other side of the leaf was used for the corresponding intact leaf position. See Photographs 2-1/4 and 2-1/5.

Each leaf disc was 1.8 cm diameter and was inserted into a hole 1.6 cm diameter, cut in 2% water agar in a plastic petri dish.

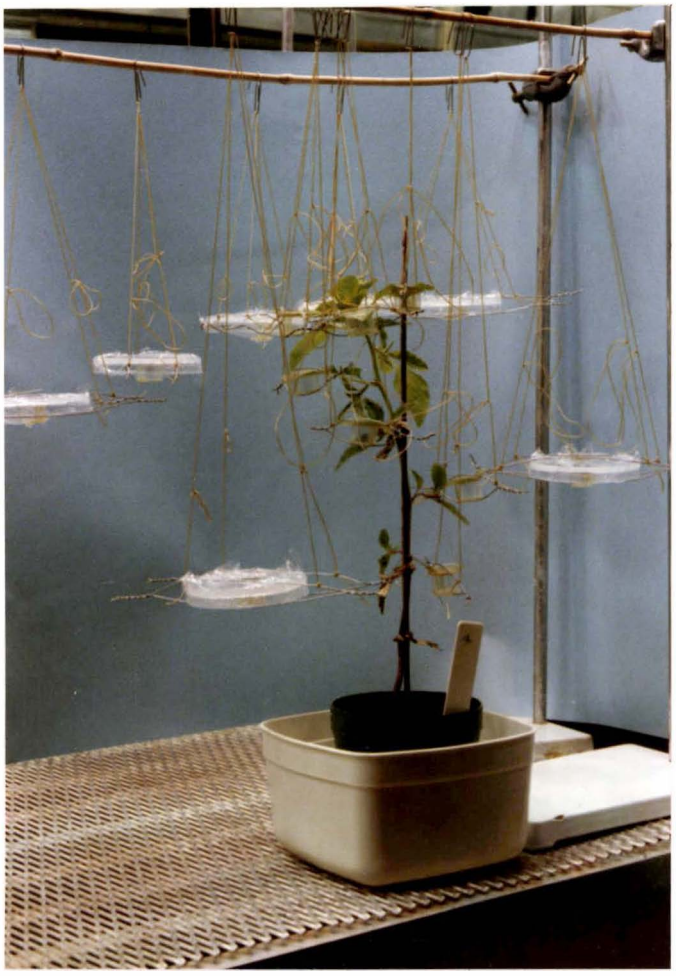
Photograph 2-1/1

Tomato plants in growth cabinet for Experiment 2-1/1.



Photograph 2-1/2

Tomato plant with cages for Experiment 2-1/1.



Photograph 2-1/3

Close up of cages for Experiment 2-1/1.
Upper: top of cages, lower: underside of cages.

Photograph 2-1/4

Tobacco plant with cages for Experiment 2-1/2.

Photograph 2-1/5

Tobacco leaf with cages for Experiment 2-1/2.

The cages were 1.8 cm diameter and 1.5 cm high and were made from Mylar overhead projector acetate sheets, covered with terylene sheer material at one end and a ring of foam plastic glued to the edge of the other end.

They were attached to the intact leaves by placing a small plastic disc cut from a petri dish on the upper leaf surface opposite the cage and the cage and disc held in place by wire clips. These consisted of two lengths of wire twisted together at each end.

The cages were attached to the leaf discs in the petri dishes in a similar way except that no plastic disc was necessary and the cage and petri dish were first wrapped in plastic film (Gladwrap) and a hole torn in the film over the gauze to provide ventilation within the cage. The film was needed to prevent moisture loss from the agar and consequent shrivelling of the leaf discs.

Cages attached to both intact leaves and to leaf discs were suspended from bamboo rods so that the leaf material was as horizontal as possible and each leaf and leaf disc from the same leaf pair were at the same height. See Photographs 2-1/1 and 2-1/2.

An attempt was made to place the four intact plants at four heights so that one set of the four leaf ages (one age from each plant) was at the same distance from the light source. The aim was to eliminate any effect of differences in light intensity on oviposition at the different leaf ages. The attempt was abandoned as being too difficult to set up and analyze. The effect of light intensity on oviposition was investigated in two later experiments (Experiments 2-2/3 and 2-2/4) and these indicated that the range of light intensities that would be encountered in these two experiments would have had no differential effect on oviposition.

Five anaesthetized female whiteflies 1 to 7 days old were placed in each cage and the number alive were counted after 2 days when the egg counts were made. This gave a whitefly density of 1 pair of adults per 1.01 cm^2 of leaf area which is above the 1 pair per 1 cm^2 which Xu et al (1984) found to cause a reduction in fecundity.

The results were analyzed using a contingency table with a loglinear model for factors leaf material (disc or intact leaf), leaf age, position within the leaf and plant number (replicate) (Bishop et al, 1975). The model of best fit was determined and then the terms in the model were further analyzed to determine which pairs of factor combinations were significantly different from each other.

Results

Fig. 2-1/1 summarises the counts of eggs for the leaf ages, positions within the leaves and leaf discs/intact leaves. The significant differences are recorded in Appendix Table A2-1/1 and the number of whiteflies alive at the end of the experiment in Table 2-1/1. The analysis for the factors 'leaf age', 'position within the leaf' and 'leaf disc/intact leaf' showed that there were two 2 way interactions for tomato: 'leaf disc/intact leaf' X 'leaf age' and 'position within the leaf' X 'leaf age' and a 3 way interaction for tobacco.

The results show that for tomato and tobacco whiteflies:

1. Laid more eggs on younger rather than older leaves.
2. Did not consistently lay more eggs on either leaf discs or intact leaves.
3. Did not consistently lay more eggs at any one position within the leaf.

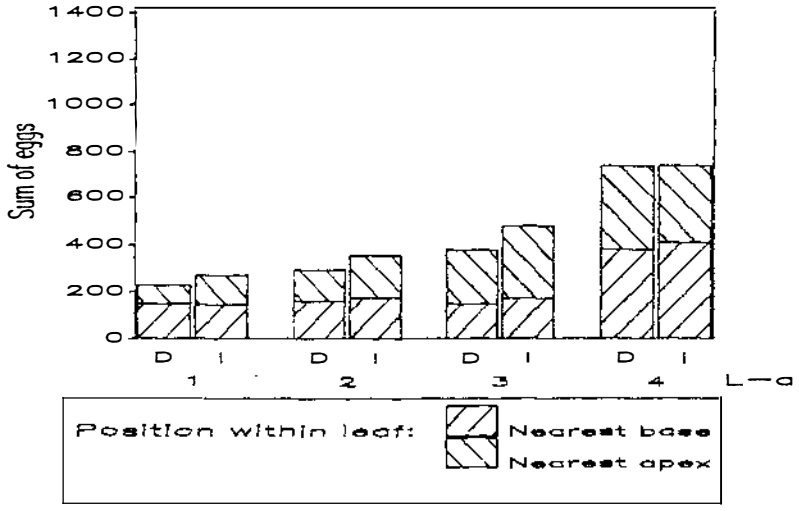
In addition for tomato:

The whiteflies laid eggs in increasing numbers as the age of the leaves decreased for intact leaves but laid more on the

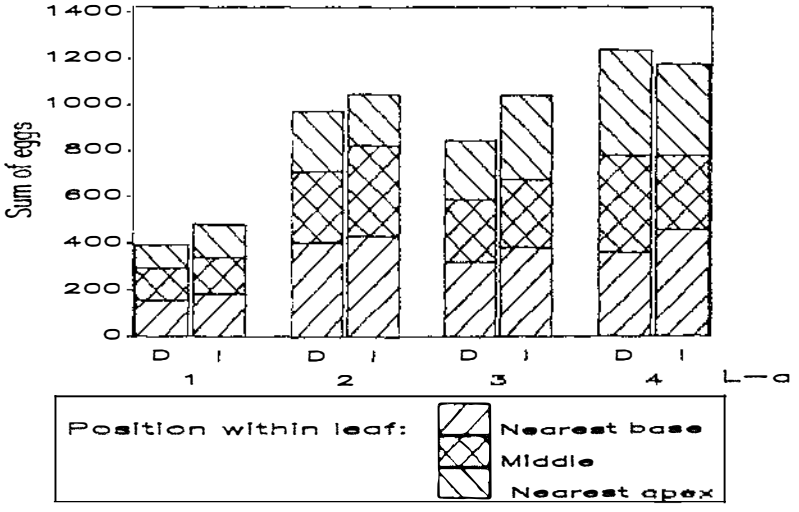
Fig. 2–1/1

Oviposition on leaf discs and intact leaves – no choice test.

i. Tomato cv. Moneymaker



ii. Tobacco cv. White Burley



L—a: leaf age — 1: oldest. D: leaf disc, I: intact leaf.
For the oldest leaf age of tobacco the number of adults was half that for the other ages.
For significant differences see Appendix Table A2—1/1.

Table 2-1/1

i. Tomato cv. Moneymaker.

Total whiteflies alive at the end of the experiment.

	Leaf disc	Intact leaf
Plant number		
1		
Leaf age		
4 Youngest		
* Nearest apex	5	5
* Nearest petiole	5	5
3		
* Nearest apex	5	5
* Nearest petiole	5	5
2		
* Nearest apex	5	5
* Nearest petiole	4	5
1 Oldest		
* Nearest apex	5	5
* Nearest petiole	5	5
2		
Leaf age		
4 Youngest		
* Nearest apex	5	5
* Nearest petiole	5	5
3		
* Nearest apex	4	4
* Nearest petiole	5	5
2		
* Nearest apex	5	5
* Nearest petiole	5	5
1 Oldest		
* Nearest apex	4	5
* Nearest petiole	5	5
3		
Leaf age		
4 Youngest		
* Nearest apex	5	5
* Nearest petiole	5	5
3		
* Nearest apex	4	5
* Nearest petiole	5	5
2		
* Nearest apex	5	5
* Nearest petiole	5	5
1 Oldest		
* Nearest apex	5	4
* Nearest petiole	5	5
4		
Leaf age		
4 Youngest		
* Nearest apex	5	4
* Nearest petiole	5	5
3		
* Nearest apex	4	5
* Nearest petiole	5	4
2		
* Nearest apex	5	4
* Nearest petiole	5	5
1 Oldest		
* Nearest apex	5	4
* Nearest petiole	5	5
Total	155	154

* Position within leaf

Table 2-1/1 continued.

ii. Tobacco cv. White Burley.

Total whiteflies alive at the end of the experiment.

	Leaf disc	Intact leaf
Plant number		
3		
Leaf age		
4 Youngest		
* Nearest apex	5	4
* Middle	5	4
* Nearest petiole	5	5
3		
* Nearest apex	3	5
* Middle	5	4
* Nearest petiole	4	4
2		
* Nearest apex	5	5
* Middle	4	5
* Nearest petiole	5	5
1 Oldest		
* Nearest apex	4	5
* Middle	4	5
* Nearest petiole	4	5
4		
Leaf age		
4 Youngest		
* Nearest apex	5	5
* Middle	5	5
* Nearest petiole	5	3
3		
* Nearest apex	4	5
* Middle	5	5
* Nearest petiole	5	5
2		
* Nearest apex	5	5
* Middle	3	4
* Nearest petiole	5	4
Total	183	193

* Position within leaf

youngest leaves for the leaf discs. See Appendix Table A2-1/1 i. This could be the result of metabolic changes ocurring within leaf discs, maybe inducing the start of senescence, and so reducing oviposition.

More eggs were laid near the petiole for the oldest and the second youngest leaf age. This would need to be re-examined to be sure that it is not an abberation as it is not consistent across all leaf ages nor shows a gradation across them.

In addition for tobacco:

Where there were significant differences between leaf discs and intact leaves no pattern could be detected in their distribution among the other factor levels within Appendix Table A2-1/1 ii.

A pattern could not be detected for oviposition and either leaf age or position within the leaf within the other factors. See Appendix Table A2-1/1 ii. It may be that if there were real differences they were small and far more whiteflies would be needed in the experiment in order to prove statistically that position within the leaf or use of leaf discs versus intact leaves affect oviposition.

Some of the variation could be caused by other factors. It is, however, not caused by whitefly mortality as very few whiteflies died during the experiments (See Table 2-1/1). Variation in whitefly age could have contributed to some of the unexplained variation observed as younger whiteflies lay fewer eggs than older ones. Sas et al (1978) made the assumptions that, "During the first days after emergence oviposition frequency increases till a maximum is reached. This maximum value varies per plant species." It would appear from their figures (Their graph is impossible to read accurately) that the maximum is reached after about 2-4

days and that there is still considerable variation in the number of eggs laid per female per day after the maximum is reached. For example: between about 8 and 13 eggs per female per day were laid on eggplant and 8 eggs per female per day on tomato cv. Moneymaker when the whiteflies were about 5 days old. This dropped sharply to 1 or 2 eggs per female per day when the whiteflies were about 10 days old. Hence, even if a narrower age range were used and the whiteflies were over 4 days old there would most likely still be substantial variation in the eggs per female per day.

During preliminary trials for these experiments it was observed that significantly fewer eggs were laid if any wilting or shrivelling of the leaf discs occurred. Therefore great care was taken to prevent this.

The considerable variation in eggs laid per whitefly in these experiments could probably be reduced by making the following modifications:

1. Increase the number of whiteflies per cage to 10.
2. Use a narrower whitefly age range.
3. Use whiteflies at least 5 days old.

The age range could be narrowed in part by collecting whiteflies from leaves of a similar age. Noldus et al (1985) showed that whiteflies take about 3 days from emergence to reach their final settling sites on the younger leaves. Thus whiteflies collected from older leaves are probably younger than those collected from younger leaves. It would be difficult to ensure a very narrow age range even though all whiteflies were from a batch of eggs laid over two days as was the case for these experiments as the variation in the rate of development to the adult is quite wide with adults emerging over about 8 or 10 days. Even if an attempt were made to select adults over the peak emergence time of say 3 days these whiteflies because they are still very young would

have a wide range in the number of eggs laid per female. Narrowing down the time for egg-laying would help but the dichlorvos pest strip can take up to 12 hours or more to kill all the adults. During this time further eggs may be laid thus making it hard to accurately measure the period of egg-laying. If the strip is nearing the end of activity of the dichlorvos and also if there is considerable condensation in which the dichlorvos may dissolve the effective concentration in the cage is reduced and the time taken to kill all adults is increased.

Conclusions

These results show that for tomato and tobacco there is no consistent difference in the number of eggs laid on leaf discs compared with intact leaves over a two day period. Whiteflies also tend to lay more eggs on younger than older leaves.

The leaf disc technique would be particularly useful for studying oviposition on plants growing in the field as it eliminates time and space problems that would occur if such plants had to be raised for laboratory experiments on intact leaves.

(2) Oviposition on intact plants - both leaf surfaces and 4 leaf ages.

Experiment 2-1/3, described in this section, was conducted at the same time and in the same growth cabinet as Experiment 1-3/5 on the selection of leaf surfaces and leaf ages by adult whiteflies using leaf discs. It was a no choice test whereas Experiment 1-3/5 involved choice.

Materials and Method

Whitefly adults that developed from eggs laid over a period of two days were caged on the lower or upper leaf surface of leaves of four ages of intact tomato (*Lycopersicon esculentum*) cv. Virosa plants and the live adults and eggs laid were counted after two days. The experiments were carried out in a growth cabinet at 20+/-1° C.

Eight tomato plants of similar height (about 35 cm) and the same age were used. They were grown in 10 cm pots in standard potting mix used in the Plant Pathology glasshouse facilities at Massey University. They were fed twice a week with about 200 ml of nutrient solution (Appendix 1).

The four leaf ages were selected as follows: leaf age 1 was the youngest leaf whose leaflets were at least 1.5 cm wide and leaf ages 2, 3 and 4 were the next but two leaves down the stem in order. Leaf age 4 was the oldest leaf which had a pair of left and right leaflets. One pair of leaflets was selected for each leaf age. One of these leaflets was turned over so that the upper leaf surface faced down. A cage containing 5 anaesthetised adult female whiteflies 1-7 days old was attached to the 'down' side of each leaflet selected.

The cages and their support system were the same as those for Experiments 2-1/1 and 2-1/2 where oviposition on intact leaves versus discs was investigated.

The leaves on which the whiteflies had laid eggs were analyzed for nitrogen, potassium and phosphorus content and the density and type of leaf hairs measured.

The results were analyzed using a contingency table with a loglinear model for the factors leaf surface (lower or upper), leaf age and plant number (replicate) (Bishop et al, 1975). The model of best fit was determined and then each

term was further analyzed to determine which pairs of factor combinations were significantly different from each other.

Results

Fig. 2-1/2 summarises the results for oviposition and the significant differences are recorded in Appendix Table A2-1/2 i.

The analysis showed that there was an interaction between leaf age and leaf surface.

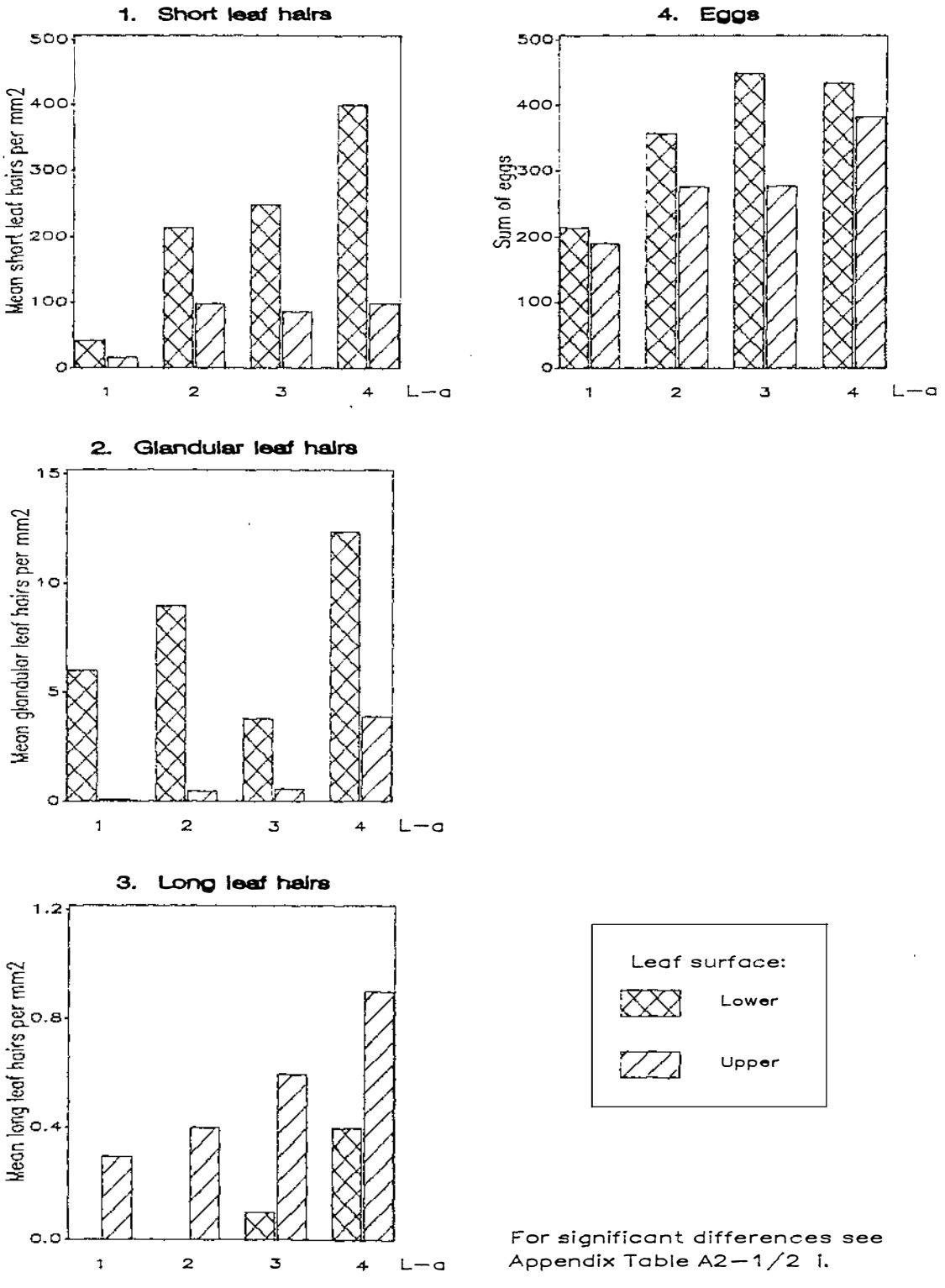
The results showed that whiteflies tended to lay more eggs on younger than older leaves and on the lower leaf surface where leaf age was in between oldest and youngest.

Greater leaf hair density was not the reason why fewer eggs were laid on older leaves as the younger leaves were more hairy. A summary of numbers of leaf hairs per mm sq for intact leaves (Experiment 2-1/3) is presented in Appendix Table A2-1/2 i. and Fig. 2-1/2. Regression analyses of eggs per female per day with numbers of leaf hairs of the three types: 1 (short, pointed) and 2 (glandular) gave results of percentage variance accounted for: type 1: 19.1% and type 2: 0.6%. There were too few long leaf hairs to analyze.

The nitrogen, phosphorus and potassium content of the leaves could not be analyzed statistically as there was insufficient material to run replicates but only the nitrogen content of leaves showed any pattern that correspond with the number of eggs laid. See Fig. 2-1/3 and Appendix Table A2-1/2 ii.

Fig. 2−1/2 continued.

ii. No choice test using intact plants



For significant differences see Appendix Table A2−1/2 i.

Fig. 2-1/3

Oviposition and nitrogen, phosphorus and potassium content for 4 leaf ages.

Tomato cv. Virosa

I. Choice test using leaf discs

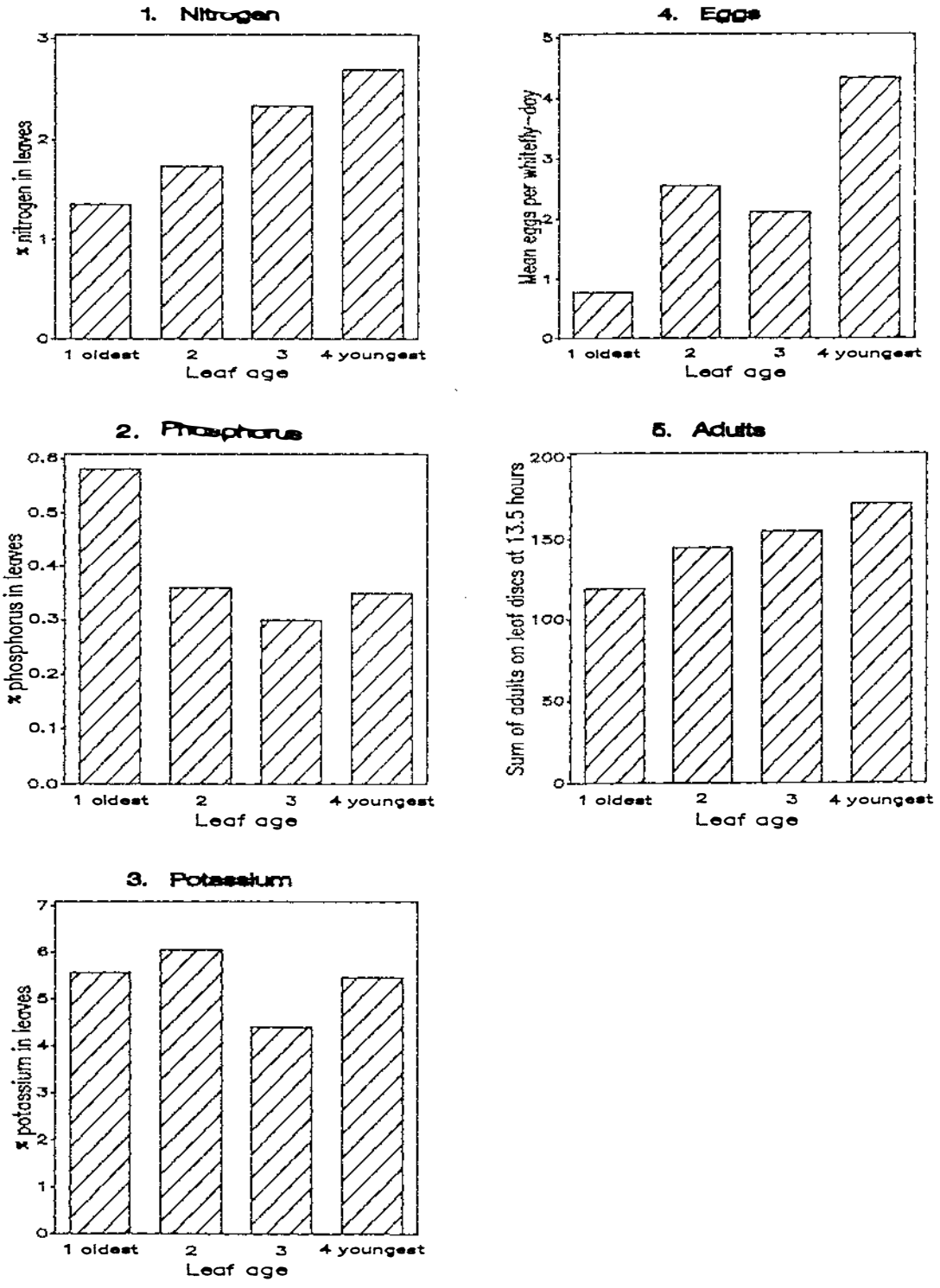
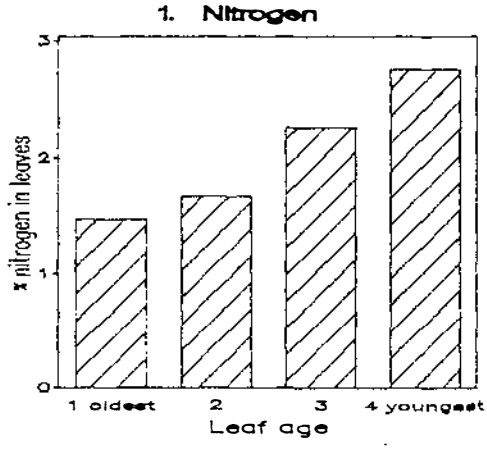
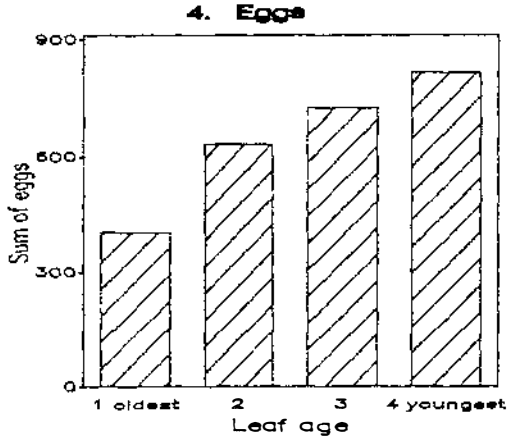
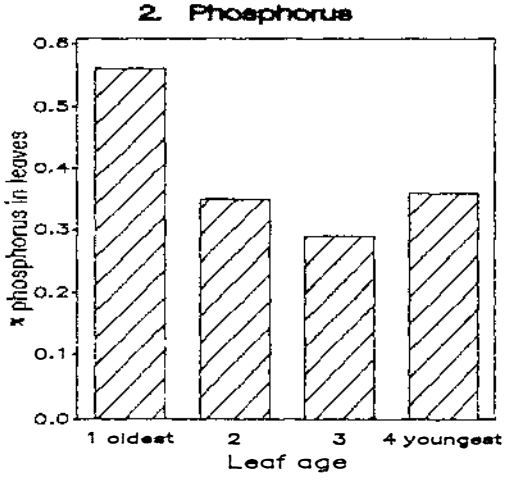


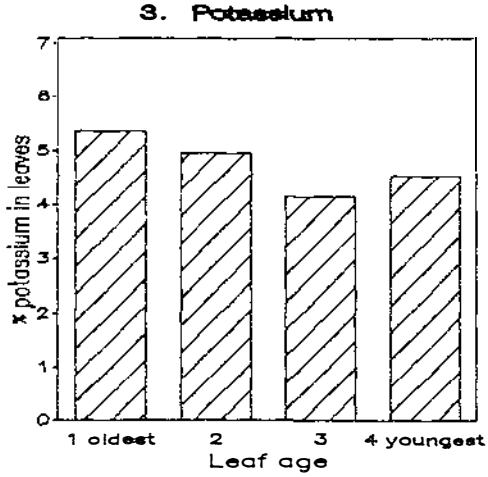
Fig. 2-1/3 continued

ii. No choice test using intact plants





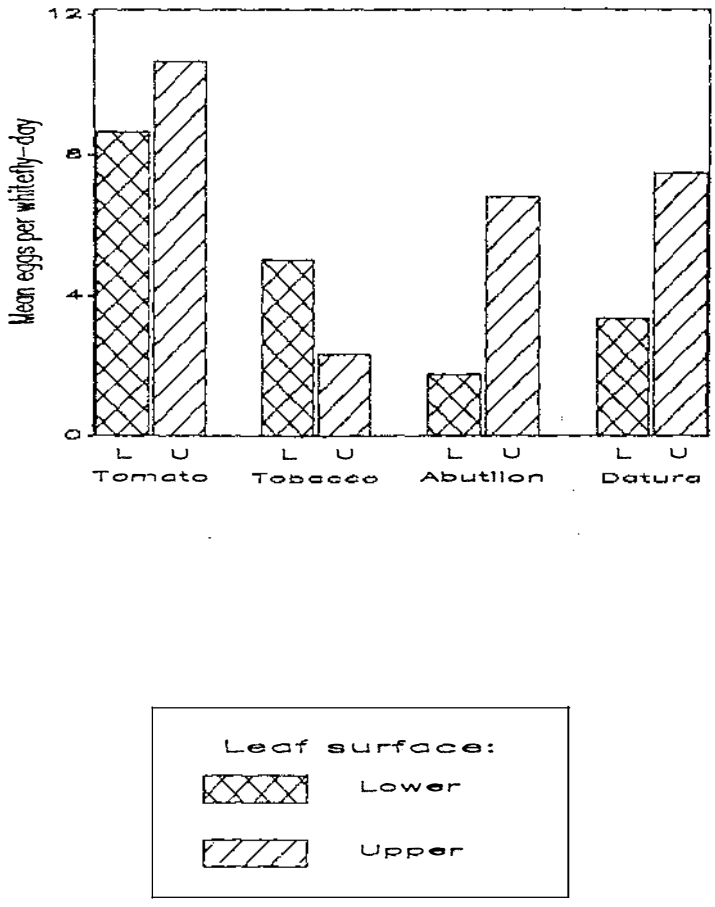




For significant differences see Appendix Table A2-1/2 ii.

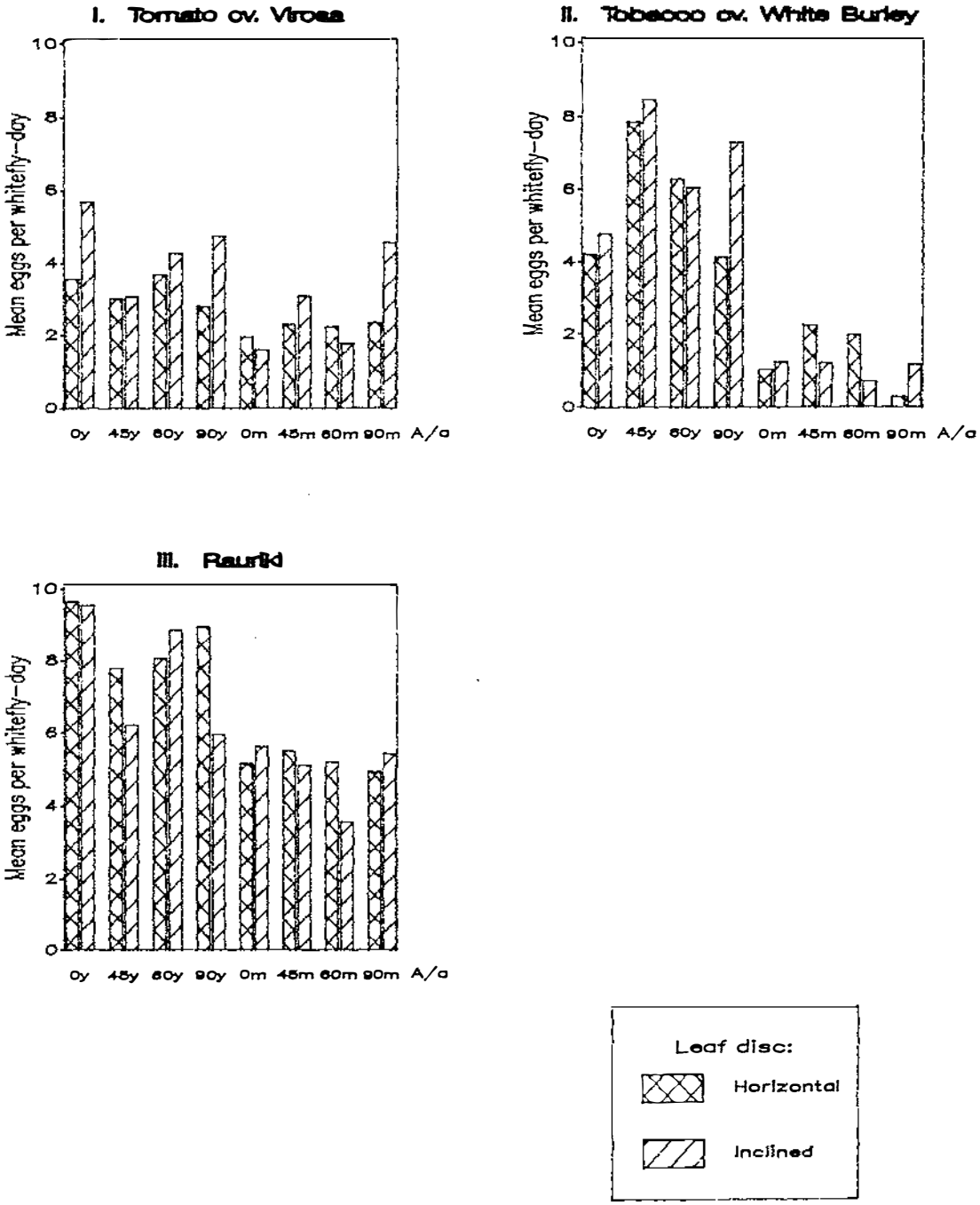
Percentages are % dry weight.

Fig. 2–1/4
Oviposition on lower or upper surface of leaf discs of 4 plant species – choice test.



L: lower, U: upper leaf surface.
For significant differences see Appendix Table A2–1/3.

Fig. 2-1/5
Oviposition on horizontal or inclined (0, 45, 60 or 90 deg.) leaf discs of younger or mature age.



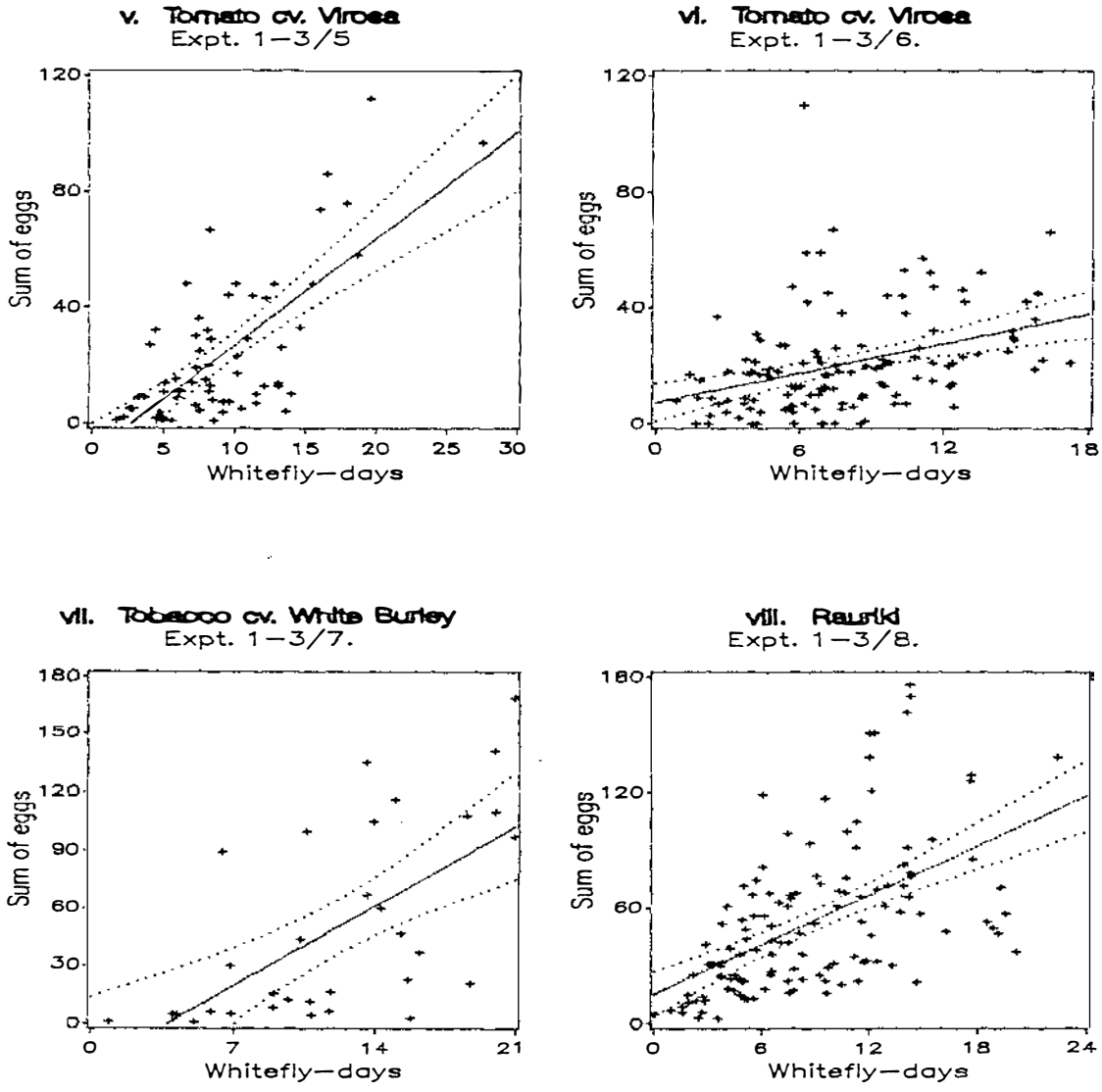
For significant differences see Appendix Table A2-1/5.
A/a: angle/age - y: younger, m: mature leaf discs.

They show that whiteflies prefer to oviposit on younger rather than mature leaves and that leaf angle makes no difference.

Assumptions used

Throughout the experiments assumptions have been made: Firstly, that the longer the time spent on the leaf surface the higher the number of eggs laid. Secondly, that where adult females were caged without choice on plant material they spent all their time on the leaf surface and where they had a choice the calculation of the time spent is only an approximation. The regression graphs (Fig. 2-1/6) show that these assumptions are not good in all cases. Part of the explanation may be that when the adult whitefly density exceeded 1 pair per cm^2 of leaf disc area (which it did for many of the discs) then the fecundity was reduced as was found by Xu et al (1984).

Fig. 2–1/6 continued.



Dotted lines are 95% confidence intervals.

2-2 Oviposition on sucrose sachets and the effects of light intensity and light/dark regimes.

Much work has been carried out on the artificial feeding of sucking insects, especially aphids, on nutrient solutions sandwiched between two layers of Nescofilm or Parafilm to form sachets. One of the earliest records was in 1935 by Hamilton. A number of people worked on improving the nutrient solution used. Some important papers, dominated by the authors Mittler and Dadd, are: Mittler and Dadd, 1962, 1963a, 1963b, 1964, 1965, 1967; Dadd and Mittler, 1965; Mittler, 1967a, 1967b; Parry and Ford, 1967, 1969, 1971; Dadd and Krieger, 1968; Griffiths et al, 1975. Eventually a completely defined diet was produced (Mittler and Dadd, 1962) and it became possible to rear green peach aphid through several generations (Dadd and Mittler, 1966). As the technique became more widely known it was tried with other aphids e.g. pea aphid (*Acyrthosiphon pisum*) (Auclair and Cartier, 1963; Auclair, 1965; McLean and Kinsey, 1967; Mclean, 1971), bean aphid (*Aphis fabae*) (Dadd and Krieger, 1967), cotton aphid (*Aphis gossypii*) (Auclair, 1967, 1978), black citrus aphid (*Toxoptera aurantii*) (Tahori and Hazan, 1970). Other Hemipterous insects were found to be amenable to the technique e.g. a froghopper (Hagley, 1967), planthopppers (Mitsuhashi and Koyama, 1971; Koyama, 1979; Koyama and Mitsuhashi, 1980, Koyama et al, 1981); leafhoppers (Hou and Brooks, 1975; Maramarosch and Harris, 1979; Magayarosy, 1980) and tobacco whitefly (*Bemisia tabaci*) (Berlinger et al, 1983).

Not only was there interest in finding the complete list of essential nutrients, their optimum relative proportions and pH but also the technique was used to test the effects of insecticides (Mittler and Pennel, 1964; Holtgräwe, 1977), the effects of secondary plant substances (Junde and Lidao, 1984) and in work with virus transmission (Magayarosy, 1980). Preference for settling and feeding in choice tests, probing

responses, adult life span and larviposition or oviposition rate were used to measure the effects of the solutions used.

Probably the most important chemical for incorporation in artificial diets for Hemipterous insects is sucrose and the optimum concentration needs to be found for each insect species. For green peach aphid it is 10-20% (Mittler and Dadd, 1963a), cotton aphid 20-30% (Auclair, 1967), pea aphid 20% (Strong, 1967); black citrus aphid (*Toxoptera aurantii*) 55% (Tahori and Hazan, 1970) and 15% for tobacco whitefly (Berlinger et al, 1983).

Simple sucrose solutions and sometimes other test chemicals (e.g. various sugars) have proved satisfactory for bioassays e.g. screening for susceptibility to systemic insecticides with green peach aphid (Mittler and Pennell, 1964) and determining aggregation behaviour in pea aphids (Strong, 1967). Therefore, a sucrose solution with no additives was considered to be satisfactory for testing various parameters for greenhouse whitefly.

The first part (1) of this section addresses three questions: 'What is the optimum sucrose concentration to use for maximum oviposition and longevity when greenhouse whitefly feeds through Nescofilm?' It was necessary to find the answer to this question before embarking on the other experiments in this section. Further questions addressed are: 'Are there differences in longevity between males and females on their own and mixed males and females?' and 'Do female whiteflies on their own lay more eggs than when in mixed sex groups?' and 'What is the percentage hatch of eggs?'

The second part (2) of this section addresses the question of the effect of light intensity on oviposition and the third part (3) the effect of different light/dark periods on oviposition.

(1) Adult longevity and oviposition with a range of sucrose concentrations.

Since there are no reports in the literature of oviposition by greenhouse whitefly on sucrose sachets and since the range of sucrose concentrations found to be optimum for other sap sucking insects ranges from 15 to 55% it was decided to use a wide range of concentrations for the first experiment.

The experiments described below were carried out to find the optimum concentration of sucrose that gives rise to the maximum number of eggs laid and the maximum survival or the best compromise if the optimum concentration is not the same for both. The intention was to use this concentration for the experiments on light intensity and light/dark regimes.

Materials and Method

Whiteflies were placed in cages with a sachet at the upper end containing a solution of sucrose. The eggs laid on the sachets, number of whiteflies alive and larvae that hatched from the eggs were counted every day until all whiteflies were dead.

A range of concentrations of aqueous sucrose solutions were used in two experiments:

Experiment 2-2/1:

0 (water only) 10% 20% 30% 40% 50% 60% air.

Experiment 2-2/2:

0 (water only) 15% 20% 25%.

As Experiment 2-2/1 used a wide range of sucrose concentrations (0-60%) the number of replicates had to be reduced to 2 due to the time taken to make counts and the availability of the cages. Experiment 2-2/2 used a narrow range of sucrose concentrations (0 to 25%) and the number of replicates was increased to 8.

The whiteflies, 2-9 days old, were collected using a pooter, anaesthetized with carbon dioxide and 8 adults counted out and placed in each cage. This gave a density of 1 pair of adults per 1.33 cm^2 of sachet surface which is above the density which may cause a reduction in fecundity (Xu et al, 1984). The 8 adults were in one of the following sex groups:

all female or
all male or
half female and half male

The sex groups were included as whiteflies can lay eggs both parthenogenetically and as the result of mating and it was thought there could be differences between all female and mixed sex groups. Ideally the all female group should have been virgin but it would have been difficult to obtain large numbers to run these experiments.

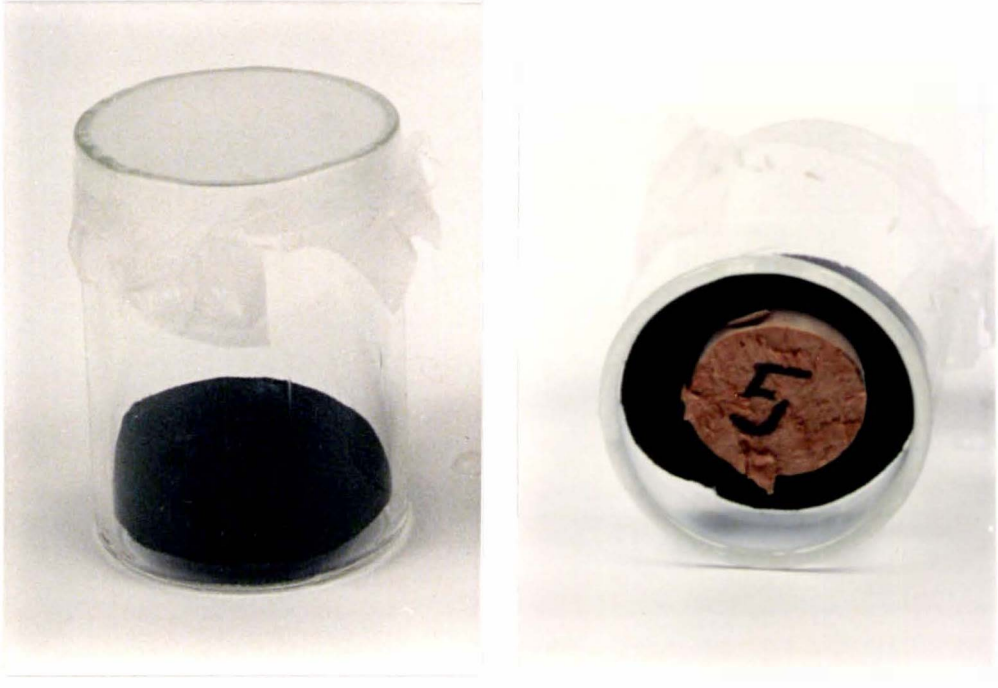
The sucrose sachets were made by stretching an approximately 1 cm square piece of Nescofilm over one end of a cage of glass tubing (2.6 cm diameter, 3.6 cm height), pipetting 1 ml of the appropriate sucrose solution onto the stretched Nescofilm and sealing it with another similarly stretched piece of Nescofilm.

The open end of each cage was closed with a disc of black filter paper (Whatman No.29) to which a piece of cork had been attached bearing the number of the cage. The cork facilitated the easy insertion and removal of the filter paper disc with forceps. The cages were placed sachet side up on a tray in an incubator. See Photograph 2-2.

The cages were arranged in rows across the incubator in order to overcome any variation in light intensity from the back to the front of the incubator. It was not feasible to set up a randomised complete block design for Experiment 2-2/1 as two rows of 24 cages each would not fit across the

Photograph 2-2

Close up of cages with sucrose sachets.
Left: side view, right: underside.



incubator. Therefore each row had 8 cages: one representative for each of the 8 sucrose concentrations and at least 2 and no more than 3 representatives of each of the sex groups. Otherwise the treatments were randomly allocated to positions within the rows. There were 48 cages in total. For Experiment 2-2/2 the rows across the incubator each had 12 cages with one representative from each sucrose concentration and sex group combination allocated randomly to a position within the row. There were 96 cages in total.

The temperature in the incubator was 20+/-1° C with a 12/12 hour light/dark regime. The lights were at the back of the cabinet and the intensity range was 6.7 to 10 μeinsteins/m^2/s.

The counts of eggs and adults were made at approximately the same time each day. When the eggs began to hatch the numbers of live and dead larvae and egg cases were also counted.

The larvae were assumed to be only on the sachet surface during the first experiment but during the second experiment, when it was realised that some larvae were crawling onto the glass sides of the cage this area was checked for larvae too.

Making accurate counts proved to be fraught with problems. The counts of dead adults were made with the naked eye for the single sex groups. For the mixed sexes case a stereo microscope was used to sex the dead adults and from this the number of each sex alive was calculated.

Eggs, egg cases and larvae were counted under a stereo microscope in the following way until all adults were dead:

The eggs and egg cases by viewing them through the glass sides of the cage. Care needed to be taken that double images of eggs were not seen. Newly laid cream eggs needed a dark background and older purple-black eggs needed a light background. Hence, it was easy to miss counting eggs

when one or other background was used.

The larvae by viewing them through the sachet against the black of the filter paper closure. The sachet's transparency depended on how much the Nescofilm was stretched and the depth of the sucrose.

When all the adults were dead the filter paper disc was removed so that from then on the counts for eggs, egg cases and larvae were made from the inner side of the sachet i.e. without viewing them through glass or sachet.

Some difficulty was experienced in distinguishing some items from others:

Egg cases can be distinguished from unhatched eggs by their more flattened appearance and curved tips but to see this it is necessary to view them from an appropriate direction - not always possible.

Live larvae could only be distinguished from dead larvae with certainty when they were moving. Dead larvae were only clearly dead when they became reduced in width (i.e. shrivelled) and this may not have always occurred and it appears to occur 1-3 days after death. Dead larvae can even look like newly laid eggs leaning at an angle. Of course if larvae were seen to be moving or to excrete droplets of honeydew they were obviously alive but there was no time to wait to see if this was occurring. So a count of total larvae rather than live and dead separately was made during most of the second experiment. Larvae appeared to survive for only about 1-3 days after emergence.

The lack of 'landmark' features on the sachet surface made it difficult to ensure that any individuals of any item were not missed or counted twice.

From the counts calculations were performed and analysis carried out as follows:

The adult numbers were analyzed for each experiment using a contingency table with a loglinear model for the factors sucrose concentration, sex group and time (Bishop et al, 1975). The model of best fit was determined and then each term in the model was further analyzed to determine which pairs of factor combinations were significantly different from each other.

It would not be valid to analyze the sum of eggs laid each day as this depends on the number of adults alive on that day and this is not the same for each treatment. Therefore the mean eggs laid over the previous day per surviving adult was calculated for each treatment and an analysis of variance used to determine any significant differences among the sucrose concentrations, sex groups and days. The number of surviving adults was calculated as the number alive that day plus half the difference between the count for that day and the count for the previous day as the adults that died the previous day could have laid some eggs.

The cumulative numbers of larvae (alive plus dead) were analyzed for each experiment using a contingency table with a loglinear model for the factors sucrose concentration, sex group and time (Bishop et al, 1975). This calculation and analysis is not strictly valid as the number of eggs laid for each treatment is not the same and the numbers on consecutive days are not independent. However, a comparison with the results for egg-laying may indicate differences among treatments for egg hatch that do not correspond with differences among treatments for egg-laying. The model of best fit was determined and then each term in the model was further analyzed to determine which pairs of factor combinations were significantly different from each other.

Where comparisons were made of eggs or larvae between the sex groups the numbers in the female only group were halved so that the analysis would be valid.

Results and Discussion

Summaries of the counts of adults over time are presented in Figs. 2-2/1 and 2-2/2, the mean eggs per female per day in Figs. 2-2/3 and 2-2/4 and the counts of larvae and eggs over time in Figs. 2-2/5 and 2-2/6. Fig. 2-2/7 summarises the percentage egg hatch. The significant differences are found in Appendix Tables A2-2/1 to A2-2/7 and will be referred to at appropriate points below.

Adult survival

The analysis for the factors sucrose concentration and sex group was carried out separately for each day and concentration levels were omitted from the contingency tables if the whiteflies at that level had all or almost all died. These levels are indicated in Appendix Table A2-2/1.

The results show that adult survival differs with sucrose concentration but not with sex group. There were two exceptions to this: an interaction between the two factors at days 3 and 4 for Experiment 2-2/1. This has arisen because, unlike all the other sucrose concentrations, the 40% level shows significantly fewer adults have survived for the all male sex group. Day 5 also shows this but the numbers for the three sex groups must be too close to non significant differences for the interaction to show with the contingency table analysis. Indeed the numbers for the 40% sucrose sex groups are so small that a change of 1-2 whiteflies would remove the interaction results.

The significant differences among the sucrose concentrations for each day are recorded in Appendix Table A2-2/2. In Experiment 2-2/1 adult survival reduced rapidly for sucrose concentrations of 40% or more and for water. For the remainder of the concentrations (10%, 20% and 30%) adult

Fig. 2—2/1

Survival of adults, sucrose concentration and sex group.

I. Experiment 2—2/1

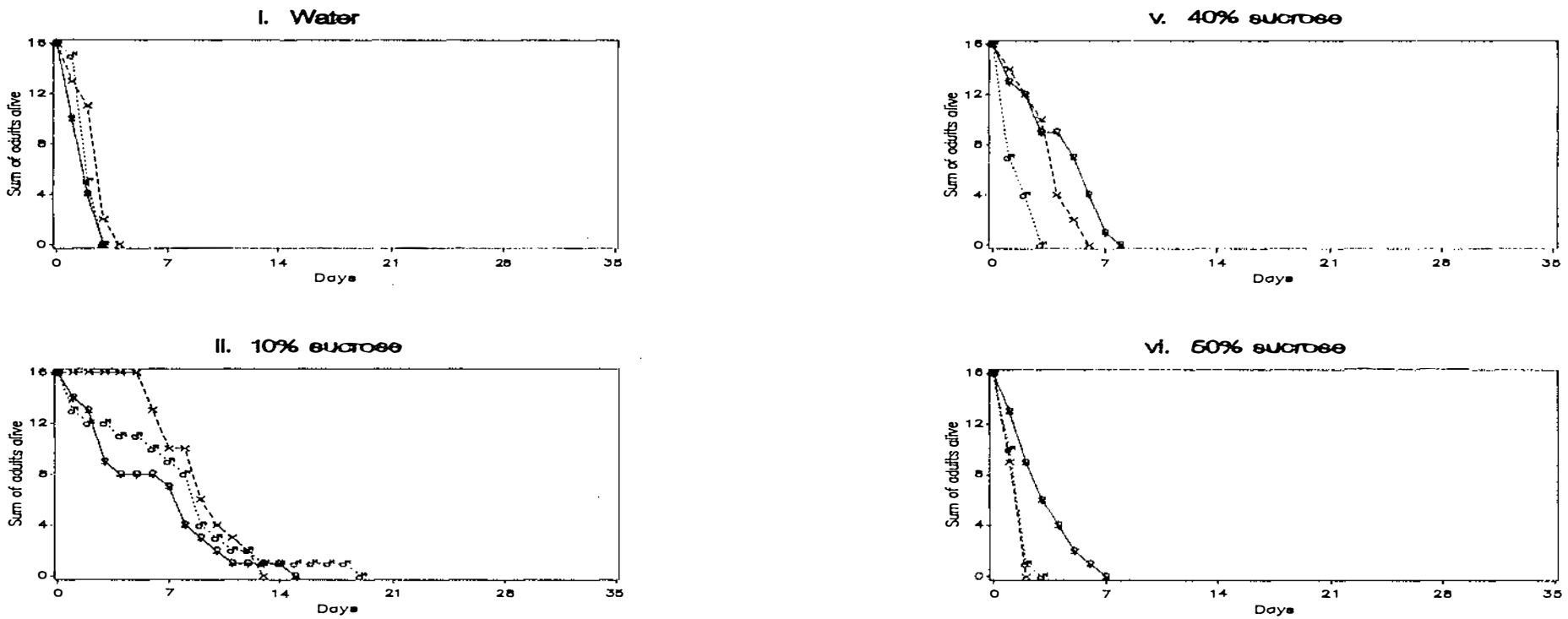
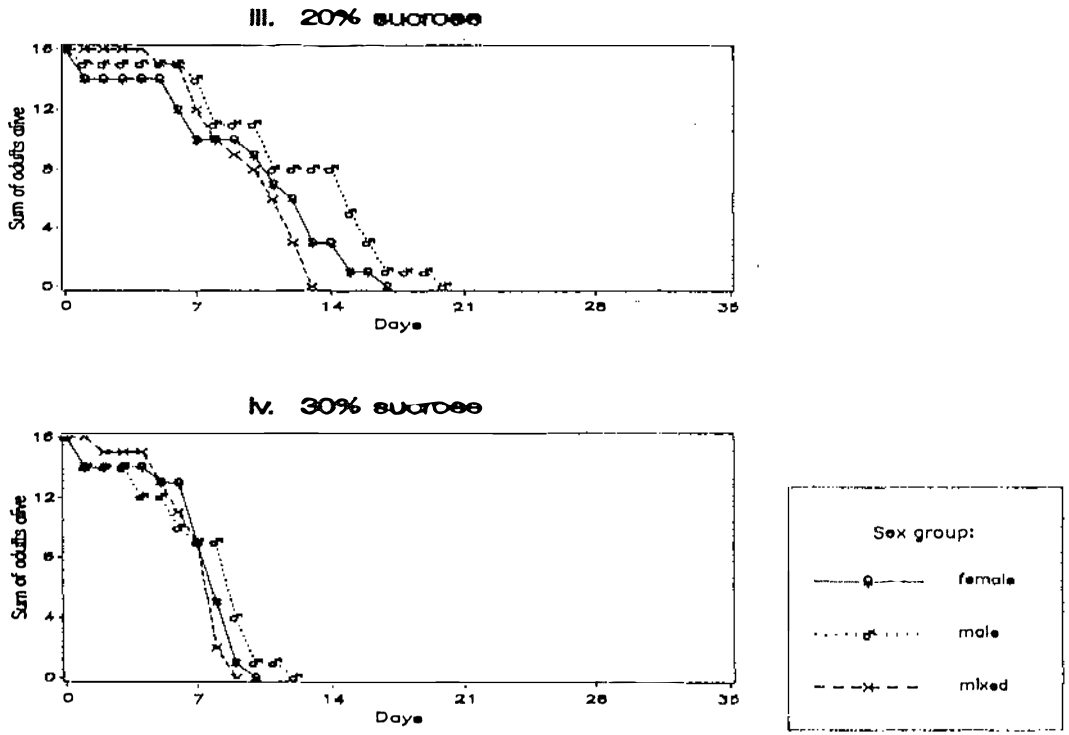


Fig. 2—2/1

i. Experiment 2—2/1 continued.

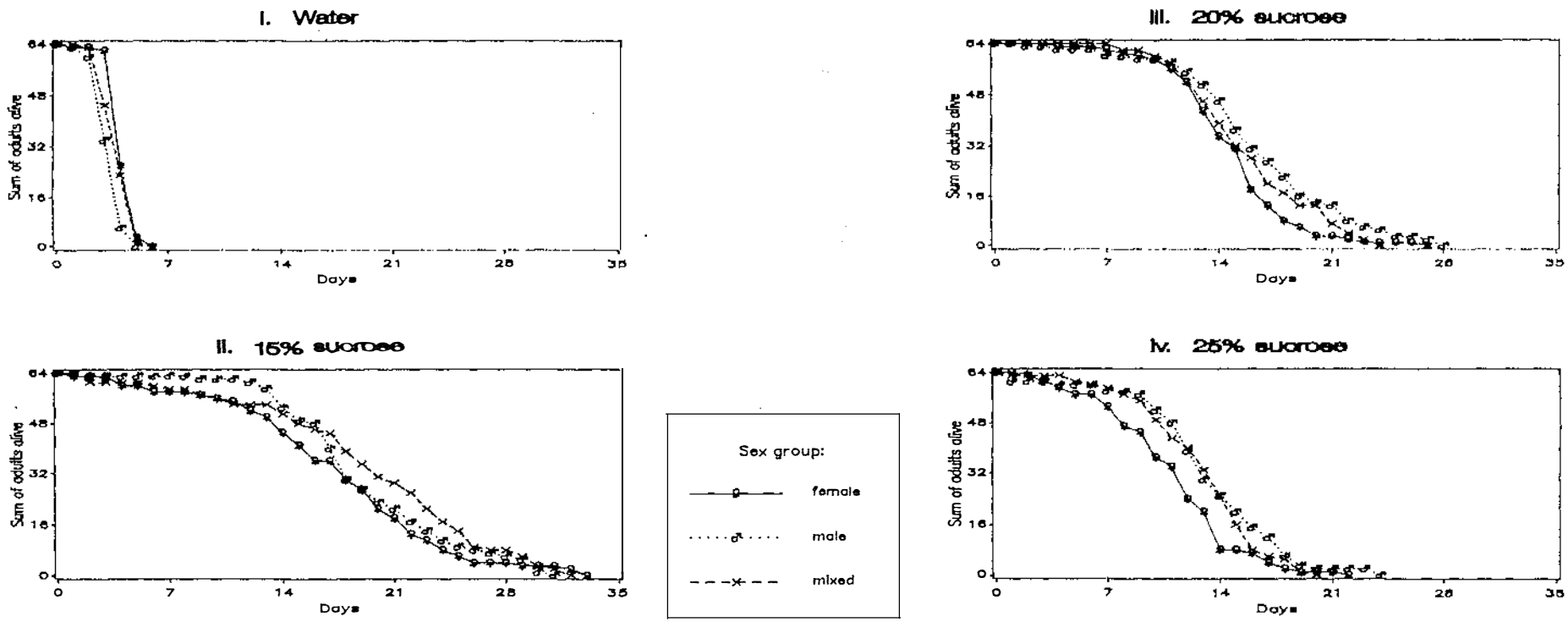


For significant differences see Appendix Table A2—2/1.

Fig. 2—2/1 continued.

Survival of adults, sucrose concentration and sex group.

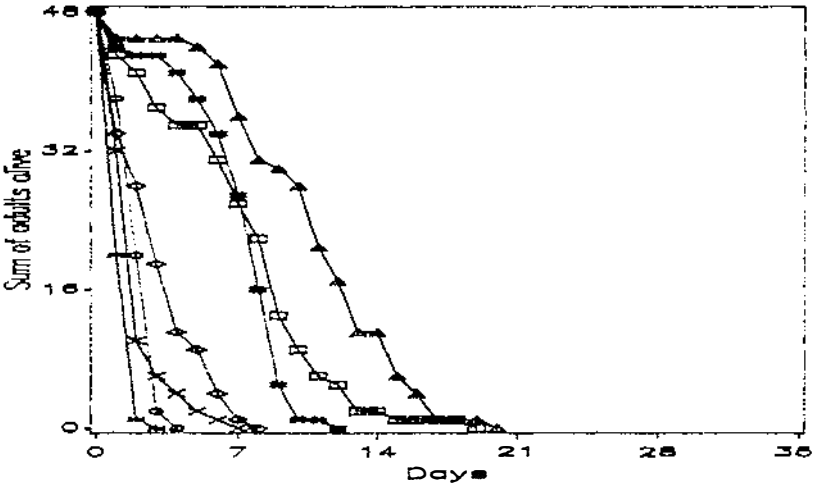
II. Experiment 2—2/2



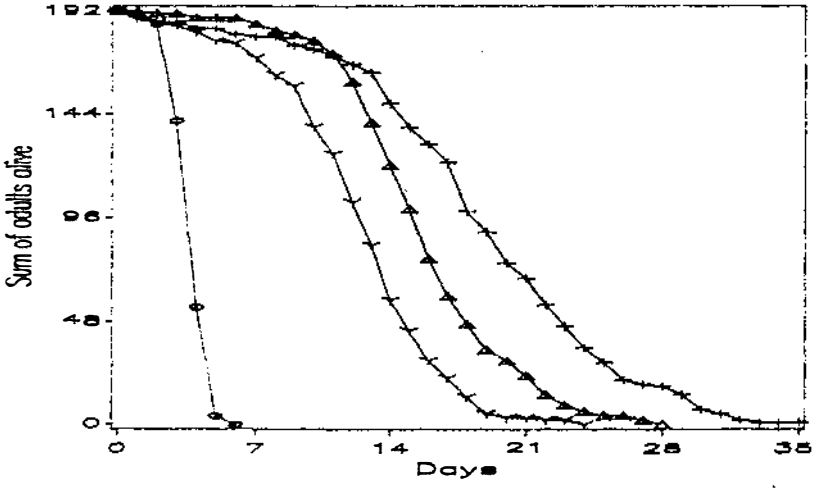
For significant differences see Appendix Table A2—2/1.

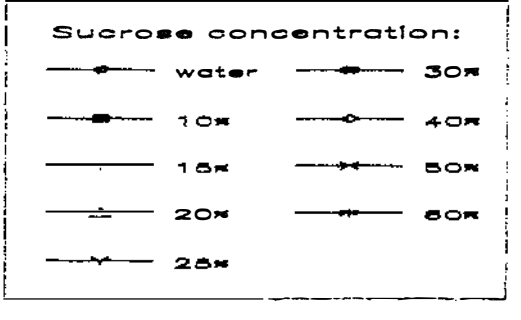
Fig. 2-2/2
Survival of adults feeding on sucrose solutions

I. Experiment 2-2/1



II. Experiment 2-2/2





For significant differences see Appendix Table A2-2/2.

survival was not significantly different initially but survival on 20% sucrose became significantly higher than both by day 10. In Experiment 2-2/2 adult survival for water again dropped rapidly and was significantly less for 25% by day 11. Then, of the two other concentrations, 15% emerged as having significantly more adults surviving by day 16. Hence, for Experiment 2-2/1 20% and for Experiment 2-2/2 15% sucrose resulted in the best adult survival.

Appendix Table A2-2/2 i. b and ii. b show when adult survival dropped significantly. Adult survival for 20% sucrose concentration, which gave the optimum in Experiment 2-2/1, dropped significantly compared with the initial number of adults by day 10. Correspondingly adult survival for 15% sucrose concentration in Experiment 2-2/2 dropped significantly by day 15.

Oviposition

Oviposition (eggs per female per day) results are summarised in Figs. 2-2/3 and 2-2/4 and the significant differences ($P<0.01$) are in Appendix Tables A2-2/3 and A2-2/4. The negative figures in the tables have arisen because of count inaccuracies. Counting problems are discussed on pages 149-150. The analysis for the factors 'day', 'sex group' and 'sucrose concentration' showed that there was no significant difference between the female and mixed sex groups ($P>0.01$) for either experiment. Very few eggs were laid at the sucrose concentrations 40%, 50% and 60% so they were omitted from the analysis. For Experiment 2-2/1 the analysis was done over days 1 to 14 and it showed significant differences ($P>0.01$) among the sucrose concentrations, among the days and an interaction Figure 2-2/3 between 'day' and 'sucrose concentration'. However, by day 14 some of the sucrose concentrations have nil oviposition because all whiteflies are dead and this skews the results. Therefore the analysis was repeated with the factors 'sucrose concentration' and 'day' for days 1 to 8.

Fig. 2—2/3

Oviposition and sucrose concentration and sex group.

I. Experiment 2—2/1

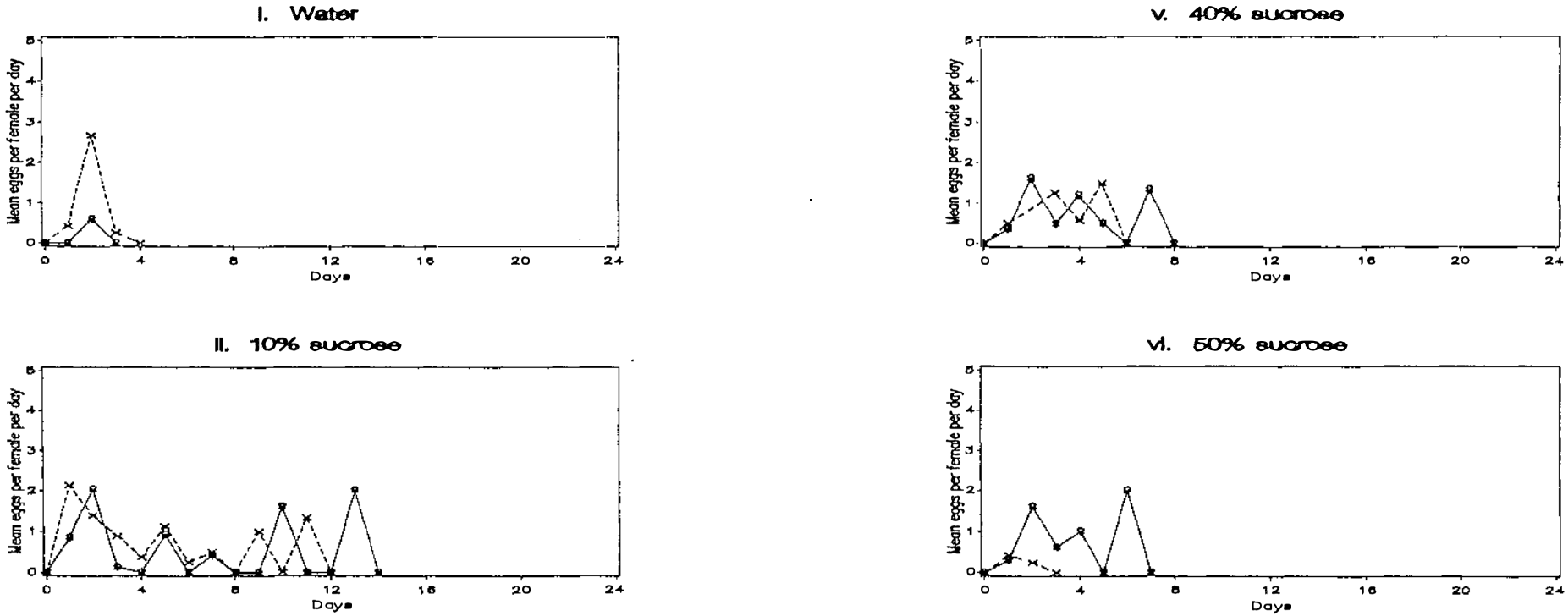
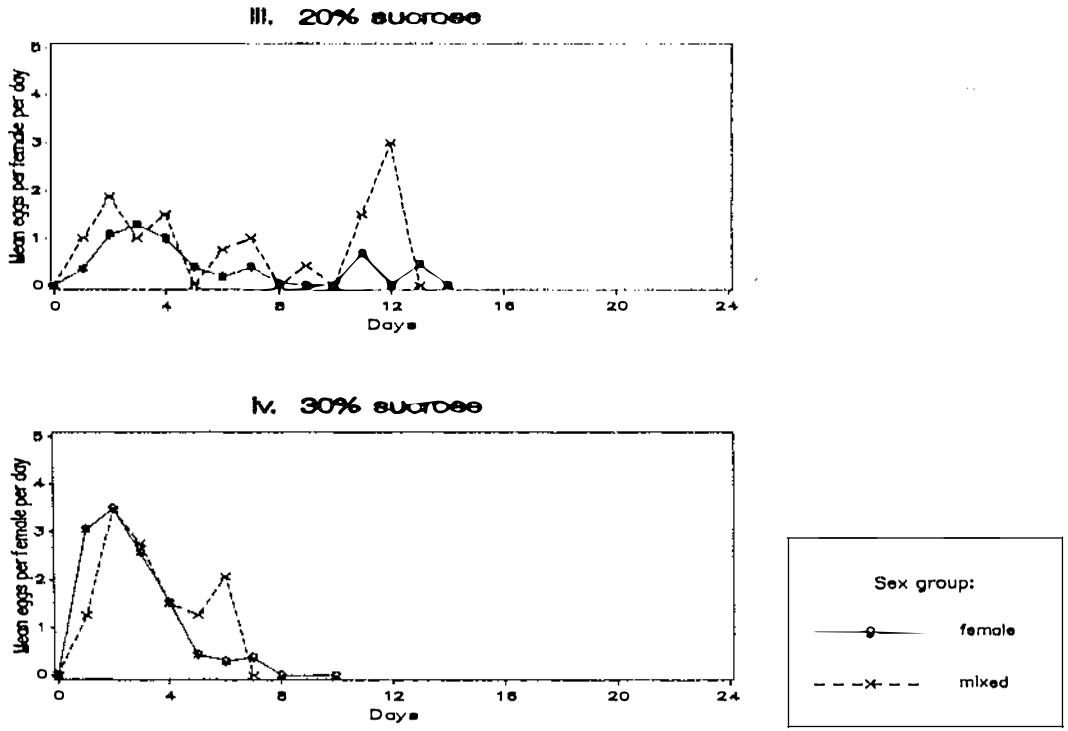


Fig. 2—2/3 i. continued.

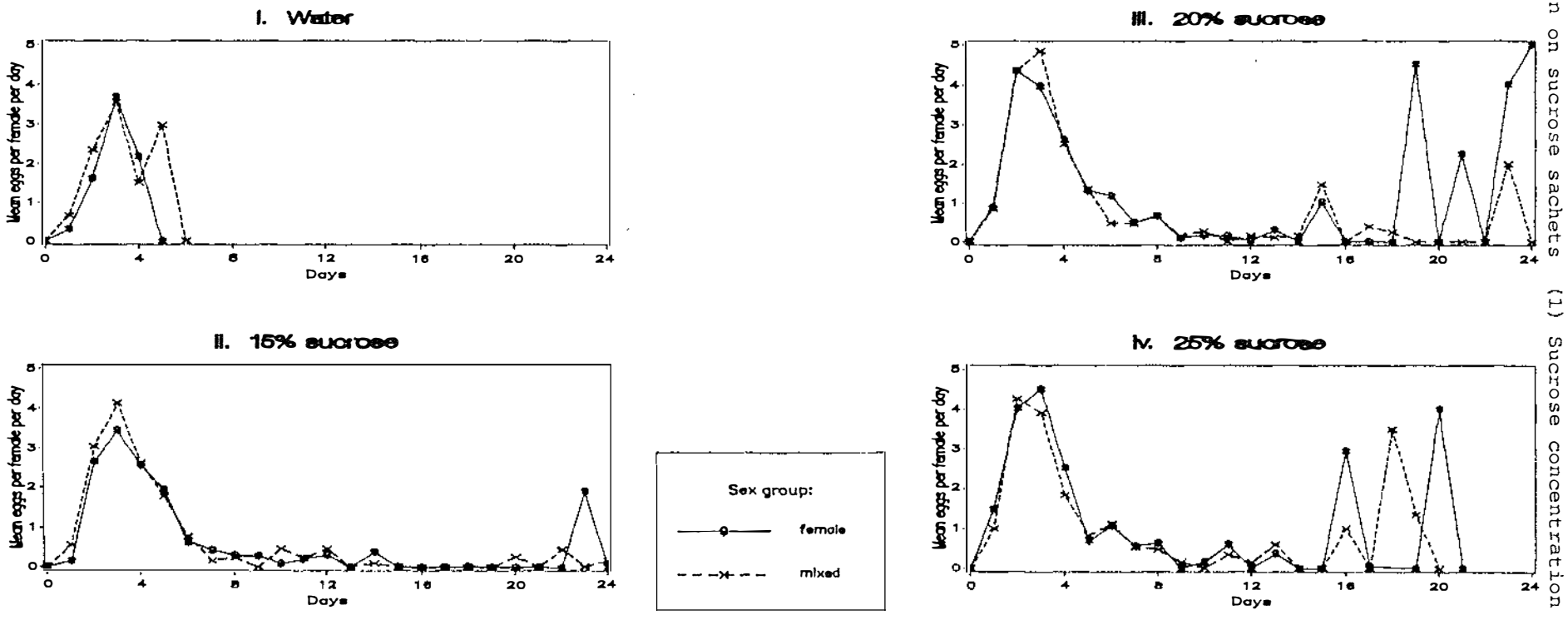


For significant differences see Appendix Table A2—2/3.

Fig. 2—2/3

Oviposition and sucrose concentration and sex group.

II. Experiment 2—2/2



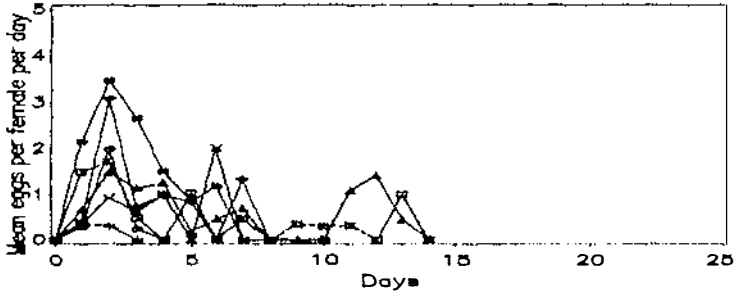
For significant differences see Appendix Table A2—2/3.

Fig. 2—2/4

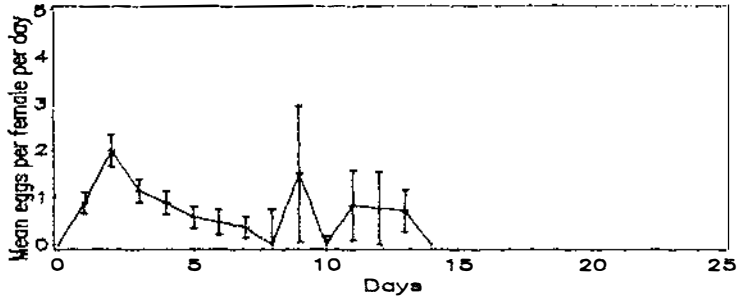
Oviposition and sucrose concentration.

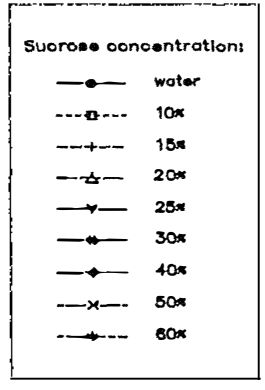
I. Experiment 2—2/1

1. Sex groups combined



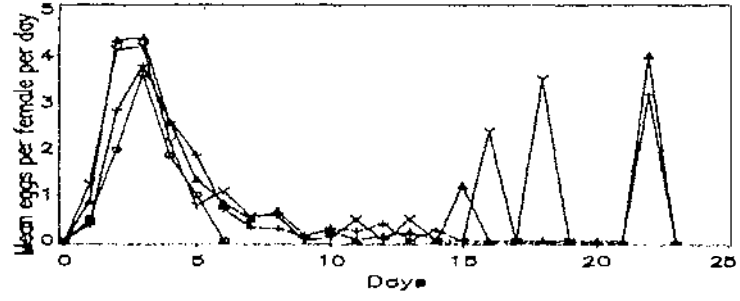
2. Sex groups and sucrose concentrations combined



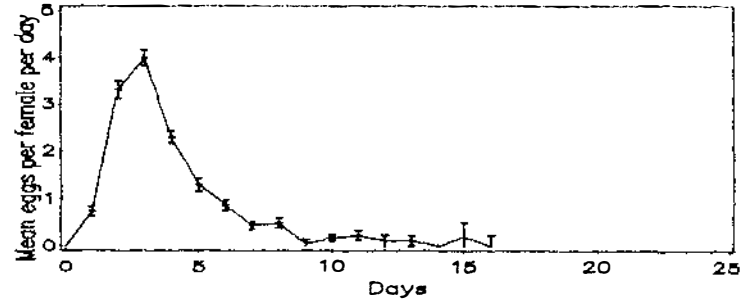


II. Experiment 2—2/2

1. Sex groups combined



2. Sex groups and sucrose concentrations combined



Barred lines are standard errors of the means.
For significant differences see Appendix Table A2—2/4.

This showed that there were no significant differences among the sucrose concentrations but there were among the days and the 'day' by 'sucrose concentration' interaction had disappeared.

For Experiment 2-2/2 the analysis was done over days 1 to 15, with water omitted, and showed that there were no significant differences ($P>0.01$) among the sucrose concentrations but there were among the days and there was also a 'day' by 'sucrose concentration' interaction. Inspection of Appendix Table A2-2/4 (1) ii. shows that this interaction arises because initially the higher sucrose concentrations had significantly ($P<0.01$) more eggs than others. However, throughout most of the experiment there were no significant differences among the sucrose concentrations.

The results for the sucrose concentrations were combined and eggs per female per day were plotted against time in Fig. 2-2/4. The oviposition rate rose rapidly to reach a peak at day 2 or 3 then fell sharply to zero for both experiments. This result suggests that the diet offered to whiteflies in these experiments is inadequate to maintain egg-laying.

Cumulative larvae

It was decided to analyze cumulative larvae (dead and alive) rather than the total larvae per day as it does not give rise to negative values. Any attempt to calculate larvae per female or larvae as a proportion of eggs laid is fraught with problems such as which figures to use from which day for the number of females alive. Therefore it needs to be kept in mind that the number of eggs from which the larvae hatched are not the same for each treatment.

The cumulative eggs are plotted with the cumulative larvae for each experiment in Figs. 2-2/5 and 2-2/6 so that a visual

Fig. 2-2/5

Oviposition, larval hatch and sucrose concentration and sex group.

I. Experiment 2-2/1

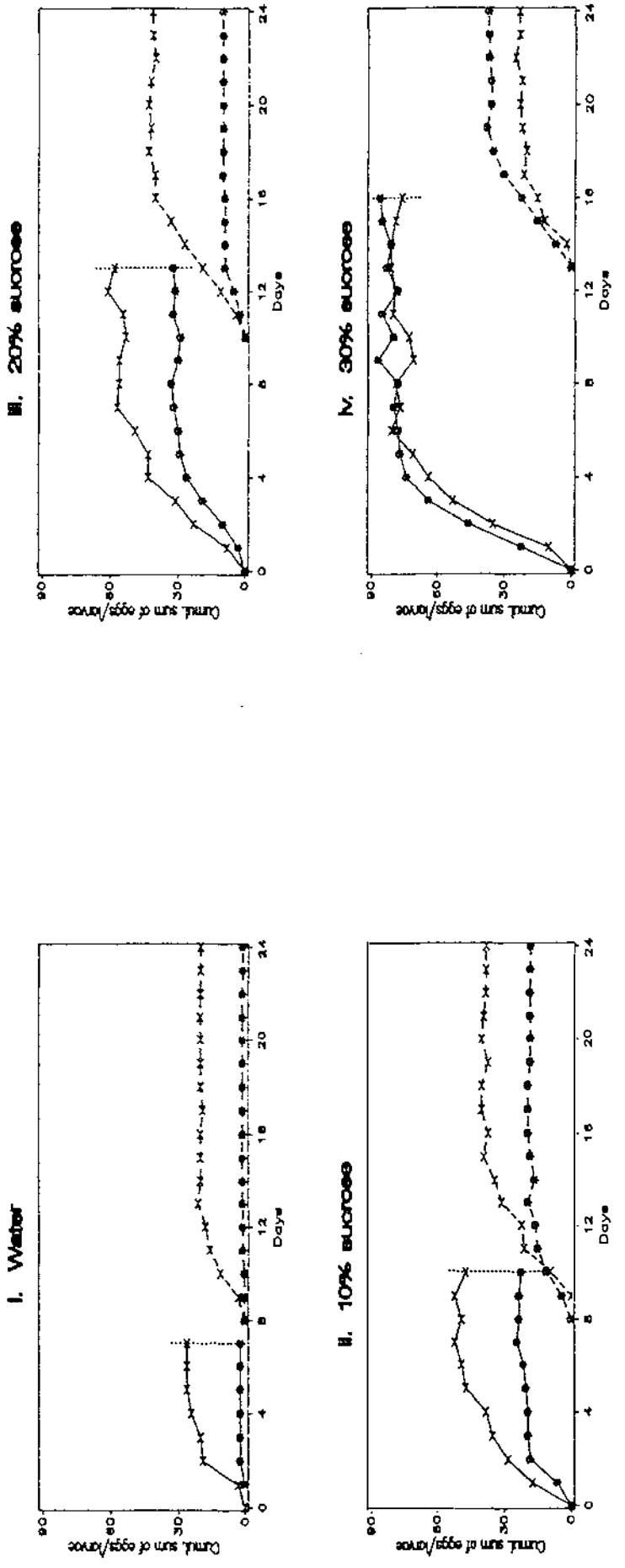
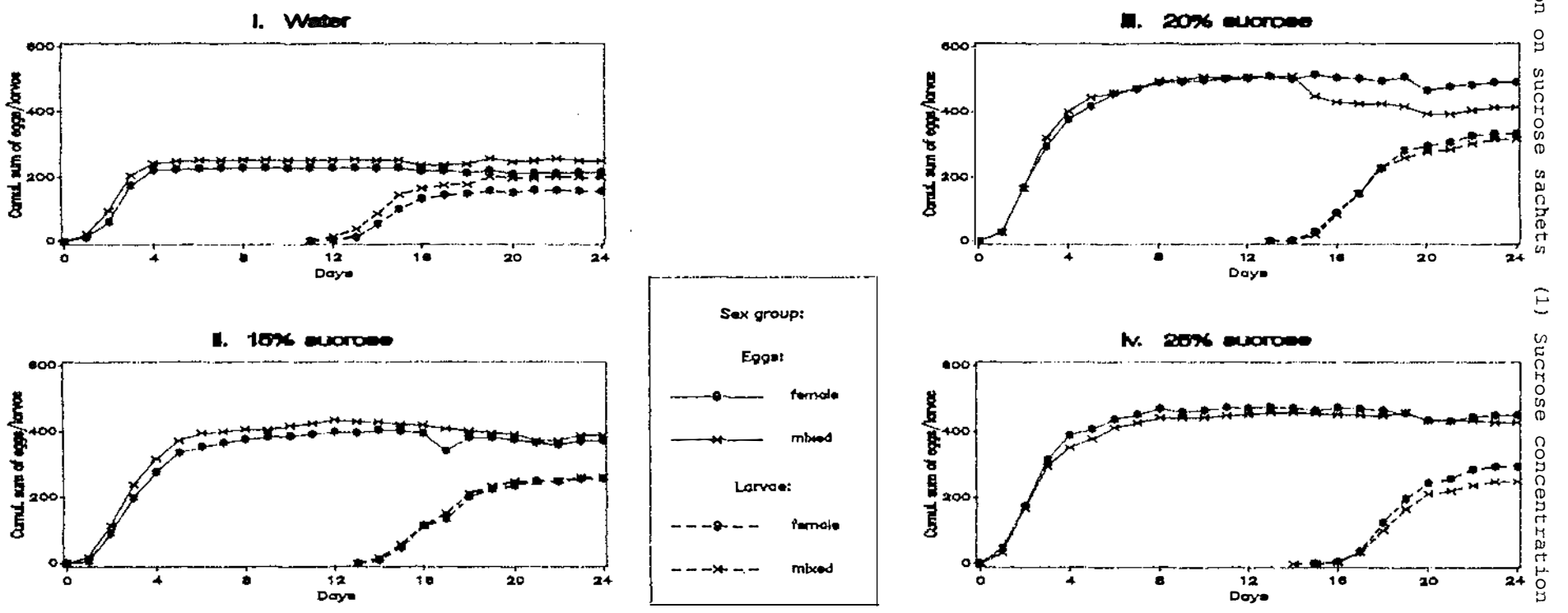


Fig. 2—2/5 continued.

II. Experiment 2—2/2



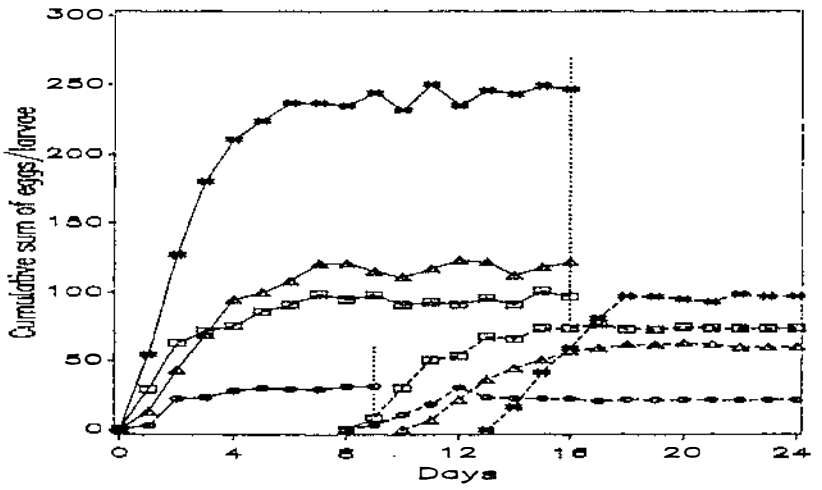
For significant differences see Appendix Table A2—2/5.

Totals for female only sex group have been halved so that comparisons can be made with the mixed sex group.

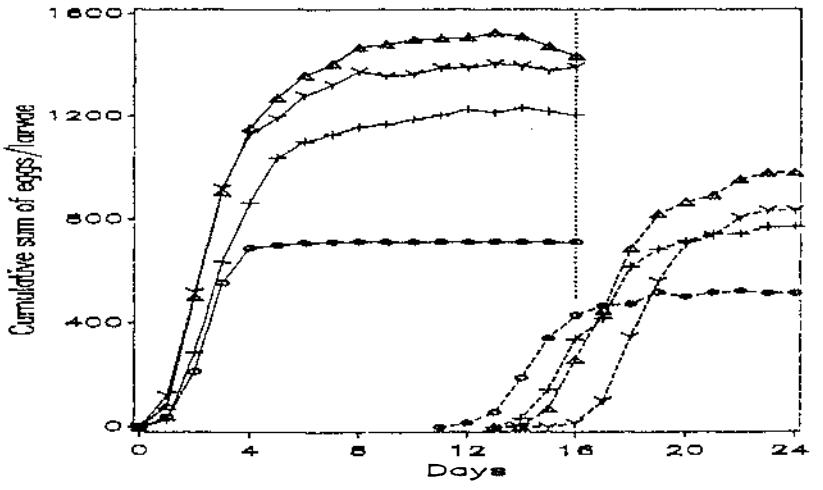
The cumulative sum of eggs/larvae show a decline in some cases because of counting inaccuracies. See page157.

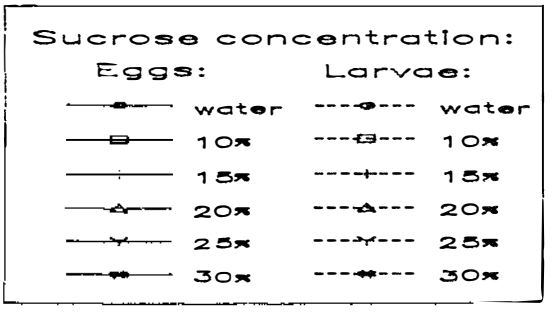
Fig. 2-2/6
Oviposition, larval hatch and sucrose concentration

I. Experiment 2-2/1



II. Experiment 2-2/2





For significant differences see Appendix Tables A2-2/6 and A2-2/7.

comparison can be made of the proportion of eggs that hatched and of the time from egg-laying to egg hatch.

Analysis showed that for days 9 to 24 for Experiment 2-2/1 there were two 2 way interactions: 'day' by 'sucrose concentration' and 'sex group' by 'sucrose concentration' and for days 12 to 23 for Experiment 2-2/2 one 2 way interaction: 'day' by 'sucrose concentration' and significant differences for 'sex group'. The sucrose concentration 'air' was omitted for Experiment 2-2/2.

The 'sucrose concentration' by 'sex group' interaction arose because, as Experiment 2-2/1 progressed, all sucrose concentrations except 30% showed a significantly ($P<0.01$) greater number of larvae for the mixed sex group (see Appendix Table A2-2/5 i. (2)). However, an inspection of Appendix Table A2-2/5 i. (1) for cumulative eggs shows that the same differences existed for the eggs. Therefore this is a reflection of the number of eggs rather than a real effect of sucrose concentration on larval hatch. In turn the number of eggs in the sex groups was a reflection of the number of adults alive as there were no significant ($P<0.01$) differences between the sex groups for mean eggs per female per day (see Appendix Table A2-2/3 i.). But upon inspection of Appendix Table A2-2/1 i. it can be seen that there were no significant ($P>0.01$) differences for adults between female and mixed sex groups. Possibly this anomaly is merely a reflection of the considerable variation in eggs laid per female and the few females used in this experiment. For Experiment 2-2/2 the significant ($P<0.01$) differences indicated between females and mixed sex groups does not make biological sense as the figures have been summed across days and the counts for each day are not independent and will have been added in several times over as they were cumulative. It makes better sense to analyze the cumulative larvae for each day. The results of this, in Appendix Table A2-2/5 ii. (2), show that there were no significant ($P<0.01$) differences

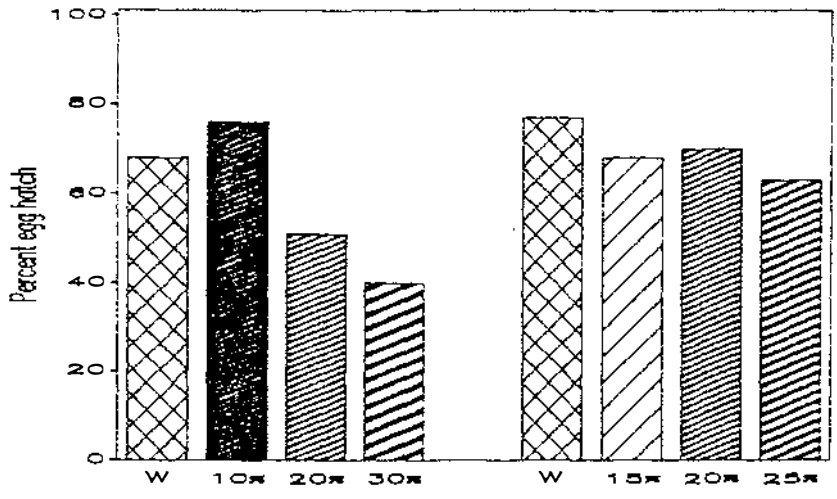
between female and mixed sex groups. This is so for eggs and adults also.

The 'sucrose concentration' by 'day' interactions for both experiments showed that the larvae for the lower sucrose concentrations tended to hatch earlier rather than there being differences among the sucrose concentrations. See Fig. 2-2/6 and Appendix Table A2-2/6 i. (2) and ii. (2).
The percentage hatch figures in Fig. 2-2/7 and Appendix Table A2-2/7 show that with the exception of 30% sucrose there were no significant ($P<0.01$) differences among the sucrose concentrations.

Conclusions

Adult survival was independent of sex group and was optimum for 15-20% sucrose concentration. At this sucrose concentration it did not drop significantly ($P<0.01$) for at least 10 days. Oviposition was independent of sex group and sucrose concentration. It rose to a maximum at day 2 or 3 then dropped sharply. The numbers of larvae were also independent of sex group and sucrose concentration but higher sucrose concentrations appear to induce larvae to hatch later.

Fig. 2-2/7
Percent egg hatch and sucrose concentration.



W: water.
For significant differences see Appendix Table A2-2/7.

(2) Light intensity and oviposition.

The experiments in Sections 1-1 and 1-2 showed that light intensity is a factor in selection of settling sites by adults within a plant but it is not known whether light intensity affects oviposition by greenhouse whitefly. Therefore the following experiment was carried out to examine the effect of light intensity, from complete darkness to the brightest artificial light available, on oviposition. Sucrose sachets were provided as an egg-laying substrate so that any effects of changes in leaf chemicals with changes in light and darkness or with day length would be eliminated.

The experiments described in this section do not strictly adhere to principles of good experimental design because the increased input of labour, time and materials necessary to satisfy good design fully was considered unwarranted merely to determine if there was any effect at all of light intensity on oviposition. A major reason for this choice was the findings of Hussey and Gurney (1959) that low light yielded fewer eggs on tomato and a range of light intensities yielded no consistent pattern.

Materials and Method

Whiteflies were caged with 20% sucrose sachets under 5 light intensities and counts of eggs made as follows:

Experiment 2-2/3: eggs and live whiteflies were counted each day for 4 days.

Experiment 2-2/4: eggs and live whiteflies were counted at day 4 only.

By comparing Experiment 2-2/4 and the results at day 4 for Experiment 2-2/3 the effect on egg-laying of light intensity could be determined.

The cages and sucrose sachets used were of the same design as those in Experiments 2-2/1 and 2-2/2 which investigated adult survival and oviposition with a range of sucrose concentrations. A twenty percent sucrose concentration was used because it gave optimum survival in Experiment 2-2/1.

Eight cages (replicates) each with ten female whiteflies were assigned to each light intensity for each experiment and were placed in a 2 litre plastic (ice cream) container lined inside with black plastic. These containers were randomly distributed in a growth cabinet at 20+/-1° C.

The five light intensities were created by placing sheets of white paper over the plastic containers or, for complete darkness, by covering the whole container with black plastic. The light intensities in each container were measured with a quantum sensor in μeinsteins/m^2/s) and were:

0.025	complete darkness; covered with black plastic
21	covered with 6 sheets of white paper
53	" " 3 " " " "
150	" " 1 " " " "
630	" " 0 " " " "

The 4 day duration of the experiments was chosen as virtually all the whiteflies were still alive at this time in Experiments 2-2/1 and 2-2/2.

Strictly speaking each individual cage should have been provided with separate shading cover and all cages randomised throughout the growth cabinet to minimise any affect of position within the cabinet. However, unwrapping and wrapping each cage to make the egg counts would have taken too long for them to be considered as counts at one point in time. Also there was a high chance of puncturing the sachet during the wrapping/unwrapping process because of adherence of the plastic cover to the Nescofilm.

The total eggs laid over 4 days and the number of adults alive were analyzed using contingency tables and a loglinear model with factors light intensity and experiment (Bishop et al, 1975). The model of best fit was determined and then for each term in the model the hypothesis that there is no difference between any pair of values for that term was tested.

Similarly the total eggs and adults alive were analyzed for Experiment 2-2/3 for the factors light intensity and day.

Results and Discussion

Analysis showed that for total eggs present at day 4 there was an interaction between light intensity and the experiments and, for survival of the adults at day 4, no significant ($P>0.01$) differences among the light intensities or between the experiments. These results are summarised in Figs. 2-2/8 to 2-2/10. The significant ($P<0.01$) differences are recorded in Appendix Tables A2-2/8 to A2-2/10.

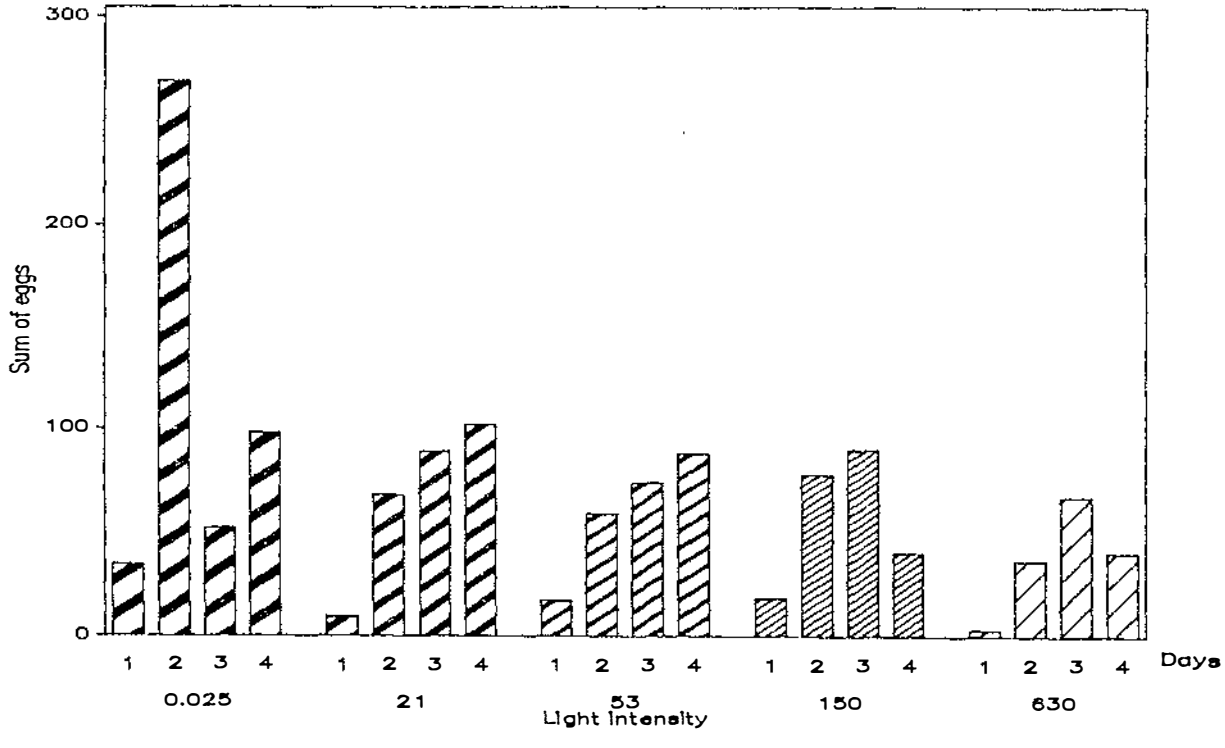
For Experiment 2-2/3 analysis showed that for eggs per day there was an interaction between 'day' and light intensity (see Fig. 2-2/8) and no significant ($P>0.01$) differences among the number of adults alive each day. See Appendix Tables A2-2/8 and A2-2/10 ii.

The results showed that in complete darkness whiteflies lay significantly ($P<0.01$) more eggs. Indeed the number approaches twice the number for any other light intensity. This is in complete contradiction to the findings of Hussey and Gurney (1959). However, they used plant material as a oviposition substrate and changes in this with reduced light intensity may have affected oviposition. Also they do

Fig. 2—2/8

Oviposition during 4 days under 5 light intensities.

20% sucrose sachets

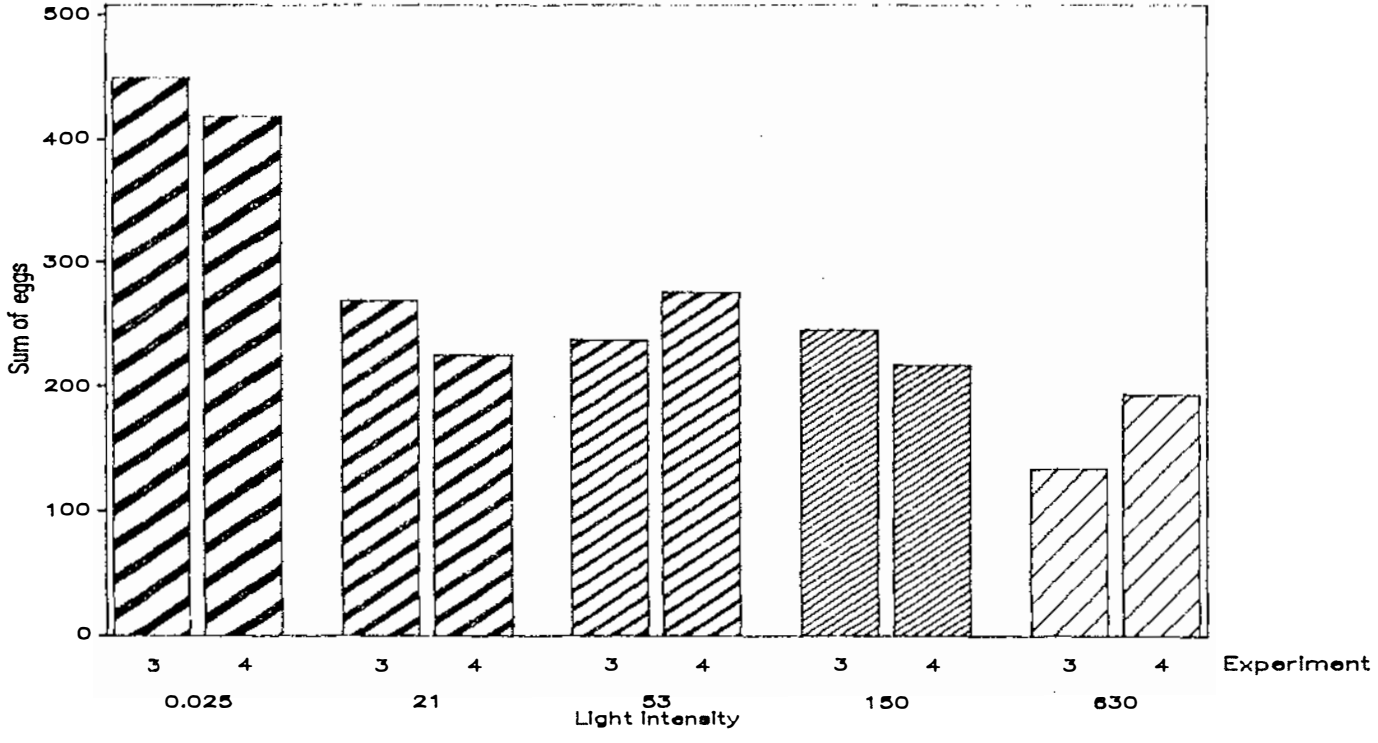


Light was measured in microeinsteins/m2/s.
For significant differences see Appendix Table A2—2/8.

Fig. 2—2/9

Sum of eggs at 4 days under 5 light intensities

20% sucrose sachets

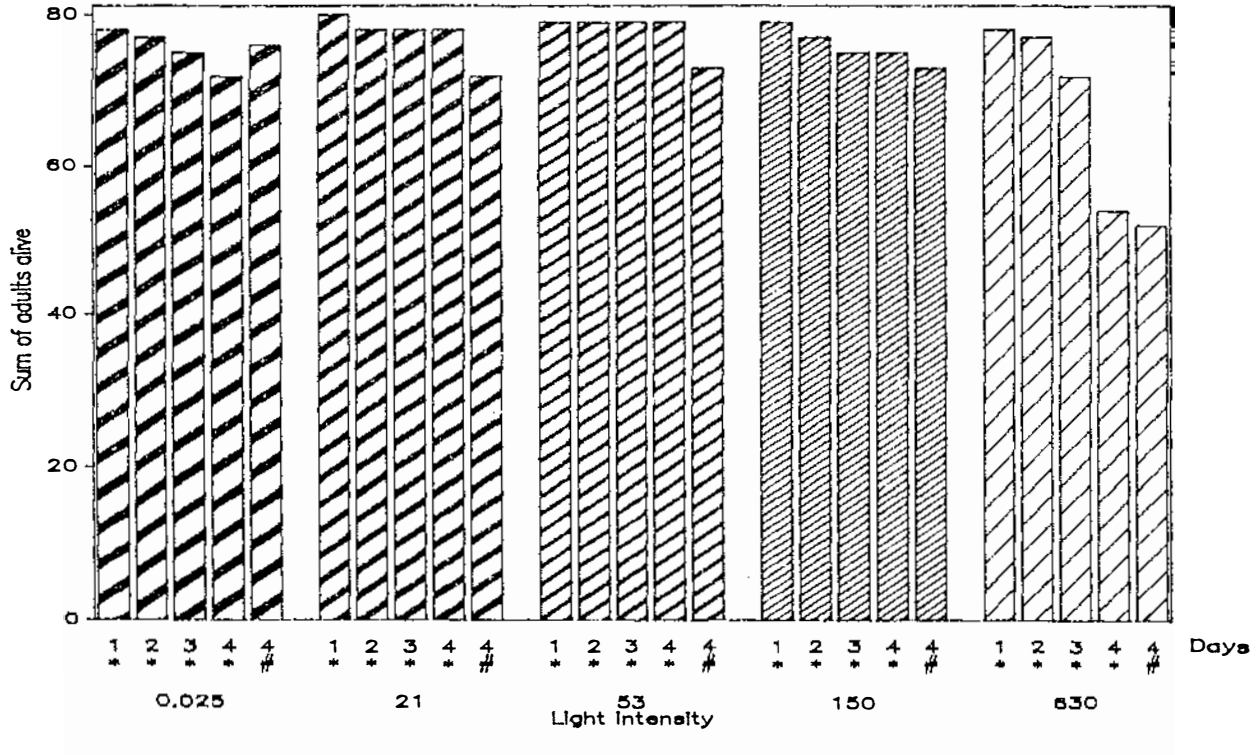


Experiment: 3: 2—2/3, 4: 2—2/4.
Light was measured in microeinsteins/m2/s.
For significant differences see Appendix Table A2—2/9.

Fig. 2—2/10

Survival of adults under 5 light intensities

20% sucrose sachets



* : Experiment 2—2/3; # : Experiment 2—2/4.
Light was measured in microeinsteins/m2/s.
For significant differences see Appendix Table A2—2/10.

not state the time span of the experiment nor do they provide a measure of the light intensity. At the higher light intensities the differences, although in some cases significant, were relatively small (Appendix Table A2-2/9). Next it needs to be determined whether these differences were due to differences in the number of whiteflies: although the results for survival showed no significant differences when the significance level was set at P=0.01 they did show significantly fewer whiteflies alive at day 4 for the 630 μeinsteins/m^2/s light intensity if the level is set at P=0.05. It could be argued that if more whiteflies had been used then the 630 μeinsteins/m^2/s light intensity would have shown a significant difference in the number of eggs for P=0.01. Also, assuming each female would lay an average of 5 eggs per day, a small non significant difference in the number of adults could give rise to a significant difference in the corresponding egg counts. The lower egg count for 630 μeinsteins/m^2/s may, therefore, be due to fewer adults being present rather than a light intensity effect. Despite the significant differences among the light intensities there was no relationship between light intensity and the number of eggs laid.

The brief change in light intensity that occurred when the eggs were counted for Experiment 2-2/3 did not affect the number of eggs laid except at 630 μeinsteins/m^2/s light intensity where the number was significantly ($P<0.01$) lower.

The eggs laid per day over four days for Experiment 2-2/3 are shown in Fig. 2-2/8 and significant differences recorded in Appendix Table A2-2/8. The results show that:

1. In complete darkness the number of eggs laid was very large initially. It then dropped back to be comparable with other light intensities before increasing again. This indicates that darkness may stimulate egg-laying. The drop may indicate that the oviposition rate could not be sustained but perhaps after further feeding it

began to pick up again.

2. The other light intensities showed an increase in eggs laid to a maximum which was then either maintained (21 and 53 μeinsteins/m^2/s) or dropped back (150 and 630 μeinsteins/m^2/s), at day 4. This fall in egg-laying agrees with the results from Experiments 2-2/1 and 2-2/2.

The most surprising result from these experiments was the very large number of eggs laid in complete darkness.

(3) Light/dark regimes and oviposition.

Experiments 2-2/3 and 2-2/4 showed firstly, that more eggs are laid on sucrose sachets in darkness than in light for a range of four intensities but they did not indicate the length of the dark period needed to produce the effect. Secondly Experiments 2-2/3 and 2-2/4 showed that eggs are laid in both light and darkness but did not show whether they are laid uniformly or otherwise throughout the light or dark periods.

Therefore the following experiment (2-2/5) was set up to investigate:

1. The effect of light/dark regimes on eggs laid per day.
2. The minimum period of darkness needed to induce an increase in eggs laid as observed in Experiments 2-2/3 and 2-2/4.
3. The distribution of egglaying throughout light/dark periods.
4. Whether more eggs are laid in dark or light periods.

Materials and Method

Throughout this section the word 'day' refers to a period of 24 hours.

Whiteflies were caged with 15% sucrose sachets and placed in one of 6 light/dark regimes over 4 days. A sucrose concentration of 15% was chosen because it proved to be the optimum concentration in the second experiment (2-2/2) in section 2-2-1. This second experiment had not been analyzed when Experiments 2-2/3 were run. The number of eggs counted every 4 hours during the light periods.

The light/dark regimes were:
0/24, 4/20, 8/16, 12/12, 16/8, 24/0 hours.

It was not possible to carry out all the treatments of the experiment at the same time as there were insufficient cages and it would have taken too long to make the counts at any one point in time. Therefore it was carried out in four batches as follows:

1. 12/12, 16/8 and 24/0 light/dark regimes (10 cages each; 1 run each; 30 cages in total).
2. 4/20 and 8/16 light/dark regimes (10 cages each; 1 run each; 20 cages in total).
3. 0/24 light/dark regime (4 cages per count time; first run of this treatment; 80 cages in total).
4. 0/24 light/dark regime (5 cages per count time; second run of this treatment; 100 cages in total).

Only 4 cages per treatment were used in batch 3 as there were insufficient cages to have 5 cages per treatment. All the runs of the experiment were carried out over a period of about 5 weeks in August and September.

For the 4/20, 8/16, 12/12, 16/8, 24/0 light/dark regimes counts were made of the same whiteflies throughout the experiment. For the 0/24 light/dark regime (complete darkness) counts were made of whiteflies in a new set of cages every 4 hours each day (except at 20 hours) over the four days. This was done to eliminate any effect of bringing the whiteflies into light to make the counts. This would have been a better method to use for the other light/dark regimes as the counts at each time would then have been independent. However, if used, it would, firstly, have required a far larger number of cages and whiteflies than the method used for the other light/dark regimes. Secondly, the time taken to wrap and unwrap individual cages would have made each counting time slot inordinately long or if, to overcome this, the experiment were carried out in a series of identical batches it would take at least 12 weeks to complete and this would have possibly introduced variation in whitefly response according to the differing light /dark regimes in which they had been reared. Thirdly, it would have been difficult to schedule because of other commitments.

The individual cages were set up in the same way as those used for Experiment 2-2/3 and 2-2/4 where the effect of light intensity on oviposition was investigated.

The 10 cages for each of the light/dark regimes (except 0/24 hours) were placed in 2 litre plastic (ice cream) containers covered on the inside with black plastic. During the dark periods each plastic container was covered over the top with black plastic. Throughout the experiment the plastic containers were covered with a single sheet of white paper to prevent the undue whitefly mortality observed in Experiments 2-2/3 and 2-2/4. The plastic containers were randomly distributed in a growth cabinet at 20+/-1° C. The humidity could not be controlled. However it would not necessarily be the same inside the cages as in the rest of the growth cabinet.

For the 0/24 light/dark regime the cages were wrapped individually in black plastic and randomly allocated to a place on a grid labelled with the time for the egg counts.

Ten female whiteflies approximately 2-9 days old were placed in each cage. The eggs laid on the sachets were counted every 4 hours during the light periods over 4 days for the light/dark regimes 4/20, 8/16, 12/12, 16/8 and 24/0 hours except that for 24/0 hours no count was made at 20 hours in the light period.

For each of the light/dark regimes the total eggs laid on each of the four days of the experiment was calculated and also the cumulative eggs laid over the four days. These totals were analyzed using a contingency table and a loglinear model with factors light/dark regime and time (Bishop, Fienberg and Holland, 1975). The model of best fit was determined and then for each term in the model the hypothesis that there is no difference between any pair of values for that term was tested. Similarly the total whiteflies alive each day was calculated and a similar analysis carried out. It was necessary to remove one cage from the calculations for those with 10 in order to make valid comparisons among all the light/dark regimes. For this analysis the replicates are each individual whitefly and it is the total eggs laid by the same number of whiteflies per treatment which are analyzed. This assumes that each whitefly within any one treatment has exactly the same conditions applied to it and that conditions other than the treatment are the same across all treatments. This was not strictly so

as all runs of the experiment were not carried out at the same time nor were all whiteflies in the same cage. However, all conditions were kept as uniform as possible and the variations that could occur, such as minor variations in temperature from batch to batch, would be minor and unlikely to affect the results. Probably the biggest effect would be from whiteflies dying before the experiment was completed, hence the need to analyze the whiteflies alive each day and to use a large number of whiteflies so that the few that may die have a very minor effect.

The mean eggs per female per hour for each light/dark regime (where applicable) was calculated for each time period and also for the light and the dark periods for each day and an analysis of variance was carried out for each day. For this analysis the replicates are the individual cages. Ideally the runs should be taken into account in the analysis but to do this there would need to be an equal number of cages from each treatment in each batch. It was not practical to do this because of other commitments. Again differences in conditions between batches could have had a minor effect on the results.

Results and Discussion

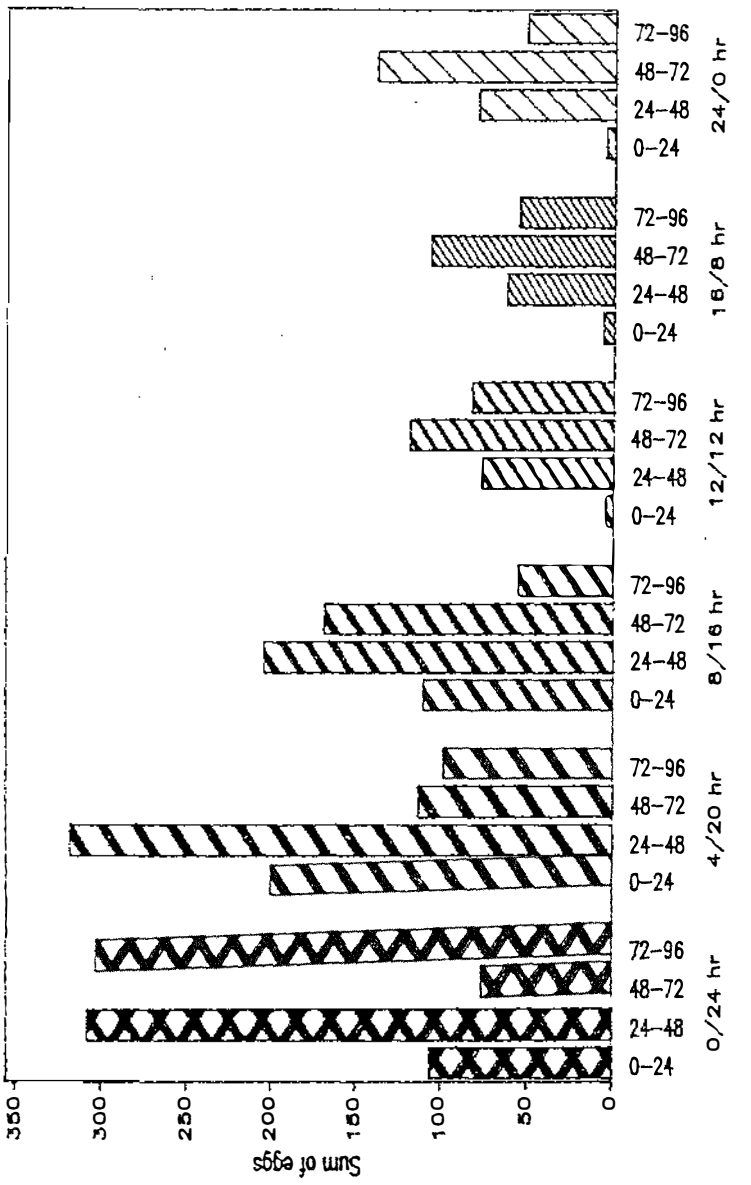
The results for the effect of day length on oviposition are presented in Figures 2-2/11 to 2-2/14, those showing the distribution of eggs during the day and between the light and dark periods of the day are presented in Figure 2-2/14. Figure 2-2/15 shows the number of whiteflies alive during the course of the experiment. The significant differences are recorded in the Appendix Tables A2-2/11 to A2-2/15.

Counts at 96 hours are not available for all the light hours. The times of the final counts are indicated in Figures 2-2/13. This means that the total eggs for day 4 in Figure 2-2/11 are not all for a full 24 hour day and therefore strictly speaking they cannot be compared statistically. However the analysis was still carried out as there were some very large differences among the results.

Fig. 2—2/11

Oviposition during 96 hours under 6 light/dark regimes.

15% sucrose sachets

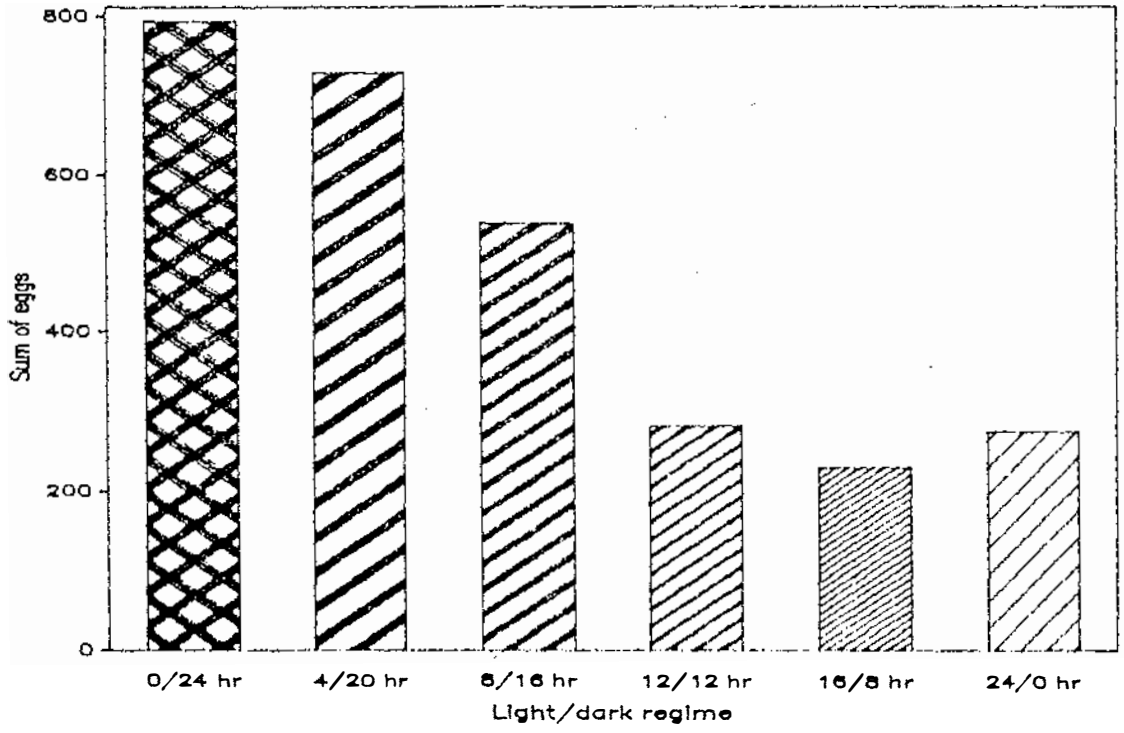


Time: 1: 0—24, 2: 24—48, 3: 48—72, 4: 72—96 hours.
For significant differences see Appendix Table A2—2/11.

Fig. 2-2/12

Sum of eggs at 96 hours under 6 light/dark regimes.

15% sucrose sachets

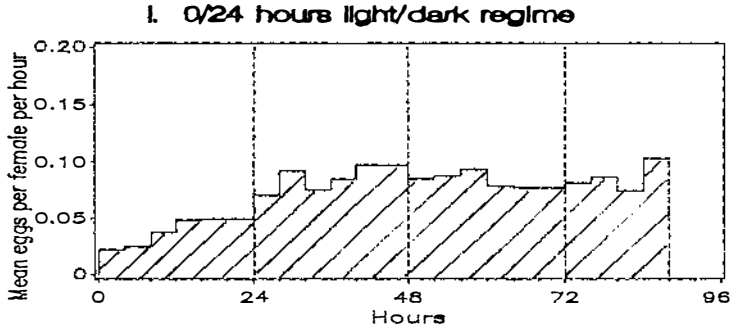


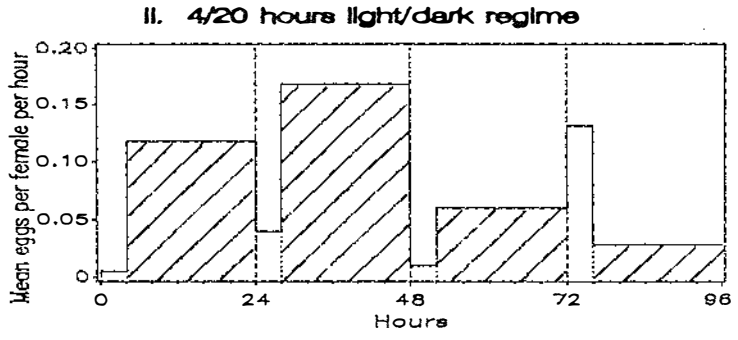
For significant differences see Appendix Table A2-2/12.

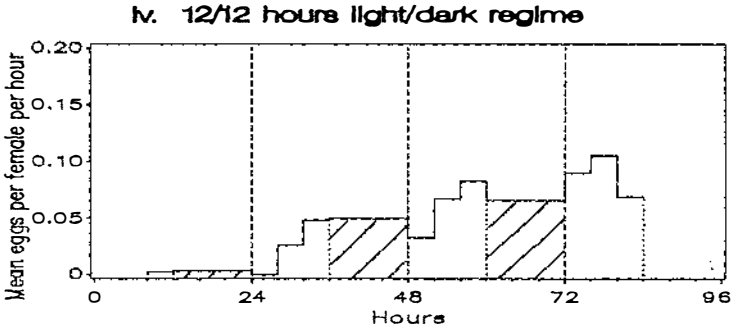
Fig. 2—2/13

Distribution of egg—laying over 96 hours under 6 light/dark regimes.

15% sucrose sachets







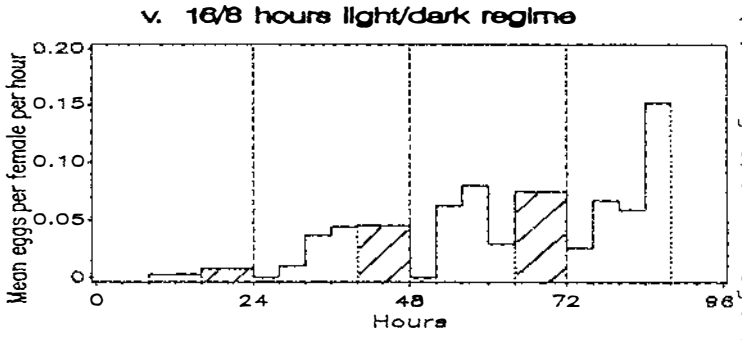
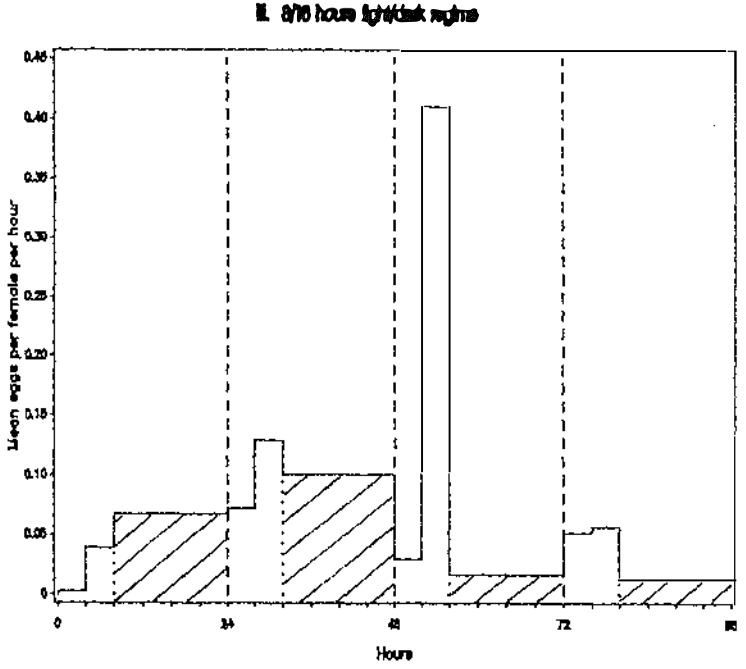
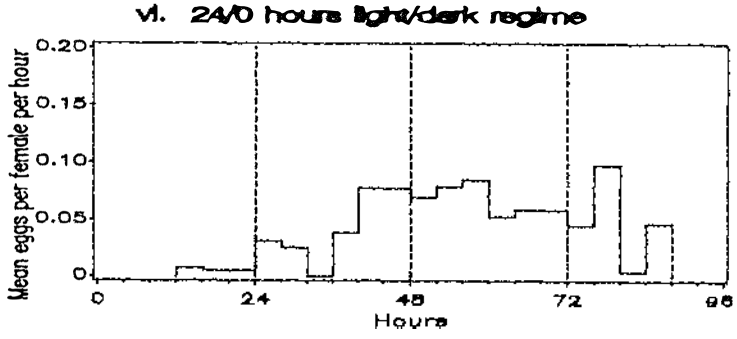


Fig. 2—2/13 continued.



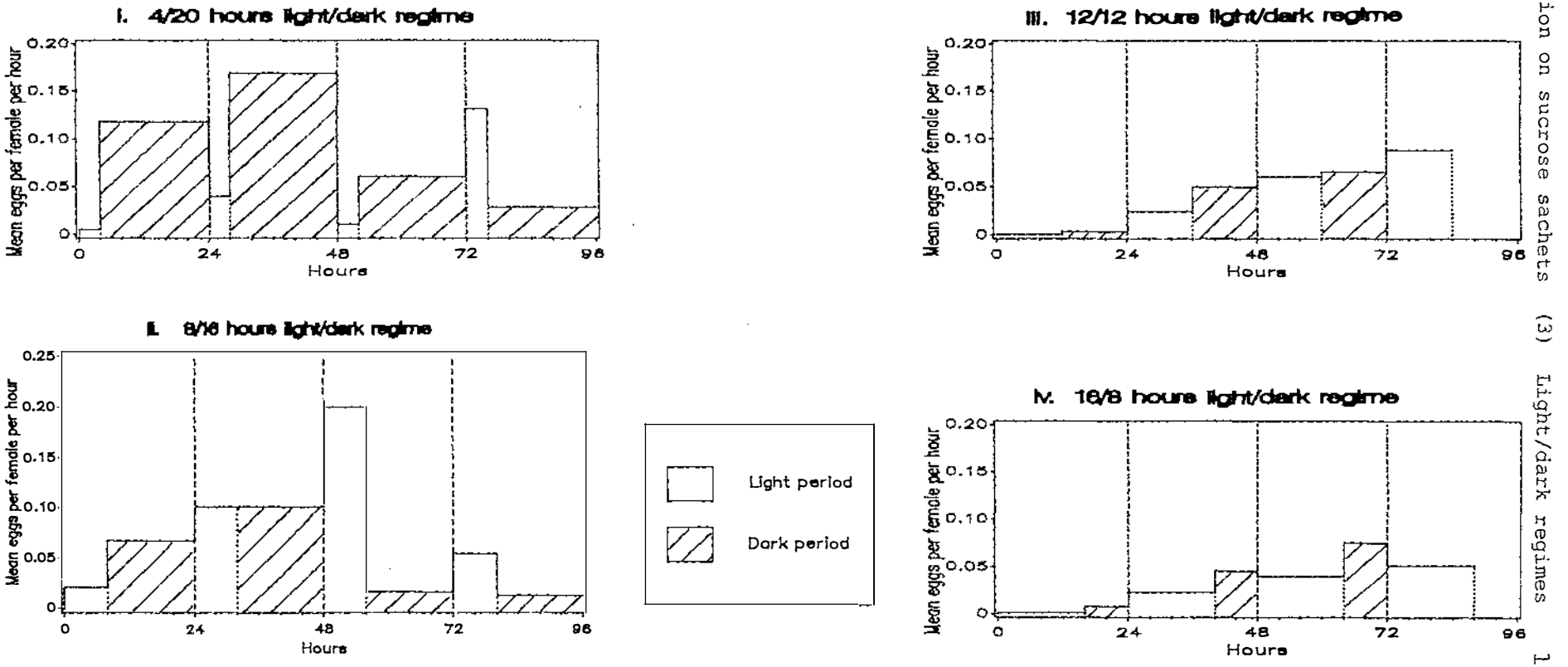


For significant diferences see Appendix Table A2—2/13.

Fig. 2—2/14

Oviposition in light versus dark periods under 4 light/dark regimes.

15% sucrose sachets



For significant differences see Appendix Table A2—2/14.

Light/dark regime and eggs laid per day

Initially (days 1 and 2) far more eggs were laid with shorter (0/24, 4/20 and 8/16) than with longer light period (12/12, 16/8 and 24/0) light/dark regimes. Within the longer light period group (12/12, 16/8 and 24/0) there were no significant differences ($P>0.01$) but within the shorter light period group (0/24, 4/20 and 8/16) there were some significant differences ($P<0.01$) but they showed no pattern (see Appendix Table A2-2/11).

At day 3 the egglaying pattern changed. There were no longer the two distinct groups among the light/dark regimes. Some significant differences were present but showed no correlation with the hours of light per day. At day 4 the 0/24 light/dark regime was far larger than any of the others which showed some significant ($P<0.01$) differences among themselves but again no correlation with the hours of light per day. It is difficult to separate the changes over time from differences among the light/dark regimes. However there does seem to be a pattern. Consider Fig. 2-2/11. Note the following points for the eggs laid per day:

1. The lower hours of light per day had more rapid increases than the higher hours of light per day.
2. The lower hours of light per day had higher maximum numbers.
3. All showed a decrease at either days 3 or 4.
4. Only the 0/24 light/dark regime showed an increase thereafter and it is a very large increase.

There are three possible explanations for the results for the first two days:

1. Longer light periods (from greater than somewhere between 8 and 12 hours per day) may inhibit egglaying.
2. Longer dark periods (from greater than somewhere between 12 and 16 hours per day) may stimulate egglaying.

3. Both the above effects could occur simultaneously.

The drop in eggs laid at days 3 or 4 may indicate that the whiteflies were running out of eggs to lay or that 15% sucrose provides insufficient nutrients to sustain egglaying. However the increase for the 0/24 light/dark regime would seem to mitigate against this suggestion.

For the 0/24 light/dark regime it needs to be borne in mind that it was not the same whiteflies that were laying the eggs each day and it might be thought that the results for days 3 and 4 were anomalous. Therefore consider the total eggs laid by each intermediate count time between day 2 and day 4 in Table 2-2/1. The results were not completely out of line with the results for day 3 (72 hours). However for day 4 (88 hours) the number appears somewhat high but the totals at 76 and 80 hours do indicate that egg laying is increasing.

Figure 2-2/15 appears to indicate that there is a steady decrease in whiteflies alive for the longer day lengths (12/12, 16/8 and 24/0 hours) but not the shorter ones but in fact there are no significant differences ($P>0.01$) among the figures within any one day length. However, in the same way as was argued for Experiments 2-2/3 and 2-2/4, if the number of whiteflies used were higher the mortality may become significant.

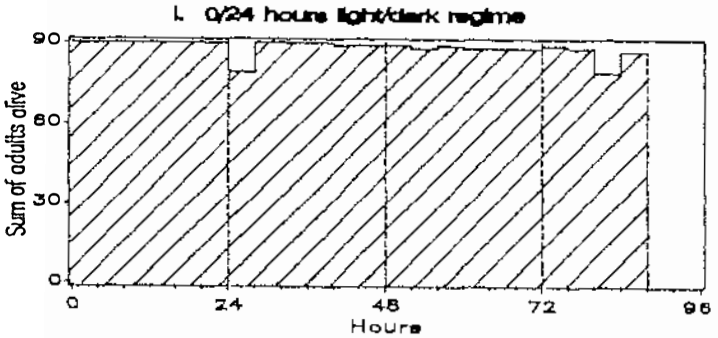
Whitefly mortality

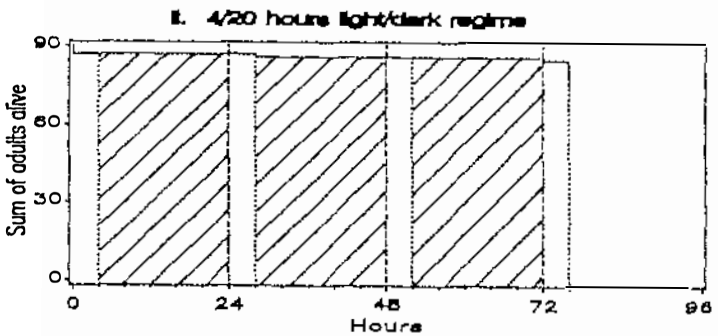
In Experiment 2-2/3 a sheet of paper was placed over the cages and there were no significant differences among the light/dark regimes no matter whether the significance level were 0.01 or 0.05 (Appendix Table A2-2/15).

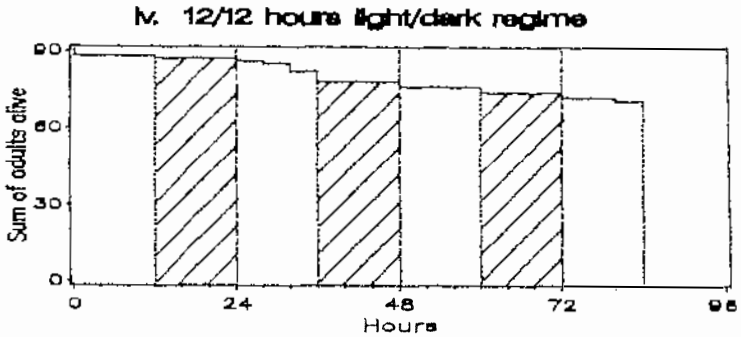
Fig. 2--2/15

Adult survival under 6 light/dark regimes.

15% sucrose sachets







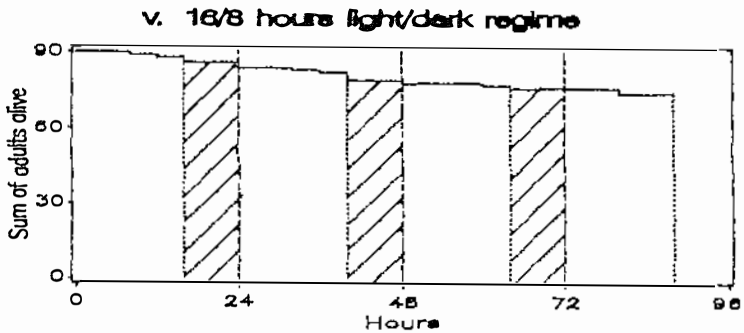
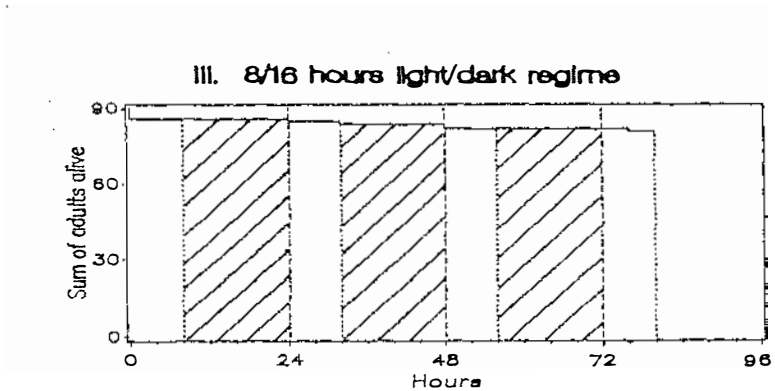
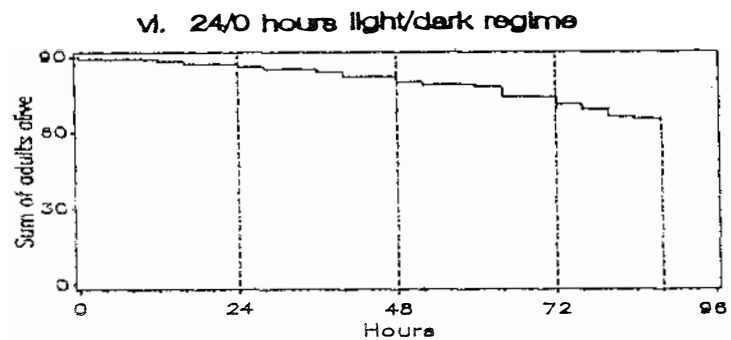
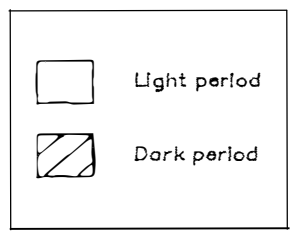


Fig. 2—2/15 continued.







There are no significant differences (0.01) between any figures within any of the light/dark regimes. See Appendix Table A2—2/15.

Table 2-2/1

Sum of eggs for each count time between day 3 and day 4 for the 0/24 light/dark regime.

Count time in hours from start				
48	52	56	60	64
414 (88)	397 (87)	432 (86)	497 (87)	442 (86)
Count time in hours from start				
72	76	80	84	88
490 (86)	542 (87)	609 (85)	488 (77)	793 (83)

The figures in brackets are the total whiteflies alive. There were 90 whiteflies at the start. There was one missing value for 84 hours.

Distribution of egglaying throughout each day for the light/dark regimes

Generally the mean eggs per female per hour for any one day did not change significantly throughout that day (See Fig. 2-2/13 and Appendix Table A2-2/13). The significant differences ($P<0.01$) that did occur were for 4/20 and 8/16 hours light/dark regimes and were not consistent during the experiment for all four days.

Egglaying in light versus dark periods of the day and light/dark regimes

The mean eggs per female per hour during light versus dark periods generally showed no significant ($P<0.01$) differences. See Fig. 2-2/14 and Appendix Table A2-2/14. The significant differences show no obvious pattern although all but one show more eggs were laid in the dark

period. It can be concluded from these results that whiteflies do not exhibit diurnal fluctuations in egglaying.

Conclusions

This experiment shows that whiteflies tend to lay more eggs where the dark period is longer i.e. for light/dark regimes between 8/16 and 12/12 hours. This is possibly because the periods of darkness of these shorter days induce the whiteflies to lay more eggs. No diurnal fluctuation occurs in egglaying and more eggs are not laid in dark than light periods.

Discussion

The results of the experiments in Section 1 above clearly confirm the observation that the selection of settling sites within plants by adult greenhouse whitefly is not the result of random movement as gravity, light direction and leaf characteristics had an effect on their distribution at the end of the experiments. The description by Southwood (1962) of the flight of hemipterous insects as migratory and not the results of responses to stimuli such as food or sex pheromones fits the results of the experiments in Section 1 as the physical factors, light and gravity were shown to have a greater impact on settling site selection than the characteristics of leaves which may act as feeding stimulants for both selection of the younger leaves and the lower leaf surface.

Effects of gravity, light direction and quality on selection of younger leaves

The suggestion of Hussey and Gurney (1959) that orientation by greenhouse whitefly adults to younger leaves of tomato is induced by negative geotaxis was confirmed by the upward movement on intact tomato plants even when upside-down with light from below in Experiments 1-1/1 and 1-1/2. Negative geotaxis is the most important factor in initial selection of the younger leaves given the light intensities used in these experiments. The literature however, suggests that positive phototaxis is important especially where the colour is predominantly yellow. Positive phototaxis was confirmed by Experiments 1-1/1 and 1-1/2 where it had a marked though slightly lesser effect than gravity. Responses to both these factors must occur while the adult is in flight after they have been induced to take off from the leaf on which they first land either by light as shown by Noldus (1985) and/or after a test probe (Noldus, 1986b).

The precise features of the light to which the adult whiteflies respond is not clear from Experiments 1-1/1 and 1-1/2 with intact plants. For example the critical light intensity above which the adults show a positive phototaxis has not been investigated. The light intensity in the experiments was 10-40 $\mu mol/m^2/s$ and is equivalent to the shadelight of 27-35 $\mu mol/m^2/s$ of Morgan et al (1985). This is much lower than their measures of clear daylight of 1400 $\mu mol/m^2/s$ and overcast daylight of 450 $\mu mol/m^2/s$. It is, therefore, possible that if the light intensity were increased in Experiments 1-1/1 and 1-1/2 it could over-ride the gravity effect. The units used to measure light intensity are also critical as most are weighted for human vision (e.g. lux) and not what is detected by insects (Young et al, 1987).

Another aspect of light that may affect selection is the degree of contrast provided by the background around the leaves as suggested by Propoky and Owens (1983). It was not precisely controlled in the experiments in this thesis and could be a useful topic for further investigation.

The colour of the youngest leaves was suggested by Hussey and Gurney (1959) to be a potential attractant in tomato. Colour differences between tomato leaves was not measured in any of the experiments in this thesis but no visually detectable differences were observed. If there are colour differences among leaf ages of tomato plants a method to investigate whether whiteflies will respond to them independently of chemicals within the leaves would need to be devised. That they do respond to differences in the colour of leaves of different plant species has been demonstrated by van Lenteren et al (1977) and Verschoor-van der Poel and van Lenteren (1978). However, Hussey and Gurney (1959) showed that whiteflies do not congregate below the younger of two leaf portions of tomato when they are unable to probe. This indicates that leaf colour may not be as important in

selection of younger leaves within a plant as the chemicals detected by probing. However, Hussey and Gurney did not measure the colour of the leaf portions nor count the number of first landings on each to get an estimate of whether the colour of the leaf portions was a factor in orientation. Perhaps their method could be adapted for use with intact plants and the numbers landing observed.

When artificial light is used in experiments with insects it is important to remove the heat produced as a potential factor affecting responses. Heat from the light source would not have affected the results for Experiments 1-3/1 to 1-3/5 as there was a flowing water barrier between the lights and the cages to remove heat.

The spectral quality of the light was not measured in this thesis except for the cool light source used in the experiments on the selection of leaf surface using excised tomato leaflets (Experiment 1-2). It is important that it be measured for artificial light sources as these may not correspond well to sunlight and may distort whitefly responses. The lighting system in the growth cabinets used has been designed to approximate sunlight in spectral quality.

Effects of characteristics of leaves on selection of younger leaves for settling

After the adult whiteflies have landed on a plant surface they determine whether they have arrived on a satisfactory settling site, mainly by sampling chemicals just below the surface of the leaf in test probes (Verschoor-van der Poel and van Lenteren, 1978; Noldus, 1986b; van Vianen et al 1988a). Experiments 1-1/1, 1-1/2 and 1-3/5 showed that characteristics of leaves are not of paramount importance in the selection of the younger leaves within tomato plants.

Characteristics of leaves came a decided third after negative geotaxis and positive phototaxis in Experiments 1-1/1 and 1-1/2 and adults were not able to distinguish the leaf ages when the light and gravity factors were identical for all leaf ages in Experiment 1-3/5 with leaf discs. However, in this experiment the leaf age range may not have been wide enough to be comparable with the intact plant experiments and so the small differences due to characteristics of leaves found with intact plants in Experiments 1-1/1 and 1-1/2 may not have shown up in the leaf disc experiment. Characteristics of leaves, especially chemicals detected by probing, are important in causing adults to settle and continue feeding. That they move off old leaves was shown by Noldus (1986b) and that probes are necessary to induce settling by Hussey and Gurney (1959). Hence, in Experiments 1-1/1 and 1-1/2 the low numbers on the older leaves where the plants were upside-down may be the result of movement off these leaves because the adults found the chemical content unsatisfactory for feeding.

Where excised leaflets or intact plants are offered the whiteflies select leaves and not, for example, stems or petioles. The reasons for this are not addressed by this thesis but the characteristics of these parts must surely play some role in their non selection. In contrast aphids will often feed on leaf blades, petioles and stems. The characteristics of leaves of different ages may play a greater role in the selection of the younger leaves in plant species other than those used in these experiments.

The nature of the leaf characteristics producing the limited response in the selection of younger leaves, has only been cursorily addressed in this thesis. As there were no differences in adult selection among leaf ages in Experiment 1-3/5 with leaf discs, the differences in nitrogen content of the leaves and in leaf hairiness can have had no appreciable influence. Leaf angle had no effect on selection of the

younger leaf discs in Experiments 1-3/6 to 1-3/8 but these experiments were not entirely satisfactory as the discs were not completely flat and were possibly too small. Perhaps the experiments could be repeated with excised leaflets at least with tomato - tobacco and rauriki do not lend themselves to this technique. It would be of interest to devise an experiment to check the effect of leaf angle and leaf age with tobacco as the youngest leaves are almost vertical naturally and the older ones close to horizontal.

Effects of gravity, light direction and quality on selection of the lower leaf surface

The selection of the lower leaf surface of tomato by greenhouse whitefly adults is predominantly a gravity response shown by the far larger number in the 'down' category no matter the level of the other factors in Experiment 1-2 with excised leaflets and similarly in Experiments 1-1/1 and 1-1/2 using intact plants. This finding does not support the statement of Coombe (1981) that light is the dominant factor inducing whitefly adults to go to the underside of the leaf. From the description of his experiments it is not clear whether or how he removed the heat from the lamp nor does he allow for the possibility of a gravity as well as a light effect. The light he used would be far brighter than that used in the experiments in this thesis and therefore, providing he had taken care to remove the heat factor, the higher light intensity could have overridden the effect of gravity and so explain the difference between his results and those in this thesis.

The effect of light came second in order of importance in selection of the lower leaf surface in all the Experiments 1-1/1, 1-1/2 and 1-2. The chain of events that changes the adult response from positive phototaxis in flight to a negative phototaxis when walking is not clear. They may, fly

upwards in response to light direction (and gravity), land on a younger leaf, take a test probe and, if they are on the upper surface then walk until they reach the edge of the leaf, move to the other side to an ultimate settling site to feed. It could be that if they are right way up on the upper surface (a gravity effect) they are induced to walk to the edge of the leaf rather than that they walk out of strong light into shade (a light effect). If this is so, it is not clear exactly how or at what stage the light is having its effect - immediately on landing? before/after a test probe? when walking/standing? only when in the brighter light on the upper leaf surface? There is also the question of the magnitude of the critical light intensity above which a response will occur.

There could be a colour or light intensity difference between the upper and lower leaf surfaces. Woolley (1971) in a study of reflectance and transmittance of light by leaves found that there was greater reflectance from the upper surface of leaves of various plants in the visible range but from the lower surface in the very near infrared. This was due in some plant species to the raised veins tending to reflect light away from the spectrophotometer. Another factor that may cause leaf discs to change colour is loss of turgidity as a decrease of relative water content from 97% to 77% in maize increases reflectance considerably; in soybeans it remains the same and in cotton it is decreased (Woolley, 1971). Thus some leaf discs could conceivably lose turgidity at a greater rate than others and so alter relative reflectance and hence, the response of the whiteflies. In the experiments using leaf discs it was observed that the lower and upper leaf surface discs appeared to be different colours. To confirm whether this colour difference explains the greater selection of the lower surface, the leaf discs could be covered with glass smeared with a sticky substance and counts made of the whiteflies that landed below the lower and upper surfaces. This would measure the response to light in flight and

separate it from any response to chemicals after probing or other features of the leaf. Any response to differences in colour between leaf surfaces would show up in the characteristics of leaves not the light category in Experiments 1-1/1, 1-1/2 an 1-2.

Effects of characteristics of leaves on selection of the lower leaf surface

Experiments 1-3/1 to 1-3/5 using leaf discs showed that the characteristics of leaves may result in either lower or upper leaf surface being selected or the two surfaces being selected equally and this is dependent on the plant species. Experiments 1-1/1 and 1-1/2 with intact tomato plants and Experiment 1-2 with excised tomato leaflets showed similar selection of the lower leaf surface to Experiment 1-3/1 with leaf discs.

In Experiments 1-1/1, 1-1/2 and 1-2 characteristics of leaves was the least important of the three factors investigated for their effects on leaf surface selection. In Experiments 1-3/1 to 5 using leaf discs the small difference in the numbers on the two leaf surfaces compared with the almost exclusive presence of adults on the lower surface in the natural situation indicates that other factors must be involved in the selection of the lower surface.

The rather cursory examination of leaf hair density and types in Experiment 1-3/5 provided no evidence that higher hair density is associated with fewer whiteflies. The younger leaves are more hairy than older and the lower than the upper leaf surface. This being so, if leaf hair density were critically important then adult whiteflies would be on the upper surface of older leaves. However, the dense stellate hairs on the lower surface of the *Abutilon* may have been a factor in inducing more whiteflies to go to the upper leaf

surface of this plant. It may be the type of hair rather than the density that is more important in host plant selection as found by Georgiev and Sotirova (1986). In contrast to the effect of glandular leaf hairs on some aphids (Johnson, 1955), adult whiteflies did not become entangled in exudate from glandular leaf hairs of the plants used in any of the experiments in this thesis.

Access to the phloem, where whiteflies are known to feed (Janssen et al, 1988), may be easier from the lower than the upper surface. However, cross sections of leaves of the plants used in the leaf disc experiments showed that there were no fibres or xylem or phloem bundles that would impede penetration from either surface. The literature was checked for the presence of these in the families of the plants used and they were found to be absent (Metcalfe and Chalk, 1983).

It would be of interest to investigate whether *Datura*, *Abutilon* and tobacco produce the same result as tomato for the relative importance of negative geotaxis, leaf characteristics and positive phototaxis. However, the larger leaves of these plants would make comparable experiments difficult.

Although it was confirmed in Experiments 1-1/1, 1-1/2, 1-2 and 1-3/1 to 5 that leaf characteristics are important in the selection of the lower leaf surface no new information on the nature of these characteristics was gained.

Time taken to settle

Noldus et al (1985) found that the time taken to select a settling site on intact tomato plants after emergence from pupae is approximately 3 days but it would appear from Experiments 1-1/1 and 1-1/2 with intact plants that the choice of settling site is generally made within 2 hours on

tomato and from Experiments 1-3/1 to 1-3/11 with leaf discs within 1 hour. It may be that the 24 hours allowed in the Experiments 1-1/1 and 1-1/2 with intact plants is insufficient for the whiteflies to move to their ultimate settling sites. However, in the work of Noldus et al (1985) the whiteflies emerged on the experimental plants whereas in these experiments they were introduced from elsewhere. Furthermore Noldus et al found that the movement pattern of whiteflies changes with their age and it could be that because the whiteflies used in Experiments 1-1/1 and 1-1/2 were 2-7 days older and had a wider age range that the expected time to settling may be different.

Temperature will also have a significant effect on the time taken to settle. For the experiments of Noldus et al it was 24.6+/-2.7° C and in Experiments 1-1/1 and 1-1/2 it varied between 10 and 31.5° C. It is therefore, not possible to compare the relative activity of the adults between these two experiments due to these temperature differences.

Aggregation

The evidence for an aggregation effect from Experiment 1-2 is weak and insufficient to contradict the findings of van Vianen et al (1988b) that adult whiteflies are not attracted to leaves where adults are already present.

Relationship between adult selection and oviposition

There was no correlation between number of eggs laid by adult female whiteflies and the number of adults selecting the different leaf ages of leaf discs in Experiment 1-3/5. Counts of adults showed no significant differences ($P>0.10$) but mean eggs per whitefly-day did. This suggests that characteristics of the leaves affect egg-laying but have a minor effect on adult selection - the light and gravity factors were identical for all the discs so only differences in the leaves themselves affected the selection by the adults.

Oviposition and leaf age

Female whiteflies consistently laid more eggs on younger than older leaves in all experiments. This agrees with the findings of Hussey and Gurney (1959) for oviposition on a range of leaf ages of tomato. Similar results occur for other insects (see the literature review).

There is some evidence for an increase in number of eggs with increasing leaf nitrogen content which in turn decreases with leaf age. It was not possible to carry out statistical analysis as there were no replicates for the nitrogen analysis. There is some evidence for such a correlation for aphids but Hussey and Gurney's (1959) experiment with excised tomato leaves showed no such relationship. However, they did find that fecundity declined with leaf age.

Leaf hair density and type do not appear to have an effect on the relative oviposition for different leaf ages as high leaf hair densities and high numbers of the different hair types are both associated with higher egg numbers. Thus high leaf hair densities do not appear to inhibit penetration to the leaf surface for egg-laying in the plant species used.

Oviposition and leaf surface

The relative number of eggs per female per day laid on each leaf surface varies with the plant species. For *Datura*, and *Abutilon* more were laid on the upper leaf surface. This may be because whiteflies find it easier to reach the leaf surface with their ovipositors as the hairs on the upper leaf surface are less dense. This may especially be so with *Abutilon*, which has very dense stellate hairs on the lower leaf surface. However, the results for tobacco contradict this as more were laid on the more hairy lower surface. For tomato the results were not completely consistent: on intact plants more were laid on the lower surface only in the middle leaf age range but where leaf discs were used the results varied with the experiment. There was no difference between numbers of eggs laid on lower and upper leaf surfaces for Experiments 1-3/1 and 1-3/5 and yet for Experiment 1-3/6 more were laid on the lower leaf surface. Perhaps the leaf ages chosen for Experiment 1-3/1 and 1-3/5 were outside the middle range of Experiment 2-1/2 and the youngest leaf age of Experiment 1-3/6 was within the middle range of Experiment 2-1/2. Or perhaps the explanation lies in the very wide variation in number of eggs laid per female per day (see the literature review) or maybe too few whiteflies were used to detect differences in numbers of eggs laid on the two surfaces. It is also possible that the nutrient status of the leaf discs and the sap pressure could change with time and this may account for some of the differences between the results for intact leaves and leaf discs.

In contrast to these results Georgiev and Sotirova (1986) found that cultivar resistance in tomatoes varied according to the presence of particular hair types but the abstract does not make clear how the resistance was measured nor what their types b and c hairs are. Probably their type b corresponds to the type b glandular hairs, with a single vesicle at the tip, described by Tingey et al (1982) and

Gibson and Pickett (1983) on potato and also correspond to Luckwill's (1943) type I (see literature review). There was no relationship between any of the three hair type categories in this experiment and oviposition on the lower and upper leaf surfaces.

Oviposition and leaf angle

Experiments 1-3/6 to 8 showed no effect of leaf angle on oviposition and there is no indication in the literature that leaf angle affects oviposition by whiteflies. Nor was any evidence found in the literature for effects of leaf angle on oviposition for other related insects.

Selection of the optimum sucrose concentration for use in sucrose sachets for experiments with adult whiteflies

The two main aspects considered, adult survival and reproductive capacity were used to select the optimum sucrose concentration for use with aphids notably for green peach aphid (*Myzus persicae*). No statistical analysis was used in the earlier experiments - visual evidence from graphs are usually provided (Mittler and Dadd, 1963a). Similar graphed results to theirs were obtained for greenhouse whitefly in Experiments 2-2/1 and 2-2/2 for adult survival and oviposition (corresponding to larviposition) over time.

Oviposition. The number of eggs laid per female per day was independent of the sucrose concentration when it was below 40%. Above 40% too few eggs were laid to make a fair comparison with other sucrose concentrations. Hence, for maximum oviposition a sucrose concentration between 10% and 30% is suitable.

The comparison between the all female and mixed sex groups in Experiments 2-2/1 and 2-2/2 was not strictly valid as the

whiteflies in the all female group were not virgin and their oviposition rate may not in fact be different from the mixed sex group as females can continue to produce fertile eggs throughout their lives without repeated matings (Åhman and Ekbom, 1981).

The oviposition rate was not the same throughout the experiments. For all sucrose concentrations, after the maximum oviposition per day was reached at 2-3 days, the rate fell sharply. The decrease in egg-laying may be the result of insufficient nutrients to maintain the rate of egg-laying. This could be verified by supplying necessary nutrients in the sachets. However, no work has been done on determining the optimum artificial diet for greenhouse whitefly.

Adult survival. Adult survival varied with the sucrose concentration and was optimum at 15-20% sucrose - a much narrower range than for oviposition. There were no differences in survival between male, female and mixed sex groups. This does not agree with the findings of Collman and All (1980) that females live longer than males. However, these authors used bean leaves as the feeding substrate. The lifespan of the adults is highly variable (1 to 36 days) as is indicated by the gradual decline of adults alive in Fig. 2-2/2. Where the sucrose concentration was optimum the lifespan did not differ markedly from that reported for plant material which can be as short as 24 hours but is on average about 21 days (Collman and All, 1980).

Egg hatch. There were no significant differences among the sex groups in the number of larvae that hatched. It was possible to make this comparison because there were no significant differences in the number of eggs between the sex groups. It was not possible to make strictly valid comparisons among the sucrose concentrations for egg hatch because the number of eggs for each concentration was not the

same. The only significant differences in percentage egg hatch were a lower hatch for 30% sucrose than all others except 20% sucrose. Egg hatch ranged from 40% (30% sucrose) to 77% (water) which is lower than that obtained by van de Merendonk and van Lenteren (1978).

The similar percent egg hatch obtained for all sucrose concentrations indicates that although eggs take up water from the substrate on which they are laid (Byrne et al, 1990) the sucrose concentrations have no adverse effect by causing dehydration or excessive water uptake which could result in bursting of the egg membrane. However, the lower value obtained for 30% sucrose may indicate an effect. Some of the observed differences in the ranking of cumulative numbers of eggs compared with ranking of cumulative numbers of larvae (see Appendix Tables A2-2/5 and A2-2/6) may be explained by the later hatch for higher sucrose concentrations. This is seen clearly in Fig. 2-2/6. This effect may be the result of interchange of chemicals between eggs and substrate.

Oviposition and light intensity

Nearly twice the number of eggs were laid in complete darkness than under any other light intensity in Experiment 2-2/3. Under the next lowest light intensity of 21 μeinsteins/m^2/s the oviposition rate was similar to that of the higher light intensities. This disagrees with the findings of Hussey and Gurney (1959) that fewer eggs are laid at low light intensity. These authors do not provide a numerical measure of the light intensities used and the eggs were laid on excised tomato leaflets - a substrate which could change with changing light intensity and so affect oviposition. They also found that the range of intensities used yielded no consistent pattern. The results of Experiment 2-2/3 agrees with this for intensities above complete darkness.

Oviposition and light/dark regimes

Experiment 2-2/5 confirmed the results of Experiments 2-2/3 and 2-2/4 in that far more eggs were laid by day 4 in complete darkness than where there was a period of light during each day. A higher number of eggs were laid by day 4 in light/dark regimes of 8/16 and 4/20 hours than for 12/12 to 24/0 hours. This disagrees with the results of Hussey and Gurney (1959) who found that there were no differences in eggs/female/day among the light/dark regimes 0/24 to 20/4 hours but they used excised tomato leaflets and although they state that the experiments were carried out under constant temperature no value is provided. Could there be a temperature/light interaction? Or does some factor associated with plant material override the darkness effect demonstrated in Experiments 2-2/3, 2-2/4 and 2-2/5?

Experiment 2-2/5 also showed that there is no diurnal fluctuation in egg-laying and no difference in numbers of eggs laid in dark and light periods no matter the light/dark regime.

Conclusions

The relative importance of gravity, light direction and characteristics of leaves for the selection of the younger leaves (for the light intensity used in the experiments) was first, negative geotaxis then, a close second, positive phototaxis and third, characteristics of the leaves. The nitrogen, phosphorus and potassium content of the leaves and the density and type of leaf hairs were not important in this selection process.

The relative importance of gravity, light and characteristics of leaves for the selection of the lower leaf surface (for the light intensity used in the experiments) was a clear

first for gravity, second a preference for shade and third, characteristics of leaves. The density and type of leaf hairs were not important. Selection of lower or upper leaf surface under the same conditions varied with the plant species.

Although these results demonstrate more clearly the relative importance of the factors that affect the selection of the younger leaves and the lower leaf surface there is no immediate application in pest control. However, the information, especially that on selection within the plant, could be taken account of in the production of future integrated pest management models.

The experiments on the factors that affect oviposition have shown, firstly, that, for at least some plant species, features of the leaves induce female adult greenhouse whiteflies to lay more eggs on the lower than the upper leaf surface. If the appropriate leaf features could be incorporated into leaves by a plant breeding programme then the results would have a practical use. Secondly, they have shown that there was no difference in oviposition with leaf age for the range used. Despite this there could still be differences for tomato if the plants were grown under different conditions such as higher nitrogen levels and as nutrient levels can be readily adjusted any positive results of studies could then be incorporated into an integrated pest management programme. Differences in oviposition with leaf age may well occur with other plant species. This would be an area for further investigation and could be usefully extended to search for the leaf features which cause the differences in oviposition.

The experiments with sucrose sachets have shown that the technique is suitable for experiments with greenhouse whitefly involving oviposition and or longevity. A sucrose concentration of 15-20% is the optimum for such assays. This sucrose concentration was then used to show that female whiteflies lay far more eggs in complete darkness than at other light intensities and more in light/dark regimes from 0/24 to 8/16 than 12/16 to 24/0 hours. The next research step would be to investigate whether the same effects occur when leaves are the oviposition substrate. If more eggs are laid with shorter day lengths in the greenhouse situation then it would need to be taken account of in the design of integrated pest control programmes. In addition the sucrose sachet technique has potential for studies on, for example: the nutrient requirements of greenhouse whitefly adults and the effect of pesticides and secondary plant substances on oviposition and longevity. Maybe there is even potential for its use in the development of an artificial rearing system.

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Appendices

Appendix 1: Rearing system for greenhouse whitefly

The whiteflies used in the experiments in this thesis were initially reared on tobacco cv. White Burley but this was changed to cv. Burley 21 as the White Burley seed mutated and the plants were no longer true to type and no fresh seed was immediately available.

The system used was adapted from the Glasshouse Crops Research Growers' Bulletin No. 2 (1975).

Plant raising

Once a fortnight 6-10 seeds were sown. Each week 3-6 plants were pricked out into 10 cm pots and 3 plants form the 10 cm pots bagged into PB5 planter bags. All plants were kept in a glasshouse in cages covered with terylene sheer to keep out all insects.

Whitefly rearing

For a general view of the whitefly rearing cages see Photograph 3.

This was carried out in a separate glasshouse. Three clean plants, with 10-12 leaves and growing tips removed, were placed in a cage with other plants infested with adult whiteflies. These plants were shaken to assist transfer of adults to the clean plants. The following day, or two days later, the three plants were shaken gently to remove some of the adults and transferred to a fumigation box consisting of a cage covered in clear plastic with a dichlorvos pest strip to kill all adults.

The following day, or two days later, when all the adults were dead the three plants were transferred to a scale development cage which was free of adults. They remained here until the adults were close to hatching. Once a week the three oldest plants in the scale development cages were transferred to the adult emergence cage. The adults that emerged from these plants were either used in experiments or became a source of adults for egg-laying on other clean plants.

Watering and feeding

The plants were watered every 1-2 days and fed twice a week with 250-400 ml of nutrient solution made up as follows:

26 g urea
26 g monoamonium phosphate
26 g potassium nitrate
9 gallons of water

Extra short term Osmocote was added when plants were bagged up.

Pest control

Slugs were controlled with Mesurol pellets and aphids with pyrimiphos at a concentration of 2.2 g/litre. Spraying in the adult emergence cage was avoided as much as possible as pyrimiphos will cause some adult mortality. Two spotted spider mites were controlled by placing the affected plants in the fumigation box for 1-2 days and again in 10 days time to kill the nymphs that have hatched from eggs.

Records

Each plant was given a number on a label. Dates of all the operations above were recorded in a notebook with the plant numbers. Also the maximum and minimum temperatures in both the plant raising and whitefly rearing glasshouse were recorded once a week.

Temperature

It was difficult to control the temperature in both glasshouses and the ranges throughout a year were: plant raising glasshouse minimum 13-20° C (mean 16.8° C) and maximum 24-41° C (mean 27.5° C); whitefly rearing glasshouse minimum 3-20° C (mean 13.5° C) and maximum 21-37° C (mean 28.3° C). This variation in temperature meant that the development time of both plants and whiteflies varied considerably. The time from sowing seed until adult whiteflies were ready to use in experiments was 5-6 months. The development time for adult whiteflies was 4-9 weeks.

Soil mix

peat 60 l
sand 40 l
dolomite 300 ml
Osmocote long term 130 ml
short term 75 ml
Micromax 90 ml
water 10 l

Photograph 3

General view of cages of whitefly rearing system.

Table A1-1/1

Adult preference for lower or upper leaf surface of intact plants under 4 orientation/light regimes.
Tomato cv. Virosa

a. Comparison of lower and upper leaf surfaces.

Sum of adults on leaves	2 hours			24 hours		
	Expt. 1-1/1	Expt. 1-1/2	Total	Expt. 1-1/1	Expt. 1-1/2	Total
Down						
Shade						
Lower	208 a	228 a	436 a	209 a	261 a	470 a
Upper	42 c	38 c	80 c	114 b	45 c	159 b
Light						
Lower	81 b	86 b	167 b	73 c	78 b	151 b
Upper	26 cd	25 c	51 c	27 d	17 d	44 c
Up						
Shade						
Lower	18 d	8 d	26 d	37 d	34 cd	71 c
Upper	0 e	2 d	2 e	3 e	4 e	7 ef
Light						
Lower	3 e	9 d	12 de	8 e	0 e	8 e
Upper	1 e	1 d	2 e	0 e	0 e	0 f

Figures with the same letter within each column are not significantly different (P>0.01).

continued . . .

Table A1-1/1 continued.

b: Comparison of experiments and times.

Sum of adults on leaves	Down				Up			
	Shade		Light		Shade		Light	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2 hours								
Expt. 1-1/1	208 a	42 b	81 a	26 a	18 bc	0 a	3 ab	1 a
Expt. 1-1/2	228 a	38 b	86 a	25 a	8 c	2 a	9 a	1 a
24 hours								
Expt. 1-1/1	209 a	114 a	73 a	27 a	37 a	3 a	8 a	0 a
Expt. 1-1/2	261 a	45 b	78 a	17 a	34 ab	4 a	0 b	0 a
Plant no.	2	1	3	4	4	3	1	2

Figures with the same letter within each column are not significantly different (P>0.01).

Table A1-1/2

Adult preference for younger or older leaves of intact plants under 4 orientation/light regimes. Tomato cv. Virosa

a. Leaf age grouping: oldest: 1-3; youngest: 9-13.

Sum of adults on leaves	Gravity direction: Older to younger		Younger to older		Younger to older		Older to younger	
	Light direction: Leaves nearest light source: Older		Younger		Older		Younger	
	Plant number: 1		2		3		4	
Experiment 1-1/1								
2 hours								
Leaf number								
1- 3 oldest	15	a	10	b	7	a	5	a
4- 8	22		130		61		39	
9-13	8	a	69	a	13	a	0	a
Totals	**45**		**209**		**81**		**44**	
24 hours								
Leaf number								
1- 3 oldest	36	a	21	b	6	a	15	a
4- 8	77		143		59		37	
9-13	9	b	45	a	11	a	12	a
Totals	**122**		**209**		**76**		**64**	
Experiment 1-1/2								
2 hours								
Leaf number								
1- 3 oldest	10	a	10	b	5	a	6	a
4- 8	25		142		69		25	
9-13	12	a	77	a	14	a	2	a
Totals	**47**		**229**		**88**		**33**	
24 hours								
Leaf number								
1- 3 oldest	10	a	13	b	4	a	11	a
4- 8	30		163		64		30	
9-13	5	a	85	a	14	a	10	a
Totals	**45**		**261**		**82**		**51**	

continued . . .

Table A1-1/2 continued.

b. Leaf age grouping: oldest: 1-4; youngest: 8-13.

Sum of adults on leaves	Gravity direction: Older to younger	Gravity direction: Younger to older	Gravity direction: Younger to older	Gravity direction: Older to younger
	Light direction: Leaves nearest light source: Older	Younger	Older	Younger
	Plant number: 1	2	3	4
Experiment 1-1/1				
2 hours				
Leaf number				
1- 4 oldest	22 a	23 b	19 a	15 a
5- 7	14	67	45	27
8-13	9 a	119 a	17 a	2 b
Totals	**45**	**209**	**81**	**44**
24 hours				
Leaf number				
1- 4 oldest	50 a	30 b	17 a	19 a
5- 7	38	88	42	22
8-13	24 b	91 a	17 a	23 a
Totals	**122**	**209**	**76**	**64**
Experiment 1-1/2				
2 hours				
Leaf number				
1- 4 oldest	17 a	28 b	16 a	17 a
5- 7	17	66	54	12
8-13	13 a	135 a	18 a	4 b
Totals	**47**	**229**	**88**	**33**
24 hours				
Leaf number				
1- 4 oldest	21 a	23 b	14 a	12 a
5- 7	13	111	50	22
8-13	11 a	127 a	18 a	17 a
Totals	**45**	**261**	**82**	**51**

Figures within each column (excluding totals) with the same letter are not significantly different (P>0.01).

Table A1-2/1

Adult preference for lower or upper leaf surface of excised leaflets under 16 orientation/light regimes.
Tomato cv. Virosa.

a. Sum of adults on leaflets where they were either present or absent at the start.

	0 hours		12 hours	
	Lower surface	Upper surface	Lower surface	Upper surface
A **Down In shade**				
"Present" at start	96 a (2)	109 a (1)	187 a (2)	191 a (1)
"Absent" at start	2 b (2)	1 b (1)	232 a (2)	204 a (1)
Down In light				
"Present" at start	134 a (3)	128 a (4)	219 a (3)	161 a (4)
"Absent" at start	3 b (3)	0 b (4)	217 a (3)	137 a (4)
Up In shade				
"Present" at start	88 a (4)	108 a (3)	59 a (4)	18 a (3)
"Absent" at start	2 b (4)	0 b (3)	50 a (4)	6 a (3)
Up In light				
"Present" at start	122 a (1)	108 a (2)	3 a (1)	0 a (2)
"Absent" at start	7 b (1)	0 b (2)	8 a (1)	1 a (2)
B **Down Side (L)**				
"Present" at start	74 a (7)	76 a (5)	201 a (7)	150 a (5)
"Absent" at start	8 b (7)	0 b (5)	242 a (7)	124 a (5)
Down Side (R)				
"Present" at start	68 a (8)	105 a (6)	199 a (8)	116 b (6)
"Absent" at start	0 b (8)	9 b (6)	247 a (8)	164 a (6)
Up Side (L)				
"Present" at start	75 a (5)	91 a (7)	76 a (5)	2 a (7)
"Absent" at start	2 b (5)	1 b (7)	30 b (5)	4 a (7)
Up Side (R)				
"Present" at start	93 a (6)	92 a (8)	53 a (6)	5 a (8)
"Absent" at start	11 b (6)	0 b (8)	76 a (6)	1 a (8)

continued .

Table A1-2/1 a. continued.

	0 hours		12 hours	
	Lower surface	Upper surface	Lower surface	Upper surface
C **Vert. (L) In shade**				
"Present" at start	112 a (9)	60 a (11)	206 a (9)	72 a (11)
"Absent" at start	1 b (9)	4 b (11)	205 a (9)	40 b (11)
Vert. (R) In shade				
"Present" at start	53 a (10)	115 a (12)	238 a (10)	80 a (12)
"Absent" at start	9 b (10)	1 b (12)	216 a (10)	71 a (12)
Vert. (L) In light				
"Present" at start	51 a (11)	113 a (9)	202 a (11)	28 a (9)
"Absent" at start	10 b (11)	0 b (9)	172 a (11)	7 b (9)
Vert. (R) In light				
"Present" at start	103 a (12)	65 a (11)	147 a (12)	9 a (11)
"Absent" at start	0 b (12)	2 b (11)	116 a (12)	7 a (11)
D **Vert. (L) Side (L)**				
"Present" at start	105 a (13)	83 a (13)	202 a (13)	57 a (13)
"Absent" at start	3 b (13)	1 b (13)	146 b (13)	17 b (13)
Vert. (L) Side (R)				
"Present" at start	108 a (14)	75 a (14)	174 a (14)	27 a (14)
"Absent" at start	4 b (14)	0 b (14)	193 a (14)	40 a (14)
Vert. (R) Side (L)				
"Present" at start	88 a (15)	82 a (15)	163 a (15)	28 a (15)
"Absent" at start	1 b (15)	0 b (15)	196 a (15)	39 a (15)
Vert. (R) Side (R)				
"Present" at start	110 a (16)	68 a (16)	191 a (16)	32 a (16)
"Absent" at start	1 b (16)	5 b (16)	185 a (16)	15 a (16)

Figures with the same letter for each pair of "present" and "absent" numbers are not significantly different (P>0.01). The figures in brackets are the treatment (leaflet) numbers and correspond with those in Fig. 1-2.
Figures are the sum from 4 cages.

continued . . .

Table A1-2/1 continued.

Adult preference for lower or upper leaf surface of excised leaflets under 16 orientation/light regimes.
Tomato cv. Virosa

b. Sum of adults on lower and upper surface of leaflets both under the same conditions.

		0 hours		12 hours	
		"Present" at start	"Absent" at start	"Present" at start	"Absent" at start
A	**Down In shade**				
	Lower surface	96 a (2)	2 a (2)	187 a (2)	232 a (2)
	Upper surface	109 a (1)	1 a (1)	191 a (1)	2 b (1)
	Down In light				
	Lower surface	134 a (3)	3 a (3)	219 a (3)	217 a (3)
	Upper surface	128 a (4)	0 a (4)	161 b (4)	137 b (4)
	Up In shade				
	Lower surface	88 a (4)	2 a (4)	59 a (4)	50 a (4)
	Upper surface	108 a (3)	0 a (3)	18 b (3)	6 b (3)
	Up In light				
	Lower surface	122 a (1)	7 a (1)	3 a (1)	8 a (1)
	Upper surface	108 a (2)	0 b (2)	0 a (2)	1 a (2)
B	**Down Side (L)**				
	Lower surface	74 a (7)	8 a (7)	201 a (7)	242 a (7)
	Upper surface	76 a (5)	0 b (5)	150 b (5)	124 b (5)
	Down Side (R)				
	Lower surface	68 b (8)	0 b (8)	199 a (8)	247 a (8)
	Upper surface	105 a (6)	9 a (6)	116 b (6)	164 b (6)
	Up Side (L)				
	Lower surface	75 a (5)	2 a (5)	76 a (5)	30 a (5)
	Upper surface	91 a (7)	1 a (7)	2 b (7)	4 b (7)
	Up Side (R)				
	Lower surface	93 a (6)	11 a (6)	53 a (6)	76 a (6)
	Upper surface	92 a (8)	0 b (8)	5 b (8)	1 b (8)

continued . . .

Table A1-2/1 b. continued.

	0 hours		12 hours	
	"Present" at start	"Absent" at start	"Present" at start	"Absent" at start
C **Vert. (L) In shade**				
Lower surface	112 a (9)	1 a (9)	206 a (9)	205 a (9)
Upper surface	60 b(11)	4 a (11)	72 b(11)	40 b(11)
Vert. (R) In shade				
Lower surface	53 b(10)	9 a (10)	238 a (10)	216 a (10)
Upper surface	115 a (12)	1 a (12)	80 b(12)	71 b(12)
Vert. (L) In light				
Lower surface	51 b(11)	10 a (11)	202 a (11)	172 a (11)
Upper surface	113 a (9)	0 b (9)	28 b (9)	7 b (9)
Vert. (R) In light				
Lower surface	103 a (12)	0 a (12)	147 a (12)	116 a (12)
Upper surface	65 b(10)	2 a (10)	9 b(10)	7 b(10)
D **Vert. (L) Side (L)**				
Lower surface	105 a (13)	3 a (13)	202 a (13)	146 a (13)
Upper surface	83 a (13)	1 a (13)	57 b(13)	17 b(13)
Vert. (L) Side (R)				
Lower surface	108 a (14)	4 a (14)	174 a (14)	193 a (14)
Upper surface	75 a (14)	0 a (14)	27 b(14)	40 b(14)
Vert. (R) Side (L)				
Lower surface	88 a (15)	1 a (15)	163 a (15)	196 a (15)
Upper surface	82 a (15)	0 a (15)	28 b(15)	39 b(15)
Vert. (R) Side (R)				
Lower surface	110 a (16)	1 a (16)	191 a (16)	185 a (16)
Upper surface	68 b (16)	5 a (16)	32 b(16)	15 b(16)

Figures with the same letter for each pair of lower and upper leaf surface numbers are not significantly different (P>0.01). The figures in brackets are the treatment (leaflet) numbers and correspond to those in Fig. 1-2.
Figures are the sum from 4 cages.

continued . . .

Table A1-2/1 continued.

Adult preference for lower or upper leaf surface of excised leaflets under 16 orientation/light regimes.
Tomato cv. Virosa

c. Sum of adults in the orientation/light regimes.

			0 hours				12 hours			
			"Present" at start		"Absent" at start		"Present" at start		"Absent" at start	
Lower surface										
A	Down	In shade	96 a	(2)	2 a	(2)	187 a	(2)	232 a	(2)
	Down	In light	134 a	(3)	3 a	(3)	219 a	(3)	217 a	(3)
	Up	In shade	88 a	(4)	2 a	(4)	59 b	(4)	50 b	(4)
	Up	In light	122 a	(1)	7 a	(1)	3 c	(1)	8 c	(1)
B	Down	Side (L)	74 a	(7)	8 ab	(7)	201 a	(7)	242 a	(7)
	Down	Side (R)	68 a	(8)	0 c	(8)	199 a	(8)	247 a	(8)
	Up	Side (L)	75 a	(5)	2 bc	(5)	76 b	(5)	30 c	(5)
	Up	Side (R)	93 a	(6)	11 a	(6)	53 b	(6)	76 b	(6)
C	Vert.(L)	In shade	112 a	(9)	1 bc	(9)	206 a	(9)	205 a	(9)
	Vert.(R)	In shade	53 b	(10)	9 ab	(10)	238 a	(10)	216 a	(10)
	Vert.(L)	In light	51 b	(11)	10 a	(11)	202 a	(11)	172 a	(11)
	Vert.(R)	In light	103 a	(12)	0 c	(12)	147 b	(12)	116 b	(12)
D	Vert.(L)	Side (L)	105 a	(13)	3 a	(13)	202 a	(13)	146 b	(13)
	Vert.(L)	Side (R)	108 a	(14)	4 a	(14)	174 a	(14)	193 a	(14)
	Vert.(R)	Side (L)	88 a	(15)	1 a	(15)	163 a	(15)	196 a	(15)
	Vert.(R)	Side (R)	110 a	(16)	1 a	(16)	191 a	(16)	185 a	(16)

continued . . .

Table A1-2/1 c. continued.

		0 hours		12 hours	
		"Present" at start	"Absent" at start	"Present" at start	"Absent" at start
Upper surface					
A Down	In shade	109 a (1)	1 a (1)	191 a (1)	204 a (1)
Down	In light	128 a (4)	0 a (4)	161 a (4)	137 b (4)
Up	In shade	108 a (3)	0 a (3)	18 b (3)	6 c (3)
Up	In light	108 a (2)	0 a (2)	0 c (2)	1 c (2)
B Down	Side (L)	76 a (5)	0 b (5)	150 a (5)	124 a (5)
Down	Side (R	105 a (6)	9 a (6)	116 a (6)	164 a (6)
Up	Side (L)	91 a (7)	1 ab (7)	2 b (7)	4 b (7)
Up	Side (R)	92 a (8)	0 b (8)	5 b (8)	1 b (8)
C Vert.(L)	In shade	60 b (11)	4 a (11)	72 a (11)	40 b (11)
Vert.(R)	In shade	115 a (12)	1 a (12)	80 a (12)	71 a (12)
Vert.(L)	In light	113 a (9)	0 a (9)	28 b (9)	7 c (9)
Vert.(R)	In light	65 b (10)	2 a (10)	9 c(10)	7 c(10)
D Vert.(L)	Side (L)	83 a (13)	1 a (13)	57 a (13)	17 b (13)
Vert.(L)	Side (R)	75 a (14)	0 a (14)	27 b (14)	40 a (14)
Vert.(R)	Side (L)	82 a (15)	0 a (15)	28 b (15)	39 a (15)
Vert.(R)	Side (R)	68 a (16)	5 a (16)	32 b (16)	15 b (16)

Figures with the same letter for each group of four orientation/light regime numbers are not significantly different (P>0.01). Figures in brackets are the leaflet (treatment) numbers and correspond with those in Fig. 1-2.
Figures are the sum from 4 cages.

Table A1-3/1

Adult preference for lower or upper surface of leaf discs - choice test.

i. Tomato cv. Virosa

Sum and percent of adults on leaf discs.

	Lower surface		Upper surface		
Hours					
0.25	78	59%	55	41%	
0.50	86	58%	63	42%	
0.75	88	56%	68	44%	
1.00	92	59%	65	41%	
1.25	94	59%	65	41%	
1.50	97	60%	66	40%	
1.75	99	60%	65	40%	**
2.00	101	61%	64	39%	**
2.50	99	61%	62	39%	**
3.00	100	63%	58	37%	**
3.50	96	62%	58	38%	**
4.00	93	61%	60	39%	**
5.00	87	62%	54	38%	**
6.00	87	59%	61	41%	
24.00	+ 34	74%	M 16	26%	

\+ The corresponding figure for a missing value has been removed.
M Missing value in one cage.
** Significant differences (P<0.01) for that time.

ii. Tobacco cv. White Burley.

Sum and percent of adults on leaf discs.

	Lower surface		Upper surface	
Hours				
0.25	61	54%	53	46%
0.50	70	53%	61	47%
0.75	74	54%	64	46%
1.00	73	52%	67	48%
1.25	77	52%	70	48%
1.50	76	52%	71	48%
1.75	77	52%	71	48%
2.00	76	52%	69	48%
2.50	84	55%	69	45%
3.00	86	56%	68	44%
3.50	85	56%	68	44%
4.00	88	56%	69	44%
5.00	85	56%	67	44%
6.00	98	57%	75	43%
24.00	88	54%	76	46%

None of the numbers for any one time are significantly different (P>0.01).

continued . . .

Table A1-3/1 continued.

iii. *Abutilon* sp.

Sum and percent of adults on leaf discs.

	Lower surface		Upper surface		
Hours					
0.25	80	42%	112	58%	
0.50	85	44%	110	56%	
0.75	86	43%	113	57%	
1.00	87	43%	114	57%	
1.25	87	43%	113	56%	
1.50	85	43%	114	57%	
1.75	86	44%	110	56%	
2.00	87	43%	113	56%	
2.50	77	39%	119	61%	
3.00	+ 74	37%	125	63%	**
3.50	66	33%	133	67%	
4.00	+ 66	33%	137	67%	**
5.00	+ 66	30%	152	70%	**
6.00	+ 54	32%	116	68%	**
24.00	+ 53	40%	81	60%	**

** Significant difference (P<0.01) within each time.
+ Numbers on leaf surfaces are dependent on cage number.

iv. *Datura* sp.

Sum and percent of adults on leaf discs.

	Lower surface		Upper surface		
Hours					
0.25	95	60%	63	40%	
0.50	105	59%	72	41%	
0.75	110	60%	73	40%	**
1.00	117	60%	77	40%	**
1.25	121	61%	76	39%	**
1.50	123	62%	75	38%	**
1.75	128	62%	79	38%	**
2.00	130	62%	81	38%	**
2.50	134	62%	81	38%	**
3.00	134	62%	81	38%	**
3.50	132	61%	84	39%	**
4.00	135	62%	84	38%	**
5.00	140	62%	85	38%	**
6.00	146	62%	89	38%	**
24.00	182	75%	62	25%	**

** Significant difference (P<0.01) within each time.

Table A1-3/2

i. Tomato cv. Virosa.

Adult preference for lower or upper leaf surface and four leaf ages of leaf discs - choice test.

a. Comparsion of leaf ages.

Sum of adults on leaf discs	Hours 0.17	0.50	1.00	1.30	13.50	24.00	37.50
Lower surface							
Leaf age							
4 youngest	40 a	52 a	59 a	55 a	97 a	44 a	79 a
3	58 a	69 a	78 a	51 a	91 a	45 a	77 a
2	37 a	52 a	60 a	50 a	83 a	40 a	48 b
1 oldest	34 a	52 a	65 a	49 a	78 a	34 a	34 b
Upper surface							
Leaf age							
4 youngest	33 a	41 a	44 a	32 a	41 a	25 a	40 a
3	36 a	44 a	47 a	40 a	32 a	21 a	26 a
2	48 a	55 a	59 a	50 a	47 a	26 a	33 a
1 oldest	31 a	38 a	43 a	32 a	38 a	18 a	24 a

Figures with the same letter within each time and leaf surface are not significantly different (P>0.01).

continued . . .

Table A1-3/2 i. continued.

b. Sum of adults on lower or upper surface of leaf discs.

Sum of adults on leaf discs	Hours 0.17	0.50	1.00	1.30	13.50	24.00	37.50
Leaf age							
4 youngest							
Lower	40 a	52 a	59 a	55 a	97 a	44 a	79 a
Upper	33 a	41 a	44 a	32 a	41 b	25 a	40 a
3							
Lower	58 a	69 a	78 a	51 a	91 a	45 a	77 a
Upper	36 a	44 a	47 b	40 a	32 b	21 b	26 b
2							
Lower	37 a	52 a	60 a	50 a	83 a	40 a	48 a
Upper	48 a	55 a	59 a	50 a	47 b	26 a	33 a
1 oldest							
Lower	34 a	52 a	65 a	49 a	78 a	34 a	34 a
Upper	31 a	38 a	43 a	32 a	38 b	18 a	24 a
Totals							
Lower	169 a	225 a	262 a	205 a	349 a	163 a	238 a
Upper	148 a	178 a	193 b	154 b	158 b	90 b	123 b

Figures with the same letter within each time and leaf age are not significantly different (P>0.01).

continued . . .

Table A1-3/2 continued.

ii. Mean leaf hairs per mm sq on leaf discs.

	Leaf age							
	1 Oldest		2		3		4 Youngest	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Hair type								
Short	55	23	203	97	262	89	378	100
Long	6	0	7	1	9	2	14	4
Glandular	0	0	1	0	0	0	0	1
	76	43	89	56	113	42	116	56

whitefly-days on leaf discs

Table A1-3/3

Adult preference for leaf discs at angles 0°, 45°, 60° or 90°.

i. Tomato cv. Virosa

a. Comparison of inclined and horizontal leaf discs.

Sum of adults on leaf discs	Angle 0°	45°	60°	90°
Hours				
0.25				
Horizontal disc	182 a	202 a	175 a	142 a
Inclined disc	156 a	110 b	59 b	26 b
0.50				
Horizontal disc	191 a	221 a	195 a	168 a
Inclined disc	166 a	113 b	69 b	28 b
0.75				
Horizontal disc	192 a	228 a	204 a	182 a
Inclined disc	167 a	117 b	70 b	35 b
1.00				
Horizontal disc	199 a	231 a	216 a	199 a
Inclined disc	176 a	119 b	71 b	38 b
1.50				
Horizontal disc	200 a	240 a	224 a	214 a
Inclined disc	177 a	122 b	71 b	46 b
2.00				
Horizontal disc	205 a	241 a	1M219 a	219 a
Inclined disc	182 a	130 b	1M 70 b	47 b
3.00				
Horizontal disc	208 a	251 a	1M231 a	225 a
Inclined disc	178 a	135 b	1M 69 b	50 b
4.00				
Horizontal disc	179 a	238 a	1M207 a	197 a
Inclined disc	164 a	125 b	1M 67 b	57 b
5.00				
Horizontal disc	180 a	243 a	1M202 a	201 a
Inclined disc	169 a	124 b	1M 69 b	63 b
6.00				
Horizontal disc	151 a	211 a	1M169 a	189 a
Inclined disc	176 a	112 b	1M 74 b	69 b
24.00				
Horizontal disc	2M135 a	1M139 a	3M125 a	147 a
Inclined disc	2M124 a	1M103 a	3M 67 b	69 b

Numbers with the same letter for each time, angle and disc group are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).
See page 95.

continued . . .

Table A1-3/3 i. continued.

Adult preference for leaf discs at angles 0°, 45°, 60° or 90°.

i. Tomato cv. Virosa

b. Comparison of angles.

Sum of adults on leaf discs			
	Horiz. disc	Inclined disc	Total
Hours			
0.25			
0°	182 (54%) ab	156 (46%) a	338 a
45°	202 (65%) a	110 (35%) b	312 a
60°	175 (75%) ab	59 (25%) c	234 b
90°	142 (85%) b	26 (15%) d	168 c
0.50			
0°	191 (54%) ab	166 (46%) a	357 a
45°	221 (66%) a	113 (34%) b	334 a
60°	195 (74%) ab	69 (26%) c	264 b
90°	168 (86%) b	28 (14%) d	196 c
0.75			
0°	192 (53%) a	167 (47%) a	359 a
45°	228 (66%) a	117 (34%) b	345 a
60°	204 (74%) a	70 (26%) c	274 b
90°	182 (84%) a	35 (16%) d	217 c
1.00			
0°	199 (53%) a	176 (47%) a	375 a
45°	231 (66%) a	119 (34%) b	350 a
60°	216 (75%) a	71 (25%) c	287 b
90°	199 (84%) a	38 (16%) d	237 b
1.50			
0°	200 (53%) a	177 (47%) a	377 a
45°	240 (66%) a	122 (34%) b	362 a
60°	224 (76%) a	71 (24%) c	295 b
90°	214 (82%) a	46 (18%) c	260 b
2.00			
0°	205 (53%) a	182 (47%) a	387 a
45°	241 (65%) a	130 (35%) b	371 a
60°	1M 219 (76%) a	1M 70 (24%) c	289 b
90°	219 (82%) a	47 (18%) c	266 b

continued . . .

Table A1-3/3 i. b. continued.

Sum of adults on leaf discs											
	Horiz. disc				Inclined disc				Total		
Hours											
3.00											
0°		208	(54%)	a		178	(46%)	a		386	a
45°		251	(65%)	a		135	(35%)	a		386	a
60°	1M	231	(77%)	a	1M	69	(23%)	b	2M	300	b
90°		225	(82%)	a		50	(18%)	b		275	b
4.00											
0°		179	(52%)	a		164	(48%)	a		343	a
45°		238	(66%)	a		125	(34%)	a		363	a
60°	1M	207	(76%)	a	1M	67	(24%)	b	2M	274	b
90°		197	(76%)	a		57	(22%)	b		254	b
5.00											
0°		180	(52%)	a		169	(48%)	a		349	a
45°		243	(66%)	b		124	(34%)	b		367	a
60°	1M	202	(75%)	ab	1M	69	(25%)	c	2M	271	b
90°		201	(76%)	ab		63	(24%)	c		264	b
6.00											
0°		151	(46%)	a		176	(54%)	a		327	a
45°		211	(65%)	b		112	(35%)	b		323	a
60°	1M	169	(70%)	a	1M	74	(30%)	c	2M	243	b
90°		189	(73%)	ab		69	(28%)	c		258	b
24.00											
0°	2M	135	(52%)	a	2M	124	(48%)	a	4M	259	a
45°	1M	139	(57%)	a	1M	103	(43%)	a	2M	242	ab
60°	3M	125	(65%)	a	3M	67	(35%)	b	6M	192	b
90°		147	(68%)	a		69	(32%)	b		216	ab

Numbers with the same letter for each time and disc are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).
See page 95.

continued . . .

Table A1-3/3 continued.

Adult preference for leaf discs at angles 0°, 45°, 60° or 90°.

ii. Tobacco cv. White Burley

a. Comparison of inclined and horizontal leaf discs.

Sum of adults on leaf discs	Angle 0°	45°	60°	90°	Total
Hours					
0.25					
Horizontal disc	47 a	66 a	53 a	46 a	212 a
Inclined disc	32 a	38 b	27 b	12 b	109 b
0.50					
Horizontal disc	53 a	70 a	56 a	54 a	233 a
Inclined disc	34 a	42 b	30 b	15 b	121 b
0.75					
Horizontal disc	55 a	76 a	62 a	56 a	249 a
Inclined disc	37 a	42 b	32 b	18 b	129 b
1.00					
Horizontal disc	55 a	78 a	65 a	58 a	256 a
Inclined disc	39 a	45 b	33 b	19 b	136 b
1.25					
Horizontal disc	53 a	80 a	66 a	58 a	257 a
Inclined disc	40 a	46 b	34 b	20 b	140 b
1.50					
Horizontal disc	56 a	82 a	72 a	59 a	269 a
Inclined disc	41 a	47 b	33 b	20 b	141 b
1.75					
Horizontal disc	54 a	82 a	73 a	59 a	268 a
Inclined disc	42 a	47 b	36 b	20 b	145 b
2.00					
Horizontal disc	56 a	83 a	75 a	60 a	274 a
Inclined disc	43 a	47 b	36 b	20 b	146 b
2.50					
Horizontal disc	55 a	82 a	78 a	63 a	278 a
Inclined disc	43 a	50 b	36 b	19 b	148 b
3.00 +					
Horizontal disc	56 a	88 a	78 a	68 a	290 a
Inclined disc	45 a	54 b	38 b	19 b	156 b
3.50 +					
Horizontal disc	54 a	89 a	84 a	68 a	295 a
Inclined disc	46 a	58 a	42 b	18 b	164 b
4.00 +					
Horizontal disc	57 a	89 a	86 a	68 a	300 a
Inclined disc	47 a	58 a	44 b	20 b	169 b
5.00 +					
Horizontal disc	53 a	88 a	84 a	69 a	294 a
Inclined disc	49 a	59 a	46 b	22 b	176 b
6.00					
Horizontal disc	38 a	74 a	73 a	50 a	235 a
Inclined disc	42 a	42 b	41 b	22 b	147 b
24.00 +					
Horizontal disc	38 a	57 a	62 a	50 a	207 a
Inclined disc	50 a	57 a	44 a	18 b	169 a

Numbers with the same letter for each time and angle are not significantly different (P>0.01).
+ counts for angles and disc are not independent at these times.

continued . . .

Table A1-3/3 ii. continued.

Adult preference for leaf discs at angles 0°, 45°, 60° or 90°.

ii. Tobacco cv. White Burley

b. Comparison of angles.

	Sum of adults on leaf discs		
	Horiz. disc	Inclined disc	Total
Hours			
0.25			
0°	47 (59%) a	32 (41%) a	79 b
45°	66 (63%) a	38 (37%) a	104 a
60°	53 (66%) a	27 (34%) ab	80 ab
90°	46 (79%) a	12 (21%) b	58 b
0.50			
0°	53 (61%) a	34 (39%) a	87 a
45°	70 (63%) a	42 (38%) a	112 a
60°	56 (65%) a	30 (35%) ab	86 ab
90°	54 (78%) a	15 (22%) b	69 b
0.75			
0°	55 (60%) a	37 (40%) a	92 ab
45°	76 (64%) a	42 (36%) a	118 a
60°	62 (66%) a	32 (34%) ab	94 b
90°	56 (76%) a	18 (24%) b	74 b
1.00			
0°	55 (58%) a	39 (41%) a	94 ab
45°	78 (63%) a	45 (37%) a	123 a
60°	65 (66%) a	33 (33%) ab	98 b
90°	58 (75%) a	19 (25%) b	77 b
1.25			
0°	53 (57%) a	40 (43%) a	93 ab
45°	80 (63%) a	46 (37%) a	126 a
60°	66 (66%) a	34 (34%) ab	100 ab
90°	58 (74%) a	20 (26%) b	78 b
1.50			
0°	56 (58%) a	41 (42%) a	97 ab
45°	82 (64%) a	47 (36%) a	129 a
60°	72 (69%) a	33 (31%) ab	105 ab
90°	59 (75%) a	20 (25%) b	79 b
1.75			
0°	54 (56%) a	42 (44%) a	96 ab
45°	82 (64%) a	47 (36%) a	129 a
60°	73 (67%) a	36 (33%) ab	109 ab
90°	59 (75%) a	20 (25%) b	79 b
2.00			
0°	56 (57%) a	43 (43%) a	99 ab
45°	83 (64%) a	47 (36%) a	130 a
60°	75 (68%) a	36 (32%) ab	111 ab
90°	60 (75%) a	20 (25%) b	80 b

continued . . .

Table A1-3/3 ii. b. continued.

Sum of adults on leaf discs			
	Horiz. disc	Inclined disc	Total
Hours			
2.50			
0°	55 (56%) a	43 (44%) a	98 ab
45°	82 (62%) a	50 (38%) a	132 a
60°	78 (68%) a	36 (32%) ab	114 ab
90°	63 (77%) a	19 (23%) b	82 b
3.00 +			
0°	56 (55%) b	45 (45%) a	101 b
45°	88 (62%) a	54 (38%) a	142 a
60°	78 (67%) ab	38 (33%) ab	116 ab
90°	68 (78%) ab	19 (22%) b	87 b
3.50 +			
0°	54 (54%) b	46 (46%) a	100 bc
45°	89 (61%) a	58 (39%) a	147 a
60°	84 (67%) ab	42 (33%) a	126 ab
90°	68 (79%) ab	18 (21%) b	86 c
4.00 +			
0°	57 (55%) b	47 (45%) a	104 bc
45°	89 (61%) a	58 (39%) a	147 a
60°	86 (66%) ab	44 (34%) a	130 ab
90°	68 (77%) b	20 (23%) b	88 c
5.00 +			
0°	53 (52%) c	49 (48%) a	102 bc
45°	88 (60%) a	59 (40%) a	147 a
60°	84 (65%) ab	46 (35%) a	130 ab
90°	69 (76%) bc	22 (24%) b	91 c
6.00			
0°	38 (48%) b	42 (52%) a	80 bc
45°	74 (64%) a	42 (36%) a	116 a
60°	73 (64%) a	41 (36%) a	114 ab
90°	50 (69%) ab	22 (31%) a	72 c
24.00 +			
0°	38 (43%) a	50 (57%) a	88 ab
45°	57 (50%) a	57 (50%) a	114 a
60°	62 (58%) a	44 (42%) a	106 a
90°	50 (74%) a	18 (26%) b	68 b

Numbers with the same letter for each time and disc are not significantly different (P>0.01).
+ Counts for angles and disc are not independent at these times.

continued . . .

Table A1-3/3 continued.

Adult preference for leaf discs at angles 0°, 45°, 60° or 90°.

iii. Rauriki.

a. Comparison of inclined and horizontal leaf discs.

Sum of adults on leaf discs	Angle 0°	45°	60°	90°
Hours				
0.25				
Horizontal disc	142 a	161 a	164 a	90 a
Inclined disc	147 a	40 b	30 b	26 b
0.50				
Horizontal disc	168 a	183 a	174 a	112 a
Inclined disc	158 a	47 b	38 b	30 b
0.75				
Horizontal disc	175 a	199 a	197 a	126 a
Inclined disc	165 a	54 b	41 b	32 b
1.00				
Horizontal disc	193 a	212 a	205 a	137 a
Inclined disc	170 a	71 b	41 b	37 b
1.50				
Horizontal disc	190 a	225 a	216 a	146 a
Inclined disc	175 a	57 b	43 b	41 b
2.00				
Horizontal disc	193 a	238 a	229 a	158 a
Inclined disc	182 a	60 b	46 b	41 b
3.00				
Horizontal disc	196 a	253 a	243 a	168 a
Inclined disc	180 a	61 b	52 b	47 b
4.00				
Horizontal disc	204 a	265 a	271 a	193 a
Inclined disc	185 a	73 b	59 b	57 b
5.00				
Horizontal disc	214 a	271 a	281 a	209 a
Inclined disc	200 a	74 b	70 b	69 b
6.00				
Horizontal disc	200 a	219 a 2M	218 a	165 a
Inclined disc	158 a	78 b 2M	61 b	60 b
24.00				
Horizontal disc	167 a	190 a 2M	181 a	148 a
Inclined disc	150 a	89 b 2M	68 b	83 b

Numbers with the same letter within each angle and time are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).
See page 95.

continued . . .

Table A1-3/3 iii. continued.

b. Comparison of angles.

	Sum of adults on leaf discs		
	Horiz. disc	Inclined disc	Total
Hours			
0.25			
0°	142 (49%) a	147 (51%) a	289 a
45°	161 (80%) a	40 (20%) b	201 b
60°	164 (85%) a	30 (15%) b	194 b
90°	90 (78%) b	26 (22%) b	116 c
0.50			
0°	168 (52%) a	158 (48%) a	326 a
45°	183 (80%) a	47 (20%) b	230 b
60°	174 (82%) a	38 (18%) b	212 b
90°	112 (79%) b	30 (21%) b	142 c
0.75			
0°	175 (51%) a	165 (49%) a	340 a
45°	199 (79%) a	54 (21%) b	253 b
60°	197 (83%) a	41 (17%) b	238 b
90°	126 (80%) b	32 (20%) b	158 c
1.00			
0°	193 (53%) a	170 (47%) a	363 a
45°	212 (75%) a	71 (25%) b	283 b
60°	205 (83%) a	41 (17%) c	246 b
90°	137 (79%) b	37 (21%) c	174 c
1.50			
0°	190 (52%) ab	175 (48%) a	365 a
45°	225 (80%) a	57 (20%) b	282 b
60°	216 (83%) a	43 (17%) b	259 b
90°	146 (78%) b	41 (22%) b	187 c
2.00			
0°	193 (51%) ab	182 (49%) a	375 a
45°	238 (80%) a	60 (20%) b	298 b
60°	229 (83%) a	46 (17%) b	275 b
90°	158 (79%) b	41 (21%) b	199 c
3.00			
0°	196 (52%) bc	180 (48%) a	376 a
45°	253 (81%) a	61 (19%) b	314 ab
60°	243 (82%) ab	52 (18%) b	295 b
90°	168 (78%) c	47 (22%) b	215 c

continued . . .

Table A1-3/3 iii. b. continued.

Sum of adults on leaf discs									
	Horiz. disc			Inclined disc			Total		
Hours									
4.00									
0°	204	(52%)	b	185	(48%)	a	389	a	
45°	265	(78%)	a	73	(22%)	b	338	a	
60°	271	(82%)	a	59	(18%)	b	330	a	
90°	193	(77%)	b	57	(23%)	b	250	b	
5.00									
0°	214	(52%)	bc	200	(48%)	a	414	a	
45°	271	(79%)	ab	74	(21%)	b	345	a	
60°	281	(80%)	a	70	(20%)	b	351	a	
90°	209	(75%)	c	69	(25%)	b	278	b	
6.00									
0°	200	(56%)	ab	158	(44%)	a	358	a	
45°	219	(74%)	a	78	(26%)	b	297	a	
60°	2M 218	(78%)	a	2M 61	(22%)	b	4M 279	b	
90°	165	(73%)	b	60	(27%)	b	225	b	
24.00									
0°	167	(53%)	a	150	(47%)	a	317	a	
45°	190	(68%)	a	89	(32%)	b	279	ab	
60°	2M 181	(73%)	a	2M 68	(27%)	b	4M 249	b	
90°	148	(64%)	a	83	(36%)	b	231	b	

Numbers with the same letter for each time and disc are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).
See page 95.

continued . . .

Table A1-3/3 continued.

Adult preference for leaf discs at angles 0° or 45°. Projected equal disc area.

iv. Tomato cv. Virosa.

a. Comparison of horizontal and inclined leaf discs.

Sum of adults on leaf discs	Angle 0°		Angle 45°	
Hours				
0.17				
Horizontal disc	117 a	48%	200 a	83%
Inclined disc	127 a	52%	42 b	17%
0.25				
Horizontal disc	163 a	44%	285 a	81%
Inclined disc	206 a	56%	69 b	19%
0.50				
Horizontal disc	193 a	46%	330 a	80%
Inclined disc	229 a	54%	83 b	20%
0.75				
Horizontal disc	208 a	47%	346 a	80%
Inclined disc	239 a	53%	87 b	20%
1.00				
Horizontal disc	214 a	46%	350 a	79%
Inclined disc	252 a	54%	94 b	21%

Numbers with the same letter within each angle and time are not significantly different (P>0.0).

b. Comparison of angles.

Sum of adults on leaf discs.

	Horizontal disc	Inclined disc	Total
Hours			
0.17			
0°	117 b	127 a	244 a
45°	200 a	42 b	242 a
0.25			
0°	163 b	206 a	369 a
45°	285 a	69 b	354 a
0.50			
0°	193 b	229 a	422 a
45°	330 a	83 b	413 a
0.75			
0°	208 b	239 a	447 a
45°	346 a	87 b	433 a
1.00			
0°	214 b	252 a	466 a
45°	350 a	94 b	444 a

Numbers with the same letter within each disc and time are not significantly different (P>0.01).

continued . . .

Table A1-3/3 continued.

Adult preference for leaf discs at angles 0° or 45°. Projected equal disc area.

v. Rauriki.

a. Comparison of horizontal and inclined leaf discs.

Sum of adults on leaf discs	Angle 0°		Angle 45°	
Hours				
0.17				
Horizontal disc	151 a	47%	132 a	57%
Inclined disc	173 a	53%	100 a	43%
0.25				
Horizontal disc	178 a	50%	156 a	45%
Inclined disc	181 a	50%	127 a	45%
0.50				
Horizontal disc	187 a	48%	172 a	57%
Inclined disc	201 a	52%	131 a	43%
0.75				
Horizontal disc	189 a	48%	178 a	57%
Inclined disc	205 a	52%	137 a	43%
1.00				
Horizontal disc	192 a	47%	190 a	57%
Inclined disc	213 a	53%	141 b	43%

Numbers with the same letter each angle and time are not significantly different (P>0.01).

b. Comparison of angles.

Sum of adults on leaf discs.

	Horizontal disc	Inclined disc	Total
Hours			
0.17			
0°	151 a	173 a	324 a
45°	132 a	100 b	232 b
0.25			
0°	178 a	181 a	359 a
45°	156 a	127 b	283 b
0.50			
0°	187 a	201 a	388 a
45°	172 a	131 b	303 b
0.75			
0°	189 a	205 a	394 a
45°	178 a	137 b	315 b
1.00			
0°	192 a	213 a	405 a
45°	190 a	141 b	331 b

Numbers with the same letter for each time disc and total are not significantly different (P>0.01).

continued . . .

Table A1-3/3 continued.

Adult preference for leaf discs at angles 0° or 60°. Projected equal disc area.

vi. Rauriki.

a. Comparison of horizontal and inclined leaf discs.

Sum of adults on leaf discs	Angle 0°	Angle 60°
Hours		
0.17		
Horizontal disc	17 a 45%	42 a 75%
Inclined disc	21 a 55%	14 b 25%
0.25		
Horizontal disc	32 a 48%	52 a 72%
Inclined disc	35 a 52%	20 b 28%
0.50		
Horizontal disc	43 a 48%	65 a 74%
Inclined disc	47 a 52%	23 b 26%
0.75		
Horizontal disc	56 a 50%	74 a 74%
Inclined disc	57 a 50%	26 b 26%
1.00		
Horizontal disc	59 a 45%	85 a 77%
Inclined disc	71 a 55%	25 b 23%

Numbers with the same letter within each angle and time are not significantly different (P>0.01).

b. Comparison of angles.

Sum of adults on leaf discs.

	Horizontal disc	Inclined disc	Total
Hours			
0.17			
0°	17 b	21 a	38 a
60°	42 a	14 a	56 a
0.25			
0°	32 a	35 a	67 a
60°	52 a	20 a	72 a
0.50			
0°	43 a	47 a	90 a
60°	65 a	23 b	88 a
0.75			
0°	56 a	57 a	113 a
60°	74 a	26 b	100 a
1.00			
0°	59 a	71 a	130 a
60°	85 a	25 b	110 a

Numbers with the same letter within each time and disc are not significantly different (P>0.01).

Table A1-3/4

Adult preference for younger or mature leaf discs at angles 0°, 45°, 60° or 90°.

i. Tomato cv. Virosa

Sum of adults on leaf discs	Angle 0°	45°	60°	90°	Total
Hours					
0.25					
Younger leaf	174 a	159 a	126 a	88 a	547 x
Mature leaf	164 a	153 a	108 a	80 a	505 x
0.50					
Younger leaf	178 a	174 a	143 a	99 a	594 x
Mature leaf	179 a	160 a	121 a	97 a	557 x
0.75					
Younger leaf	173 a	178 a	148 a	103 a	602 x
Mature leaf	186 a	167 a	126 a	114 a	593 x
1.00					
Younger leaf	179 a	179 a	155 a	113 a	626 x
Mature leaf	196 a	171 a	132 a	124 a	623 x
1.50					
Younger leaf	182 a	186 a	156 a	118 a	642 x
Mature leaf	195 a	176 a	139 a	142 a	652 x
2.00					
Younger leaf	186 a	191 a	160 a	118 a	655 x
Mature leaf	201 a	180 a	1M129 a	148 a	1M658 x
3.00					
Younger leaf	183 a	204 a	167 a	122 a	676 x
Mature leaf	203 a	182 a	1M133 a	153 a	1M671 x
4.00					
Younger leaf	163 a	180 a	151 a	112 a	606 x
Mature leaf	180 a	183 a	1M123 a	142 a	1M628 x
5.00					
Younger leaf	165 a	187 a	148 a	121 a	621 x
Mature leaf	184 a	180 a	1M123 a	143 a	1M630 x
6.00					
Younger leaf	160 a	161 a	124 a	123 a	568 x
Mature leaf	167 a	162 a	1M119 a	135 a	1M583 x
24.00					
Younger leaf	1M116 a	1M126 a	2M 92 a	111 a	4M445 x
Mature leaf	1M143 a	1M116 a	1M100 a	1M105 a	4M464 x

Numbers with the same letter within each time are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).
See page 95.

continued . . .

Table A1-3/4 continued.

Adult preference for younger or mature leaf discs at angles 0°, 45°, 60° or 90°.

ii. Tobacco cv. White Burley.

Sum of adults on leaf discs	Angle 0°	45°	60°	90°	Total
Hours					
0.25					
Younger leaf	59 a	49 a	43 a	37 ab	188 x
Mature leaf	20 b	55 a	37 a	21 b	133 y
0.50					
Younger leaf	63 a	52 a	46 ab	43 abc	204 x
Mature leaf	24 c	60 a	40 abc	26 bc	150 y
0.75					
Younger leaf	66 a	55 a	49 ab	47 abc	217 x
Mature leaf	26 c	63 a	45 abc	27 bc	161 y
1.00					
Younger leaf	66 a	57 a	51 ab	49 ab	223 x
Mature leaf	28 b	66 a	47 ab	28 b	169 y
1.25					
Younger leaf	65 a	58 a	52 ab	49 abc	224 x
Mature leaf	28 c	68 a	48 abc	29 c	173 y
1.50					
Younger leaf	68 a	59 a	53 a	50 ab	230 x
Mature leaf	29 b	70 a	52 ab	29 ab	180 x
1.75					
Younger leaf	66 a	60 a	54 a	51 ab	231 x
Mature leaf	30 b	69 a	55 a	28 b	182 x
2.00					
Younger leaf	68 a	60 a	54 ab	52 ab	234 x
Mature leaf	31 bc	70 a	57 a	28 c	186 x
2.50					
Younger leaf	67 a	61 a	58 a	54 ab	240 x
Mature leaf	31 bc	71 a	56 a	28 c	186 y
3.00					
Younger leaf	69 a	65 a	59 a	57 a	250 x
Mature leaf	32 b	77 a	57 a	30 b	196 x
3.50					
Younger leaf	66 a	70 a	64 a	57 ab	257 x
Mature leaf	34 bc	77 a	62 a	29 c	202 y
4.00					
Younger leaf	70 a	70 a	65 a	60 a	265 x
Mature leaf	34 b	77 a	65 a	28 b	204 y
5.00					
Younger leaf	68 a	70 a	63 a	60 a	261 x
Mature leaf	34 b	77 a	67 a	31 b	209 x
6.00					
Younger leaf	60 a	59 a	63 a	51 a	233 x
Mature leaf	20 b	57 a	51 a	21 b	149 y
24.00					
Younger leaf	57 a	55 ab	63 a	49 ab	224 x
Mature leaf	31 bc	59 a	43 ab	19 c	152 y

Numbers with the same letter within each time are not significantly different (P>0.01).

continued . . .

Table A1-3/4 continued.

Adult preference for younger or mature leaf discs at angles 0°, 45°, 60° or 90°.

iii. Rauriki.

Sum of adults on leaf discs	Angle 0°	45°	60°	90°	Total
Hours					
0.25					
Younger leaf	140 a	86 a	84 a	47 a	357 y
Mature leaf	149 a	115 a	110 a	69 a	443 x
0.50					
Younger leaf	162 a	99 b	98 a	58 a	417 x
Mature leaf	164 a	131 a	114 a	84 a	493 x
0.75					
Younger leaf	175 a	114 a	112 a	64 a	465 x
Mature leaf	165 a	139 a	126 a	94 a	524 x
1.00					
Younger leaf	188 a	123 a	115 a	74 a	500 x
Mature leaf	175 a	160 a	131 a	100 a	566 x
1.50					
Younger leaf	184 a	133 a	128 a	78 a	523 x
Mature leaf	181 a	149 a	131 a	109 a	570 x
2.00					
Younger leaf	192 a	142 a	134 a	81 b	549 x
Mature leaf	183 a	156 a	141 a	118 a	598 x
3.00					
Younger leaf	193 a	154 a	147 a	90 a	584 x
Mature leaf	183 a	160 a	148 a	125 a	616 x
4.00					
Younger leaf	197 a	161 a	163 a	111 a	632 x
Mature leaf	192 a	177 a	167 a	139 a	675 x
5.00					
Younger leaf	210 a	165 a	170 a	120 a	665 x
Mature leaf	204 a	180 a	181 a	158 a	723 x
6.00					
Younger leaf	174 a	139 a	2M137 a	97 a	2M547 x
Mature leaf	184 a	158 a	2M142 a	128 a	2M612 x
24.00					
Younger leaf	149 a	132 a	2M128 a	119 a	2M528 x
Mature leaf	168 a	147 a	2M121 a	112 a	2M548 x

Numbers with the same letter within each time are not significantly different (P>0.01).
M: some missing values for these counts (number indicated).

See page 95.

Table A1-3/5

Adult preference for inclined or horizontal leaf discs at angles 0°, 45° or 60°. Comparison of actual and projected equal disc area.

i. Tomato cv. Virosa.

Sum and percent adults on leaf discs	Angle 0°	Angle 45°
Equal actual area		
Hours		
0.25		
Horizontal disc	182 a 54%	202 a 65%
Inclined disc	156 a 46%	110 b 35%
0.50		
Horizontal disc	191 a 54%	221 a 66%
Inclined disc	166 a 46%	113 b 34%
0.75		
Horizontal disc	192 a 53%	228 a 66%
Inclined disc	167 a 47%	117 b 34%
1.00		
Horizontal disc	199 a 53%	231 a 66%
Inclined disc	176 a 47%	119 b 34%
Equal projected area		
Hours		
0.17		
Horizontal disc	117 a 48%	200 a 83%
Inclined disc	127 a 52%	42 b 17%
0.25		
Horizontal disc	163 a 44%	285 a 81%
Inclined disc	206 a 56%	69 b 19%
0.50		
Horizontal disc	193 a 46%	330 a 80%
Inclined disc	229 a 54%	83 b 20%
0.75		
Horizontal disc	208 a 47%	346 a 80%
Inclined disc	239 a 53%	87 b 20%
1.00		
Horizontal disc	214 a 46%	350 a 79%
Inclined disc	252 a 54%	94 b 21%

Numbers with the same letter for each time, angle, disc group and area group are not significantly different (P>0.01).
This table is redrawn from Appendix Table A1-3/3 i and iv.

continued . . .

Table A1-3/5 continued.

Adult preference for inclined or horizontal leaf discs for angles 0°, 45° or 60°. Comparison of actual and projected equal disc area.

ii. Rauriki.

Sum and percent adults on leaf discs	Angle		
	0°	45°	60°
Equal actual area			
Hours			
0.25			
Horizontal disc	142 a 49%	161 a 80%	164 a 85%
Inclined disc	147 a 51%	40 b 20%	30 b 15%
0.50			
Horizontal disc	168 a 52%	183 a 80%	174 a 82%
Inclined disc	158 a 48%	47 b 20%	38 b 18%
0.75			
Horizontal disc	175 a 51%	199 a 79%	197 a 83%
Inclined disc	165 a 49%	54 b 21%	41 b 17%
1.00			
Horizontal disc	193 a 53%	212 a 75%	205 a 83%
Inclined disc	170 a 47%	71 b 25%	41 b 17%
Equal projected area			
Hours			
0.17			
Horizontal disc	151 a 46%	132 a 57%	42 a 75%
Inclined disc	173 a 54%	100 a 43%	14 b 25%
0.25			
Horizontal disc	178 a 49%	156 a 55%	52 a 72%
Inclined disc	181 a 51%	127 a 45%	20 b 28%
0.50			
Horizontal disc	187 a 48%	172 a 57%	65 a 74%
Inclined disc	201 a 52%	131 a 43%	23 b 26%
0.75			
Horizontal disc	189 a 48%	178 a 57%	74 a 74%
Inclined disc	205 a 52%	137 a 43%	26 b 26%
1.00			
Horizontal disc	192 a 47%	190 a 57%	85 a 77%
Inclined disc	213 a 53%	141 b 43%	25 b 23%

Numbers with the same letter for each time, angle, disc group and area group are not significantly different (P>0.01).
This table is redrawn from Appendix Table A1-3/3 iii, v and vi.

Table A2-1/1

Oviposition on leaf discs and intact leaves of 4 leaf ages. No choice test.

i. Tomato cv. Moneymaker.

Sum of eggs	Position within leaf: Nearest apex	Position within leaf: Nearest petiole	Total
Leaf age			
4 Youngest			
Leaf disc	190 ab	205 a	395 p
Intact leaf	172 ab	165 ab	337 p
Total	362 w	370 w	
3			
Leaf disc	61 ef	86 de	147 r
Intact leaf	109 cd	150 bc	259 q
Total	170 y	236 x	
2			
Leaf disc	89 de	78 de	167 r
Intact leaf	64 e	90 de	154 r
Total	153 y	168 y	
1 Oldest			
Leaf disc	64 e	83 de	147 r
Intact leaf	36 f	62 e	98 s
Total	100 z	145 y	

Numbers with the same letter are not significantly different (P>0.01). The two sets of totals have been analyzed separately.

continued . . .

Table A2-1/1 continued.

Oviposition on leaf discs and intact leaves.
No choice test.

ii. Tobacco cv. White Burley.

Sum of eggs	Position within leaf: Nearest apex		Middle		Nearest petiole		Total
Leaf age							
4 Youngest							
Leaf disc	361 bcd	(4) 19	419 ab	(4) 19	457 a	(4) 18	1237
Intact leaf	458 a	(4) 17	321 cde	(4) 19	396 ab	(4) 18	1175
Total	819		740		853		
3							
Leaf disc	434 ab	(4) 15	312 cde	(4) 18	258 g	(4) 17	1004
Intact leaf	380 bc	(4) 20	296 ef	(4) 18	366 bc	(4) 18	1042
Total	814		608		624		
2							
Leaf disc	291 ef	(4) 19	262 efg	(4) 15	263 efg	(4) 19	816
Intact leaf	432 ab	(4) 20	393 ab	(4) 19	223 g	(4) 17	1048
Total	723		655		486		
1 Oldest							
Leaf disc	153	(2) 6	141	(2) 9	100	(2) 9	394
Intact leaf	184	(2) 10	158	(2) 8	140	(2) 9	482
Total	337		299		240		

Figures in parenthesis are the number of valid observations followed by the sum of whiteflies alive at the end of the experiment. Numbers with the same letter are not significantly different (P>0.01). The oldest leaf age and the totals have not been included in the analysis.

Table A2-1/2

Tomato cv. Virosa.

i. Oviposition and leaf hair density of intact plants - 4 leaf ages and both leaf surfaces. No choice test.

	Lower surface	Upper surface	Grand mean
Short hairs			
Leaf age			
1 oldest	41.3	15.8	28.5
2	214.0	97.8	155.9
3	249.0	86.3	167.6
4 youngest	400.1	98.3	249.2
Glandular hairs			
Leaf age			
1 oldest	6.0	.1	3.1
2	9.0	.5	4.8
3	3.8	.6	2.2
4 youngest	12.4	3.9	8.1
Long hairs			
Leaf age			
1 oldest	.0	.3	.1
2	.0	.4	.2
3	.1	.6	.4
4 youngest	.4	.9	.6
Sum of eggs			Total
Leaf age			
1 oldest	214 d	190 d	404
2	356 b	276 c	632
3	448 a	277 c	725
4 youngest	433 a	382 ab	815

Numbers with the same letter are not significantly different (P>0.01).

Table A2-1/2

Tomato cv. Virosa.

ii. Oviposition and nitrogen, phosphorus and potassium content for 4 leaf ages

	% Nitrogen	% Phosphorus	% Potassium	Eggs	Sum of adults
Leaf discs. Choice test. (Expt. 1-3/5)				Mean	
Leaf age					
4 Youngest	2.69	.35	5.46	4.331 a	138 x
3	2.33	.30	4.41	2.118 bc	123 x
2	1.73	.36	6.05	2.551 b	130 x
1 Oldest	1.35	.58	5.56	.775 c	116 x
Grand mean	2.02	.40	5.36	2.444 **Total**	508
Intact plants. No choice test. (Expt. 2-1/3)				Sum	
Leaf age					
4 youngest	2.76	.36	4.53	815 a	
3	2.26	.29	4.15	725 ab	
2	1.67	.35	4.96	632 b	
1 oldest	1.47	.56	5.36	404 c	
Grand mean	2.04	.39	4.75	**Total** 2576	

Numbers with the same letter within each experiment are not significantly different (P>0.01). Sum of adults recorded at 13.5 hours. Percentages are % dry weight.

Table A2-1/3

Oviposition on lower or upper surface of leaf discs. Choice test.

Mean eggs per whitefly-day	Lower surface			Upper surface			
Datura sp.	3.363	(.279)	10	7.493	(1.008)	10	**
Tomato cv. Virosa	8.643	(1.746)	7	10.641	(2.403)	7	
Abutilon sp.	1.787	(.791)	10	6.815	(1.054)	10	**
Tobacco cv. White Burley	5.025	(.702)	10	2.364	(.410)	10	**

Figures in parenthesis are the standard errors of the mean followed by the number of valid observations.
** Number of eggs on lower and upper leaf surfaces are significantly different ($P<0.01$).

Table A2-1/4

Tomato cv. Virosa.

Oviposition on lower or upper surface of leaf discs of 4 ages. Choice test.

Mean eggs per	Leaf surface								
	Lower			Upper			Total		
whitefly-day									
Leaf age									
1 Oldest	.755	(.141)	8	.794	(.213)	8	.775 c	(.123)	16
2	2.768	(.563)	8	2.333	(.256)	8	2.551 b	(.304)	16
3	1.962	(.414)	8	2.273	(.797)	8	2.118 bc	(.435)	16
4 Youngest	4.353	(.682)	8	4.309	(.796)	8	4.331 a	(.506)	16

Figures in parenthesis are the standard errors of the mean followed by the number of valid observations.
Numbers with the same letter are not significantly different (P>0.01).

Table A2-1/5

Oviposition on horizontal or inclined leaf discs of younger or mature leaf age.

i. Tomato cv. Virosa.

	Mean eggs per whitefly-day					
	Horizontal disc			Inclined disc		
Angle						
0°						
Younger	3.558	(.901)	7	5.684	(2.233)	7
Mature	1.947	(.454)	7	1.589	(.277)	8
45°						
Younger	3.019	(.992)	8	3.081	(.568)	8
Mature	2.290	(.721)	7	3.099	(1.139)	7
60°						
Younger	3.676	(1.779)	7	4.263	(.808)	8
Mature	2.223	(.503)	7	1.763	(.566)	8
90°						
Younger	2.806	(.514)	8	4.747	(1.007)	8
Mature	2.340	(.480)	7	4.553	(1.263)	8
Mean for all angles						
Younger	3.241	(.526)	30	4.403	(.611)	31
Mature	2.200	(.261)	28	2.740	(.477)	31

Figures in parenthesis are the standard errors of the mean followed by the number of valid observations. There is a significant difference ($P<0.01$) only between leaf ages.

continued . . .

Table A2-1/5 continued.

Oviposition on horizontal or inclined leaf discs of younger or mature leaf age.

ii. Tobacco cv. White Burley.

	Mean eggs per whitefly-day					
	Horizontal disc			Inclined disc		
Angle						
0°						
Younger	4.225	(.038)	2	4.779	(.144)	2
Mature	1.018	(.004)	2	1.239	(.007)	2
45°						
Younger	7.861	(2.051)	2	8.455	(.961)	2
Mature	2.238	(.834)	2	1.209	(.142)	2
60°						
Younger	6.282	(.782)	2	6.057	(1.671)	2
Mature	1.966	(.312)	2	.698	(.189)	2
90°						
Younger	4.128	(3.938)	2	7.294	(6.569)	2
Mature	.282	(.084)	2	1.154	(.031)	2
Total for all angles						
Younger	5.624	(1.034)	8	6.646	(1.394)	8
Mature	1.376	(.339)	8	1.075	(.095)	8

Figures in parenthesis are the standard errors of the mean followed by the number of valid observations. There is a significant difference ($P<0.01$) only between leaf ages.

continued . . .

Table A2-1/5 continued.

Oviposition on horizontal or inclined leaf discs of younger or mature leaf age.

iii. Rauriki.

	Mean eggs per whitefly-day					
	Horizontal disc			Inclined disc		
Angle						
0°						
Younger	9.650	(1.488)	8	9.547	(1.589)	8
Mature	5.150	(1.386)	8	5.588	(1.093)	8
45°						
Younger	7.782	(1.351)	8	6.209	(.669)	8
Mature	5.474	(.965)	8	5.102	(1.021)	8
60°						
Younger	8.053	(1.441)	8	8.863	(1.498)	7
Mature	5.192	(1.311)	8	3.567	(.578)	8
90°						
Younger	8.962	(1.729)	8	5.946	(1.135)	8
Mature	4.935	(1.003)	8	5.405	(.980)	8
Mean for all angles						
Younger	8.612	(.729)	32	7.602	(.665)	31
Mature	5.188	(.562)	32	4.916	(.469)	32

Figures in parenthesis are the standard errors of the mean followed by the number of valid observations. There is a significant difference ($P<0.01$) between leaf ages only.

Table A2-2/1

Adult survival and sex group within sucrose concentration over time.

i. Experiment 2-2/1.

Sum of adults	Day 0		Day 1		Day 2		Day 3	
air								
female	16 a	(2)	1 c	(2)	0 d	(2)	.	
male	16 a	(2)	0 d	(2)	0 d	(2)	.	
mixed sexes	16 a	(2)	0 d	(2)	0 d	(2)	.	
water								
female	15 a	(2)	10 ab	(2)	4 bcd	(2)	0 c	(2)
male	16 a	(2)	15 a	(2)	5 abcd	(2)	0 c	(2)
mixed sexes	16 a	(2)	13 ab	(2)	11 ab	(2)	2 bc	(2)
10% sucrose								
female	16 a	(2)	14 a	(2)	13 ab	(2)	9 ab	(2)
male	16 a	(2)	13 ab	(2)	12 ab	(2)	12 a	(2)
mixed sexes	16 a	(2)	16 a	(2)	16 a	(2)	16 a	(2)
20% sucrose								
female	16 a	(2)	14 a	(2)	14 ab	(2)	14 a	(2)
male	16 a	(2)	13 ab	(2)	12 ab	(2)	12 a	(2)
mixed sexes	16 a	(2)	16 a	(2)	16 a	(2)	16 a	(2)
30% sucrose								
female	15 a	(2)	14 a	(2)	14 ab	(2)	14 a	(2)
male	16 a	(2)	14 a	(2)	14 ab	(2)	14 a	(2)
mixed sexes	16 a	(2)	16 a	(2)	15 ab	(2)	15 a	(2)
40% sucrose								
female	16 a	(2)	13 ab	(2)	12 ab	(2)	9 ab	(2)
male	16 a	(2)	7 abc	(2)	4 bcd	(2)	0 c	(2)
mixed sexes	16 a	(2)	14 a	(2)	12 ab	(2)	10 ab	(2)
50% sucrose								
female	16 a	(2)	13 ab	(2)	9 abc	(2)	6 abc	(2)
male	16 a	(2)	10 ab	(2)	1 cd	(2)	0 c	(2)
mixed sexes	16 a	(2)	9 abc	(2)	0 d	(2)	0 c	(2)
60% sucrose								
female	16 a	(2)	11 ab	(2)	1 cd	(2)	0 c	(2)
male	16 a	(2)	6 abcd	(2)	0 d	(2)	0 c	(2)
mixed sexes	16 a	(2)	3 bcd	(2)	0 d	(2)	0 c	(2)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

i. Experiment 2-2/1.

Sum of adults	Day 4			Day 5			Day 6			Day 7		
water												
female	0	c	(2)	.			.			.		
male	0	c	(2)	.			.			.		
mixed sexes	0	c	(2)	.			.			.		
10% sucrose												
female	8	ab	(2)	8	ab	(2)	8	ab	(2)	7	a	(2)
male	11	ab	(2)	11	ab	(2)	10	a	(2)	9	a	(2)
mixed sexes	16	a	(2)	16	a	(2)	13	a	(2)	10	a	(2)
20% sucrose												
female	14	ab	(2)	14	a	(2)	12	a	(2)	10	a	(2)
male	15	ab	(2)	15	a	(2)	15	a	(2)	14	a	(2)
mixed sexes	16	a	(2)	15	a	(2)	15	a	(2)	12	a	(2)
30% sucrose												
female	14	ab	(2)	13	a	(2)	13	a	(2)	9	a	(2)
male	12	ab	(2)	12	a	(2)	10	a	(2)	9	a	(2)
mixed sexes	15	ab	(2)	13	a	(2)	11	a	(2)	9	a	(2)
40% sucrose												
female	9	ab	(2)	7	b	(2)	4	abc	(2)	1	b	(2)
male	0	c	(2)	0	c	(2)	0	c	(2)	0	b	(2)
mixed sexes	4	b	(2)	2	c	(2)	0	c	(2)	0	b	(2)
50% sucrose												
female	4	bc	(2)	2	bc	(2)	1	bc	(2)	0	b	(2)
male	0	c	(2)	0	c	(2)	0	c	(2)	0	b	(2)
mixed sexes	0	c	(2)	0	c	(2)	0	c	(2)	0	b	(2)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

i. Experiment 2-2/1.

Sum of adults	Day 8		Day 9		Day 10		Day 11	
10% sucrose								
female	4 ab	(2)	3 abc	(2)	2 abc	(2)	1 ab	(2)
male	8 a	(2)	4 abc	(2)	3 abc	(2)	2 ab	(2)
mixed sexes	10 a	(2)	6 abc	(2)	4 abc	(2)	3 ab	(2)
20% sucrose								
female	10 a	(2)	10 a	(2)	9 ab	(2)	7 a	(2)
male	11 a	(2)	11 a	(2)	11 a	(2)	8 a	(2)
mixed sexes	10 a	(2)	9 ab	(2)	8 ab	(2)	6 ab	(2)
30% sucrose								
female	5 a	(2)	1 bc	(2)	0 c	(2)	0 b	(2)
male	9 a	(2)	4 c	(2)	1 bc	(2)	1 ab	(2)
mixed sexes	2 ab	(2)	0 c	(2)	0 c	(2)	0 b	(2)
40% sucrose								
female	0 b	(2)	.		.		.	
male	0 b	(2)	.		.		.	
mixed sexes	0 b	(2)	.		.		.	

Sum of adults	Day 12		Day 13		Day 14		Day 15	
10% sucrose								
female	1 a	(2)	1 ab	(2)	1 ab	(2)	0 a	(2)
male	2 a	(2)	1 ab	(2)	1 ab	(2)	1 a	(2)
mixed sexes	2 a	(2)	0 b	(2)	0 b	(2)	0 a	(2)
20% sucrose								
female	6 a	(2)	3 ab	(2)	3 ab	(2)	1 a	(2)
male	8 a	(2)	8 a	(2)	8 a	(2)	5 a	(2)
mixed sexes	3 a	(2)	0 b	(2)	0 b	(2)	0 a	(2)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

i. Experiment 2-2/1.

Sum of adults	Day							
	16		17		18		19	
10% sucrose								
female	0 a	(2)	0 a	(2)	0 a	(2)	0 a	(2)
male	1 a	(2)	1 a	(2)	1 a	(2)	0 a	(2)
mixed sexes	0 a	(2)	0 a	(2)	0 a	(2)	0 a	(2)
20% sucrose								
female	1 a	(2)	0 a	(2)	0 a	(2)	0 a	(2)
male	3 a	(2)	1 a	(2)	1 a	(2)	1 a	(2)
mixed sexes	0 a	(2)	0 a	(2)	0 a	(2)	0 a	(2)

Numbers with the same letter within the same day are not significantly different (P>0.01).
Figures in parenthesis are the number of valid observations.

Table A2-2/1

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day 0		1		2		3	
water								
female	64	a (8)	63	a (8)	63	a (8)	62	a (8)
male	64	a (8)	63	a (8)	63	a (8)	34	b (8)
mixed sexes	64	a (8)	64	a (8)	63	a (8)	45	ab (8)
15% sucrose								
female	64	a (8)	63	a (8)	63	a (8)	63	a (8)
male	64	a (8)	64	a (8)	63	a (8)	63	a (8)
mixed sexes	64	a (8)	64	a (8)	61	a (8)	61	a (8)
20% sucrose								
female	64	a (8)	64	a (8)	64	a (8)	64	a (8)
male	64	a (8)	64	a (8)	63	a (8)	63	a (8)
mixed sexes	64	a (8)	64	a (8)	64	a (8)	64	a (8)
25% sucrose								
female	64	a (8)	64	a (8)	63	a (8)	61	a (8)
male	64	a (8)	63	a (8)	61	a (8)	61	a (8)
mixed sexes	64	a (8)	63	a (8)	63	a (8)	63	a (8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day 4		Day 5		Day 6		Day 7	
water								
female	26 b	(8)	3 b	(8)	0 b	(8)	.	
male	6 c	(8)	0 b	(8)	0 b	(8)	.	
mixed sexes	23 b	(8)	1 b	(8)	0 b	(8)	.	
15% sucrose								
female	60 a	(8)	60 a	(8)	58 a	(8)	58 a	(8)
male	63 a	(8)	63 a	(8)	63 a	(8)	63 a	(8)
mixed sexes	61 a	(8)	61 a	(8)	60 a	(8)	59 a	(8)
20% sucrose								
female	63 a	(8)	63 a	(8)	63 a	(8)	62 a	(8)
male	62 a	(8)	62 a	(8)	62 a	(8)	60 a	(8)
mixed sexes	64 a	(8)	64 a	(8)	64 a	(8)	64 a	(8)
25% sucrose								
female	59 a	(8)	57 a	(8)	57 a	(8)	53 a	(8)
male	60 a	(8)	60 a	(8)	60 a	(8)	58 a	(8)
mixed sexes	63 a	(8)	61 a	(8)	60 a	(8)	59 a	(8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day							
	8		9		10		11	
15% sucrose								
female	58 a	(8)	57 a	(8)	56 a	(8)	55 ab	(8)
male	63 a	(8)	62 a	(8)	62 a	(8)	62 a	(8)
mixed sexes	59 a	(8)	57 a	(8)	56 a	(8)	54 ab	(8)
20% sucrose								
female	61 a	(8)	60 a	(8)	59 a	(8)	56 ab	(8)
male	60 a	(8)	59 a	(8)	59 a	(8)	58 ab	(8)
mixed sexes	62 a	(8)	62 a	(8)	60 a	(8)	58 ab	(8)
25% sucrose								
female	47 a	(8)	45 a	(8)	37 a	(8)	34 b	(8)
male	58 a	(8)	57 a	(8)	52 a	(8)	48 ab	(8)
mixed sexes	58 a	(8)	55 a	(8)	49 a	(8)	43 ab	(8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day			
	12	13	14	15
15% sucrose				
female	52 a (8)	50 abc (8)	45 ab (8)	41 a (8)
male	61 a (8)	59 a (8)	53 a (8)	49 a (8)
mixed sexes	54 a (8)	54 ab (8)	51 a (8)	48 a (8)
20% sucrose				
female	52 a (8)	43 ab (8)	35 ab (8)	31 abc (8)
male	55 a (8)	51 abc (8)	46 ab (8)	37 ab (8)
mixed sexes	52 a (8)	46 abc (8)	39 ab (7)	32 abc (7)
25% sucrose				
female	24 b (8)	20 d (8)	8 c (8)	8 d (8)
male	39 ab (8)	30 cd (8)	25 b (8)	20 bcd (8)
mixed sexes	40 ab (8)	33 bcd (8)	25 b (8)	16 cd (8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day			
	16	17	18	19
15% sucrose				
female	36 ab (7)	36 ab (7)	30 ab (7)	27 ab (7)
male	48 a (8)	40 ab (8)	30 ab (8)	27 ab (8)
mixed sexes	46 a (8)	45 a (8)	39 a (8)	35 a (8)
20% sucrose				
female	18 bcd (8)	13 bcd (8)	8 cde (8)	6 cde (8)
male	31 abc (8)	27 abc (8)	22 abc (8)	16 bc (8)
mixed sexes	28 abc (7)	20 bc (7)	17 bcd (7)	13 bcd (7)
25% sucrose				
female	7 d (8)	4 d (8)	2 e (8)	1 e (8)
male	15 c (8)	12 cd (8)	6 de (8)	3 de (8)
mixed sexes	8 d (8)	6 d (8)	5 e (8)	1 e (8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day			
	20	21	22	23
15% sucrose				
female	21 ab (7)	18 ab (7)	13 abc (7)	11 abc (7)
male	23 ab (8)	21 a (8)	17 ab (8)	14 ab (8)
mixed sexes	31 a (8)	29 a (8)	26 a (8)	21 a (8)
20% sucrose				
female	3 cd (8)	3 c (8)	2 de (8)	1 d (8)
male	14 ab (8)	13 abc (8)	8 bcd (8)	6 bcd (8)
mixed sexes	13 bc (7)	7 bcd (7)	4 cde (7)	2 cd (7)
25% sucrose				
female	1 d (8)	1 cd (8)	0 e (8)	0 d (8)
male	2 d (8)	2 d (8)	2 de (8)	2 cd (8)
mixed sexes	0 d (8)	0 d (8)	0 e (8)	0 d (8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day 24		Day 25		Day 26		Day 27	
15% sucrose								
female	8	abc (7)	6	abc (7)	4	abc (7)	4	ab (7)
male	11	ab (8)	9	ab (8)	8	ab (8)	7	a (8)
mixed sexes	17	a (8)	14	a (8)	9	a (8)	8	a (8)
20% sucrose								
female	1	cd (8)	1	c (8)	1	bc (8)	0	b (8)
male	5	bcd (8)	3	bc (8)	3	abc (8)	0	b (8)
mixed sexes	0	d (7)	0	c (7)	0	c (7)	0	b (7)

Sum of adults	Day 28		Day 29		Day 30		Day 31	
15% sucrose								
female	4	a (7)	3	a (7)	3	a (7)	3	a (7)
male	6	a (8)	5	a (8)	1	a (8)	0	a (8)
mixed sexes	8	a (8)	6	a (8)	3	a (8)	2	a (8)

continued . . .

Table A2-2/1 continued.

Adult survival and sex group within sucrose concentration over time.

ii. Experiment 2-2/2.

Sum of adults	Day 32		33		34		35	
15% sucrose								
female	2 a	(7)	0 a	(7)	0 a	(7)	0 a	(7)
male	0 a	(8)	0 a	(8)	0 a	(8)	0 a	(8)
mixed sexes	1 a	(8)	1 a	(8)	1 a	(8)	1 a	(8)

Sum of adults	Day 36		37	
15% sucrose				
female	0 a	(7)	0 a	(7)
male	0 a	(8)	0 a	(8)
mixed sexes	1 a	(8)	0 a	(8)

Numbers with the same letter within the same day are not significantly different (P>0.01).
Figures in parenthesis are the number of valid observations.

Table A2-2/2

Adult survival and sucrose concentration over time.

i. Experiment 2-2/1.

a. Comparison of sucrose concentrations

Sum of adults	Day 0	Day 1	Day 2	Day 3
air	48 a (6)	1 c (6)	0 d (6)	0 c (6)
water	47 a (6)	38 ab (6)	20 c (6)	3 c (6)
10% sucrose	48 a (6)	43 a (6)	41 ab (6)	37 ab (6)
20% sucrose	48 a (6)	45 a (6)	45 a (6)	45 a (6)
30% sucrose	47 a (6)	44 a (6)	43 a (6)	43 a (6)
40% sucrose	48 a (6)	34 ab (6)	28 bc (6)	19 b (6)
50% sucrose	48 a (6)	32 ab (6)	12 c (6)	6 c (6)
60% sucrose	48 a (6)	20 b (6)	1 d (6)	0 c (6)

Sum of adults	Day 4	Day 5	Day 6	Day 7
water	0 c (6)	0 c (6)	0 b (6)	0 b (6)
10% sucrose	35 a (6)	35 a (6)	31 a (6)	26 a (6)
20% sucrose	45 a (6)	44 a (6)	42 a (6)	36 a (6)
30% sucrose	41 a (6)	38 a (6)	34 a (6)	27 a (6)
40% sucrose	13 b (6)	9 b (6)	5 b (6)	1 b (6)
50% sucrose	4 bc (6)	2 bc (6)	1 b (6)	0 b (6)

continued . . .

Table A2-2/2 continued.

Adult survival and sucrose concentration over time.

i. Experiment 2-2/1.

a. Comparisons of sucrose concentrations.

Sum of adults	Day 8		Day 9		Day 10		Day 11	
10% sucrose	22 a	(6)	15 ab	(6)	11 b	(6)	7 b	(6)
20% sucrose	31 a	(6)	30 a	(6)	28 a	(6)	21 a	(6)
30% sucrose	17 a	(6)	6 bc	(6)	1 c	(6)	1 bc	(6)
40% sucrose	0 b	(6)	0 c	(6)	0 c	(6)	0 c	(6)

Sum of adults	Day 12		Day 13		Day 14		Day 15	
10% sucrose	6 a	(6)	4 a	(6)	4 a	(6)	2 a	(6)
20% sucrose	18 a	(6)	12 a	(6)	11 a	(6)	6 a	(6)

Sum of adults	Day 16		Day 17		Day 18		Day 19	
10% sucrose	2 a	(6)	1 a	(6)	1 a	(6)	0 a	(6)
20% sucrose	4 a	(6)	1 a	(6)	1 a	(6)	1 a	(6)

Numbers with the same letter within the same day are not significantly different (P>0.01).
Figures in parenthesis are the number of valid observations.

Table A2-2/2

Adult survival over time within sucrose concentrations.

i. Experiment 2-2/1.

b. Comparisons of survival over time.

Sum of adults	Sucrose concentration			
	air	water	10%	20%
Day				
0	48 a (6)	47 a (6)	48 a (6)	48 a (6)
1	1 b (6)	38 ab (6)	43 a (6)	45 a (6)
2	0 b (6)	20 b (6)	41 ab (6)	45 a (6)
3	0 (6)	3 c (6)	37 ab (6)	45 a (6)
4	.	0 c (6)	35 ab (6)	45 a (6)
5	.	0 (6)	35 ab (6)	44 a (6)
6	.	.	31 abc (6)	42 a (6)
7	.	.	26 abcd (6)	36 ab (6)
8	.	.	22 bcd (6)	31 ab (6)
9	.	.	15 cde (6)	30 ab (6)
10	.	.	11 def (6)	28 abc (6)
11	.	.	7 efg (6)	21 bcd (6)
12	.	.	6 efg (6)	18 bcde (6)
13	.	.	4 efg (6)	12 cdef (6)
14	.	.	4 efg (6)	11 def (6)
15	.	.	2 fg (6)	6 efg (6)
16	.	.	2 fg (6)	4 fg (6)
17	.	.	1 g (6)	1 g (6)
18	.	.	1 g (6)	1 g (6)
19	.	.	0 g (6)	1 g (6)
20	.	.	.	0 g (6)

continued . . .

Table A2-2/2 continued.

Adult survival over time within sucrose concentrations.

i. Experiment 2-2/1.

b. Comparison of survival over time.

Sum of adults	Sucrose concentration			
	30%	40%	50%	60%
Day				
0	47 a (6)	48 a (6)	48 a (6)	48 a (6)
1	44 a (6)	34 ab (6)	32 a (6)	20 b (6)
2	43 a (6)	28 abc (6)	12 b (6)	1 c (6)
3	43 a (6)	19 bcd (6)	6 bc (6)	0 c (6)
4	41 a (6)	13 cde (6)	4 c (6)	.
5	38 a (6)	9 def (6)	2 c (6)	.
6	34 ab (6)	5 efg (6)	1 c (6)	.
7	27 ab (6)	1 fg (6)	0 c (6)	.
8	17 bc (6)	0 g (6)	.	.
9	6 cd (6)	.	.	.
10	1 d (6)	.	.	.
11	1 d (6)	.	.	.
12	0 d (6)	.	.	.

Numbers in brackets are the number of valid observations.

Table A2-2/2

Adult survival and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

Sum of adults	Day 0		Day 1		Day 2		Day 3	
water	192 a	(24)	190 a	(24)	186 a	(24)	141 b	(24)
15% sucrose	192 a	(24)	191 a	(24)	187 a	(24)	187 a	(24)
20% sucrose	192 a	(24)	192 a	(24)	191 a	(24)	191 a	(24)
25% sucrose	192 a	(24)	188 a	(24)	187 a	(24)	185 a	(24)

Sum of adults	Day 4		Day 5		Day 6		Day 7	
water	55 b	(24)	4 b	(24)	0 b	(24)	0 b	(24)
15% sucrose	184 a	(24)	184 a	(24)	181 a	(24)	180 a	(24)
20% sucrose	189 a	(24)	189 a	(24)	189 a	(24)	186 a	(24)
25% sucrose	182 a	(24)	178 a	(24)	177 a	(24)	170 a	(24)

Sum of adults	Day 8		Day 9		Day 10		Day 11	
15% sucrose	180 a	(24)	176 a	(24)	174 a	(24)	171 a	(24)
20% sucrose	183 a	(24)	181 a	(24)	178 a	(24)	172 a	(24)
25% sucrose	162 a	(24)	157 a	(24)	138 a	(24)	125 b	(24)

continued . . .

Table A2-2/2 continued.

Adult survival and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

Sum of adults	Day 12			Day 13			Day 14			Day 15		
15% sucrose	167	a	(24)	163	a	(24)	149	a	(24)	138	a	(24)
20% sucrose	159	a	(24)	140	a	(24)	120	a	(24)	100	a	(23)
25% sucrose	103	b	(24)	83	b	(24)	58	b	(24)	44	b	(24)

Sum of adults	Day 16			Day 17			Day 18			Day 19		
15% sucrose	130	a	(24)	121	a	(23)	99	a	(23)	89	a	(23)
20% sucrose	77	b	(23)	60	b	(23)	47	b	(23)	35	b	(23)
25% sucrose	30	c	(24)	22	c	(24)	13	c	(24)	5	c	(24)

continued . . .

Table A2-2/2 continued.

Adult survival and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

Sum of adults	Day			
	20	21	22	23
15% sucrose	75 a (23)	68 a (23)	56 a (23)	46 a (23)
20% sucrose	30 b (23)	23 b (23)	14 b (23)	9 b (23)
25% sucrose	3 c (24)	3 c (24)	2 c (24)	2 c (24)

Sum of adults	Day			
	24	25	26	27
15% sucrose	36 a (23)	29 a (23)	21 a (23)	19 a (23)
20% sucrose	6 b (23)	4 b (23)	4 b (23)	2 b (23)
25% sucrose	0 c (24)	0 c (24)	0 c (24)	0 c (24)

continued . . .

Table A2-2/2 continued.

Adult survival and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

Sum of adults	Day 28		Day 29		Day 30		Day 31	
15% sucrose	18 a	(23)	14 a	(23)	7 a	(23)	5 a	(23)
20% sucrose	0 b	(23)	0 b	(23)	0 a	(23)	0 a	(23)

Sum of adults	Day 32		Day 33		Day 34		Day 35	
15% sucrose	3 a	(23)	1 a	(23)	1	(23)	1	(23)
20% sucrose	0 a	(23)	0 a	(23)	0	(23)	0	(23)

Sum of adults	Day 36		Day 37	
15% sucrose	1	(23)	0	(23)
20% sucrose	0	(23)	0	(23)

Numbers with the same letter within the same day are not significantly different (P>0.01). Figures in parenthesis are the number of valid observations.

Table A2-2/2

ii. Experiment 2-2/2.

Adult survival over time within sucrose concentrations.

b. Comparison of survival over time.

Sum of adults	Sucrose concentration			
	water	15% sucrose	20% sucrose	25% sucrose
Day				
0	192 a (24)	192 a (24)	192 a (24)	192 a (24)
1	190 a (24)	191 a (24)	192 a (24)	188 a (24)
2	186 ab (24)	187 a (24)	191 a (24)	187 a (24)
3	141 b (24)	187 a (24)	191 a (24)	185 a (24)
4	55 c (24)	184 ab (24)	189 a (24)	182 ab (24)
5	4 d (24)	184 ab (24)	189 a (24)	178 ab (24)
6	0 d (24)	181 ab (24)	189 a (24)	177 ab (24)
7	.	180 ab (24)	186 ab (24)	170 ab (24)
8	.	180 ab (24)	183 ab (24)	162 abc (24)
9	.	176 ab (24)	181 ab (24)	157 abc (24)
10	.	174 abc (24)	178 ab (24)	138 bcd (24)
11	.	171 abc (24)	172 ab (24)	125 cde (24)
12	.	167 abc (24)	159 abc (24)	103 de (24)
13	.	163 abcd (24)	140 bcd (24)	83 ef (24)
14	.	149 abcd (24)	120 cd (24)	58 fg (24)
15	.	138 bcde (24)	100 de (23)	44 gh (24)
16	.	130 cde (24)	77 ef (23)	30 hi (24)
17	.	121 def (23)	60 fg (23)	22 ij (24)
18	.	99 efg (23)	47 gh (23)	13 ij (24)
19	.	89 fg (23)	35 ghi (23)	5 jk (24)
20	.	75 gh (23)	30 hij (23)	3 jk (24)
21	.	68 gh (23)	23 ijk (23)	3 jk (24)
22	.	56 hi (23)	14 jkl (23)	2 k (24)
23	.	46 ij (23)	9 klm (23)	2 k (24)
24	.	36 ijk (23)	6 lmn (23)	0 k (24)
25	.	29 jkl (23)	4 lmn (23)	.
26	.	21 kl (23)	4 lmn (23)	.
27	.	19 klm (23)	2 mn (23)	.
28	.	18 klm (23)	0 n (23)	.
29	.	14 lmn (23)	.	.
30	.	7 mno (23)	.	.
31	.	5 nop (23)	.	.
32	.	3 op (23)	.	.
33	.	1 op (23)	.	.
34	.	1 op (23)	.	.
35	.	1 op (23)	.	.
36	.	1 op (23)	.	.
37	.	0 p (23)	.	.

Numbers with the same letter within the same sucrose concentration are not significantly different (P>0.01). Figures in parenthesis are the number of valid observations.

Table A2-2/3

Oviposition and sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

Mean eggs per female per day									
	Day								
	1			2			3		
water									
female	.000	(.000)	1	.600	(.000)	1	.	.	0
mixed sexes	.429	(.429)	2	2.667	(.333)	2	.250	(.250)	2
10% sucrose									
female	.848	(.723)	2	2.034	(1.78)	2	.125	(.125)	2
mixed sexes	2.125	(2.13)	2	1.375	(1.38)	2	.875	(.375)	2
20% sucrose									
female	.333	(.200)	2	1.071	(.643)	2	1.286	(.143)	2
mixed sexes	1.000	(.250)	2	1.875	(.375)	2	1.000	(.500)	2
30% sucrose									
female	3.038	(.038)	2	3.479	(.354)	2	2.563	(.438)	2
mixed sexes	1.250	(.000)	2	3.446	(1.70)	2	2.750	(1.25)	2
40% sucrose									
female	.357	(.357)	2	1.615	(.385)	2	.482	(.118)	2
mixed sexes	.500	(.000)	1	6.000	(.000)	1	1.250	(.000)	1
50% sucrose									
female	.313	(.313)	2	1.610	(.676)	2	.615	(.000)	1
mixed sexes	.429	(.143)	2	.250	(.250)	2	.	.	0
60% sucrose									
female	.308	(.000)	1	.333	(.000)	1	.	.	0
mixed sexes	.333	(.000)	1	.	.	0	.	.	0

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

Mean eggs per female per day									
	Day								
	4			5			6		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
10% sucrose									
female	-.800	(1.20)	2	.929	(1.07)	2	-.214	(.786)	2
mixed sexes	.375	(.375)	2	1.125	(.375)	2	.250	(.250)	2
20% sucrose									
female	1.000	(.143)	2	.357	(.071)	2	.179	(.321)	2
mixed sexes	1.500	(.250)	2	.000	(.250)	2	.750	(.250)	2
30% sucrose									
female	1.521	(.646)	2	.433	(.100)	2	.298	(.869)	2
mixed sexes	1.500	(.500)	2	1.250	(.750)	2	2.071	(.929)	2
40% sucrose									
female	1.200	(.800)	2	.500	(1.00)	2	.000	(.000)	2
mixed sexes	.571	(.000)	1	1.500	(.000)	1	-1.000	(.000)	1
50% sucrose									
female	1.000	(.000)	1	-1.333	(.000)	1	2.000	(.000)	1
mixed sexes	.	.	0	.	.	0	.	.	0

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Mean eggs per female per day								
	Day								
	7			8			9		
10% sucrose									
female	.429	(.000)	1	-.182	(.000)	1	-.286	(.000)	1
mixed sexes	.500	(.500)	2	-.750	(.250)	2	1.000	(.000)	1
20% sucrose									
female	.385	(.385)	2	.042	(.292)	2	-.500	(.500)	2
mixed sex	1.018	(.732)	2	-.200	(.200)	2	.417	(.917)	2
30% sucrose									
female	.383	(.217)	2	-.800	(.800)	2	10.000	(.000)	1
mixed sexes	-.900	(.100)	2	-.667	(.000)	1	.	.	0
40% sucrose									
female	1.333	(.000)	1	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
50% sucrose									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

Mean eggs per female per day

	Day 10			Day 11			Day 12		
10% sucrose									
female	1.600	(.000)	1	-.667	(.000)	1	-1.000	(.000)	1
mixed sexes	-1.000	(.000)	1	1.333	(.000)	1	.000	(.000)	1
20% sucrose									
female	-.227	(.773)	2	.683	(.460)	2	-.167	(.167)	2
mixed sexes	-1.875	(2.13)	2	1.500	(2.50)	2	3.000	(1.00)	2
30% sucrose									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0

	Day 13			Day 14			Day 15		
10% sucrose									
female	2.000	(.000)	1	-2.000	(.000)	1	.	.	0
mixed sexes	.000	(.000)	1	-1.000	(.000)	1	.	.	0
20% sucrose									
female	.450	(.050)	2	-2.000	(1.00)	2	.000	(.000)	1
mixed sexes	.	.	0	.	.	0	.	.	0

	Day 16		
20% sucrose			
female	1.000	(.000)	1
mixed sexes	.	.	0

Standard errors of the mean are in parenthesis followed by the valid number of observations.
For explanation of negative values in this table see page 157.

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Mean eggs per female per day								
	Day								
	1			2			3		
water									
female	.297	(.091)	8	1.609	(.207)	8	3.678	(.483)	8
mixed sexes	.656	(.241)	8	2.344	(.403)	8	3.549	(.433)	8
15% sucrose									
female	.161	(.062)	8	2.643	(.555)	8	3.446	(.434)	8
mixed sexes	.563	(.262)	8	3.031	(.447)	8	4.135	(.484)	8
20% sucrose									
female	.875	(.151)	8	4.328	(.484)	8	3.953	(.479)	8
mixed sexes	.844	(.344)	8	4.344	(.387)	8	4.844	(.522)	8
25% sucrose									
female	1.469	(.480)	8	4.011	(.282)	8	4.497	(.416)	8
mixed sexes	1.000	(.415)	8	4.250	(.571)	8	3.906	(.612)	8
	Day								
	4			5			6		
water									
female	2.160	(.276)	8	.000	(2.00)	2	.	.	0
mixed sexes	1.500	(.412)	7	3.000	(.000)	1	.	.	0
15% sucrose									
female	2.546	(.207)	8	1.943	(.106)	8	.622	(.238)	8
mixed sexes	2.625	(.443)	8	1.771	(.258)	8	.771	(.220)	8
20% sucrose									
female	2.611	(.253)	8	1.310	(.245)	8	1.174	(.105)	8
mixed sexes	2.500	(.498)	8	1.344	(.275)	8	.469	(.180)	8
25% sucrose									
female	2.505	(.391)	8	.690	(.285)	8	1.057	(.240)	8
mixed sexes	1.813	(.323)	8	.830	(.416)	8	1.112	(.449)	8

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Mean eggs per female per day								
	Day								
	7			8			9		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	.432	(.088)	8	.297	(.272)	8	-.277	(.098)	8
mixed sexes	.167	(.184)	8	.240	(.281)	8	-.083	(.277)	8
20% sucrose									
female	.488	(.337)	8	.656	(.230)	8	.101	(.180)	8
mixed sexes	.469	(.186)	8	.656	(.216)	8	.156	(.216)	8
25% sucrose									
female	.555	(.179)	8	.637	(.332)	8	-.354	(.329)	8
mixed sexes	.531	(.224)	8	.466	(.261)	8	.158	(.253)	8
	Day								
	10			11			12		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	.096	(.147)	8	.199	(.085)	8	.306	(.132)	8
mixed sexes	.473	(.180)	8	.238	(.163)	8	.458	(.230)	8
20% sucrose									
female	.161	(.097)	8	.147	(.102)	8	.029	(.165)	8
mixed sexes	.271	(.172)	8	-.112	(.184)	8	.164	(.170)	8
25% sucrose									
female	.160	(.168)	8	.606	(.512)	8	-.439	(.593)	8
mixed sexes	-.043	(.307)	7	.346	(.246)	7	.157	(.231)	7

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

Mean eggs per female per day									
	Day								
	13			14			15		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	-.150	(.134)	8	.381	(.146)	8	-.144	(.122)	8
mixed sexes	-.417	(.316)	8	.098	(.201)	8	-.408	(.175)	7
20% sucrose									
female	.301	(.272)	8	-.555	(.333)	8	1.018	(.409)	8
mixed sexes	.106	(.212)	8	.148	(.110)	8	1.472	(1.53)	6
25% sucrose									
female	.370	(.188)	7	-.557	(.544)	5	-1.000	(.822)	5
mixed sexes	.600	(.380)	7	-.433	(.386)	5	.000	(.577)	3
	Day								
	16			17			18		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	-.285	(.430)	8	-.763	(.762)	7	.021	(.328)	7
mixed sexes	-.130	(.387)	7	-.556	(.582)	6	-.500	(.799)	6
20% sucrose									
female	-1.049	(.727)	8	-1.611	(1.77)	7	-.929	(.743)	4
mixed sexes	-3.267	(1.83)	5	.400	(.424)	4	.250	(1.60)	4
25% sucrose									
female	2.933	(2.79)	5	.056	(1.00)	3	5.333	(4.67)	2
mixed sexes	1.000	(1.00)	2	-2.000	(.000)	1	3.500	(.000)	1

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Mean eggs per female per day								
	Day								
	19			20			21		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	-.460	(.556)	8	-.607	(.528)	8	-.621	(.872)	7
mixed sexes	-.558	(.819)	6	.264	(1.53)	6	-1.606	(1.42)	6
20% sucrose									
female	4.500	(2.65)	4	-3.333	(1.33)	2	2.250	(1.75)	2
mixed sexes	-.417	(1.08)	2	-2.200	(.200)	2	-1.000	(.000)	1
25% sucrose									
female	-8.000	(.000)	1	4.000	(.000)	1	-9.000	(.000)	1
mixed sexes	1.333	(.000)	1	.	.	0	.	.	0
	Day								
	22			23			24		
water									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0
15% sucrose									
female	-1.116	(1.13)	7	1.889	(1.02)	6	-1.700	(1.34)	5
mixed sexes	.458	(.802)	6	.021	(1.77)	4	.167	(.726)	4
20% sucrose									
female	-3.500	(5.50)	2	4.000	(.000)	1	5.000	(.000)	1
mixed sexes	-2.000	(.000)	1	2.000	(.000)	1	.	.	0
25% sucrose									
female	.	.	0	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0	.	.	0

continued . . .

Table A2-2/3 continued.

Oviposition and sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Mean eggs per female per day					
	Day					
	25			26		
water						
female	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0
15% sucrose						
female	-.493	(.881)	5	-.500	(2.18)	4
mixed sexes	-1.333	(.333)	3	-.833	(.167)	2
20% sucrose						
female	-3.000	(.000)	1	-3.000	(.000)	1
mixed sexes	.	.	0	.	.	0
25% sucrose						
female	.	.	0	.	.	0
mixed sexes	.	.	0	.	.	0

Standard errors of the means are in parenthesis followed by the number of valid observations.

For explanation of negative values in this table see page 157.

Table A2-2/4

(1) Oviposition and sucrose concentrations over time.

i. Experiment 2-2/1.

Mean eggs per female per day

	Day 1			Day 2			Day 3		
water	.286 a	(.286)	3	1.978 a	(.715)	3	.250 a	(.250)	2
10% sucrose	1.487 a	(.988)	4	1.705 a	(.939)	4	.500 a	(.270)	4
20% sucrose	.667 a	(.233)	4	1.473 a	(.382)	4	1.143 a	(.228)	4
30% sucrose	2.144 a	(.517)	4	3.463 a	(.708)	4	2.656 a	(.543)	4
40% sucrose	.405 a	(.212)	3	3.077 a	(1.48)	3	.738 a	(.265)	3
50% sucrose	.371 a	(.144)	4	.930 a	(.491)	4	.615 a	(.000)	1
60% sucrose	.321 a	(.013)	2	.333 a	(.000)	1	.	.	0

	Day 4			Day 5			Day 6		
water	.	.	0	.	.	0	.	.	0
10% sucrose	-.213 a	(.615)	4	1.027 a	(.467)	4	.018 a	(.362)	4
20% sucrose	1.250 a	(.186)	4	.179 a	(.148)	4	.464 a	(.234)	4
30% sucrose	1.510 a	(.333)	4	.842 a	(.389)	4	1.185 a	(.729)	4
40% sucrose	.990 a	(.507)	3	.833 a	(.667)	3	-.333 a	(.333)	3
50% sucrose	1.000 a	(.000)	1	-1.333 a	(.000)	1	2.000 a	(.000)	1
60% sucrose	.	.	0	.	.	0	.	.	0

	Day 7			Day 8			Day 9		
10% sucrose	.476 a	(.290)	3	-.561 a	(.238)	3	.357 a	(.643)	2
20% sucrose	.701 a	(.384)	4	-.079 a	(.160)	4	-.042 a	(.502)	4
30% sucrose	-.258 a	(.383)	4	-.756 a	(.464)	3	10.000 a	(.000)	1
40% sucrose	1.333 a	(.000)	1	.	.	0	.	.	0
50% sucrose	.	.	0	.	.	0	.	.	0

continued . . .

Table A2-2/4 continued.

(1) Oviposition and sucrose concentrations over time.

i. Experiment 2-2/1.

Mean eggs per female per day

	Day 10			Day 11			Day 12		
10% sucrose	.300	(1.30)	2	.333	(1.00)	2	-.500	(.500)	2
20% sucrose	-1.051	(1.04)	4	1.091	(1.06)	4	1.417	(1.00)	4
30% sucrose	.	.	0	.	.	0	.	.	0
40% sucrose	.	.	0	.	.	0	.	.	0

	Day 13			Day 14			Day 15		
10% sucrose	1.000	(1.00)	2	-1.500	(.500)	2	.	.	0
20% sucrose	.450	(.050)	2	-2.000	(1.00)	2	.000	(.000)	1

	Day 16		
20% sucrose	1.000	(.000)	1

Standard errors of the mean are in parenthesis followed by the valid number of observations.
For explanation of negative values in this table see page 157.

Table A2-2/4

(1) Oviposition and sucrose concentrations over time.

ii. Experiment 2-2/2.

Mean eggs per female per day

	Day 1			Day 2			Day 3		
water	.477	(.133)	16	1.977	(.239)	16	3.614	(.314)	16
15% sucrose	.362	(.140)	16	2.837	(.348)	16	3.791	(.327)	16
20% sucrose	.859	(.181)	16	4.336	(.299)	16	4.398	(.361)	16
25% sucrose	1.234	(.312)	16	4.131	(.309)	16	4.202	(.366)	16

	Day 4			Day 5			Day 6		
water	1.852	(.249)	15	1.000	(1.53)	3	.	.	0
15% sucrose	2.585	(.237)	16	1.857	(.137)	16	.696	(.158)	16
20% sucrose	2.556	(.270)	16	1.327	(.178)	16	.821	(.136)	16
25% sucrose	2.159	(.261)	16	.760	(.244)	16	1.085	(.246)	16

	Day 7			Day 8			Day 9		
15% sucrose	.299	(.104)	16	.268	(.189)	16	.097	(.149)	16
20% sucrose	.478	(.186)	16	.656	(.152)	16	.129	(.136)	16
25% sucrose	.543	(.138)	16	.551	(.205)	16	-.098	(.211)	16

continued . . .

Table A2-2/4 continued.

(1) Oviposition and sucrose concentrations over time.

ii. Experiment 2-2/2.

Mean eggs per female per day

	Day 10			Day 11			Day 12		
water	.	.	0	.	.	0	.	.	0
15% sucrose	.284	(.122)	16	.219	(.089)	16	.382	(.130)	16
20% sucrose	.216	(.096)	16	.018	(.107)	16	.097	(.116)	16
25% sucrose	.065	(.165)	15	.485	(.288)	15	-.161	(.333)	15

	Day 13			Day 14			Day 15		
15% sucrose	-.283	(.169)	16	.240	(.125)	16	-.267	(.107)	15
20% sucrose	.204	(.168)	16	-.204	(.192)	16	1.213	(.665)	14
25% sucrose	.485	(.206)	14	-.495	(.315)	10	-.625	(.557)	8

	Day 16			Day 17			Day 18		
15% sucrose	-.212	(.282)	15	-.668	(.471)	13	-.219	(.397)	13
20% sucrose	-1.902	(.845)	13	-.879	(1.14)	11	-.339	(.847)	8
25% sucrose	2.381	(1.97)	7	-.458	(.875)	4	4.722	(2.76)	3

continued . . .

Table A2-2/4 continued.

(1) Oviposition and sucrose concentrations over time.

ii. Experiment 2-2/2.

Mean eggs per female per day

	Day 19			Day 20			Day 21		
15% sucrose	-.502	(.454)	14	-.234	(.696)	14	-1.075	(.781)	13
20% sucrose	2.861	(1.99)	6	-2.767	(.640)	4	1.167	(1.48)	3
25% sucrose	-3.333	(4.67)	2	4.000	(.000)	1	-9.000	(.000)	1

	Day 22			Day 23			Day 24		
15% sucrose	-.389	(.722)	13	1.142	(.926)	10	-.870	(.832)	9
20% sucrose	-3.000	(3.21)	3	3.000	(1.00)	2	5.000	(.000)	1
25% sucrose	.	.	0	.	.	0	.	.	0

	Day 25			Day 26		
15% sucrose	-.808	(.559)	8	.056	(1.41)	6
20% sucrose	-3.000	(.000)	1	-3.000	(.000)	1

Standard errors of the means are in parenthesis followed by the number of valid observations.
For explanation of negative values in this table see page 157.

Table A2-2/4

(2) Oviposition over time.

i. Experiment 2-2/1.

Mean eggs per female per day								
Day								
1	2	3	4	5	6	7	8	9
.891 bcd (.225) 24	1.990 a (.339) 23	1.140 abc (.248) 18	.885 bcde (.248) 16	.585 bcde (.232) 16	.479 bcde (.262) 16	.378 bcde (.230) 12	-.427 de (.176) 10	1.507 ab (1.45) 7

Day						
10	11	12	13	14	15	16
-.601 de (.791) 6	.839 abcde (.738) 6	.778 abcde (.763) 6	.725 abcde (.439) 4	-1.750 (.479) 4	.000 (.000) 1	1.000 (.000) 1

Standard errors of the mean are in parenthesis followed by the valid number of observations.
For explanation of negative values in this table see page 157.

Table A2-2/4

(2) Oviposition over time.

ii. Experiment 2-2/2.

Mean eggs per female per day								
Day								
1	2	3	4	5	6	7	8	9
.733 (.109) 64	3.320 (.191) 64	4.001 (.172) 64	2.295 (.130) 63	1.296 (.140) 51	.868 (.108) 48	.440 (.084) 48	.492 (.106) 48	.043 (.096) 48
Day								
10	11	12	13	14	15	16	17	18
.191 (.074) 47	.235 (.105) 47	.112 (.123) 47	.120 (.112) 46	-.104 (.121) 42	.215 (.304) 37	-.321 (.561) 35	-.721 (.499) 28	.358 (.564) 24
Day								
19	20	21	22	23	24	25	26	
.158 (.770) 22	-.544 (.628) 19	-1.146 (.827) 17	-.879 (.816) 16	1.451 (.802) 12	-.283 (.948) 10	-1.052 (.550) 9	-.381 (1.27) 7	

Standard errors of the means are in parenthesis followed by the number of valid observations.
For explanation of negative values in this table see page 157.

Table A2-2/5

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day 1			Day 2			Day 3		
water									
female	0	d	(1)	2	d	(1)	2	d	(1)
mixed sexes	3	cd	(2)	19	bc	(2)	20	c	(2)
10% sucrose									
female	6	bcd	(2)	18	bc	(2)	19	c	(2)
mixed sexes	17	ab	(2)	28	ab	(2)	35	bc	(2)
20% sucrose									
female	3	cd	(2)	10	cd	(2)	19	c	(2)
mixed sexes	8	abc	(2)	23	bc	(2)	31	bc	(2)
30% sucrose									
female	22	a	(2)	46	a	(2)	64	a	(2)
mixed sexes	10	abc	(2)	35	ab	(2)	53	ab	(2)

	Day 4			Day 5			Day 6		
water									
female	2	e	(1)	2	e	(1)	2	e	(1)
mixed sexes	24	cd	(2)	26	cd	(2)	26	d	(2)
10% sucrose									
female	19	d	(2)	20	d	(2)	21	d	(2)
mixed sexes	38	bcd	(2)	47	bc	(2)	49	bc	(2)
20% sucrose									
female	26	cd	(2)	29	cd	(2)	30	cd	(2)
mixed sexes	43	bc	(2)	43	c	(2)	49	bc	(2)
30% sucrose									
female	74	a	(2)	77	a	(2)	78	ab	(2)
mixed sexes	64	ab	(2)	71	ab	(2)	81	a	(2)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day 7			Day 8			Day 9		
water									
female	2	c	(2)	2	f	(1)	2	e	(1)
mixed sexes	26	b	(2)	27	de	(2)	27	d	(2)
10% sucrose									
female	24	b	(2)	23	e	(2)	23	d	(2)
mixed sexes	52	a	(2)	49	bcd	(2)	52	bc	(2)
20% sucrose									
female	32	b	(2)	33	cd	(2)	30	cd	(2)
mixed sexes	57	a	(2)	56	abc	(2)	56	ab	(2)
30% sucrose									
female	80	a	(2)	78	ab	(2)	87	a	(2)
mixed sexes	77	a	(2)	79	a	(2)	71	ab	(2)

	Day 10			Day 11			Day 12		
water									
female	2	e	(1)	3	f	(1)	2	e	(1)
mixed sexes	27	cd	(2)	25	e	(2)	26	cd	(2)
10% sucrose									
female	22	d	(2)	22	e	(2)	22	d	(2)
mixed sexes	47	bc	(2)	50	cd	(2)	47	bc	(2)
20% sucrose									
female	29	cd	(2)	32	cde	(2)	31	cd	(2)
mixed sexes	53	ab	(2)	54	bc	(2)	61	ab	(2)
30% sucrose									
female	80	a	(2)	85	a	(2)	78	a	(2)
mixed sexes	73	ab	(2)	80	ab	(2)	79	a	(2)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day								
	13			14			15		
water									
female	2	d	(1)	2	e	(1)	2	e	(1)
mixed sexes	27	c	(2)	27	cd	(2)	26	d	(2)
10% sucrose									
female	25	c	(2)	22	d	(2)	25	d	(2)
mixed sexes	47	bc	(2)	48	bc	(2)	52	bc	(2)
20% sucrose									
female	32	c	(2)	30	bcd	(2)	31	cd	(2)
mixed sexes	58	ab	(2)	53	ab	(2)	57	ab	(2)
30% sucrose									
female	83	a	(2)	81	a	(2)	85	a	(2)
mixed sexes	81	a	(2)	81	a	(2)	79	ab	(2)

	Day								
	16			17			18		
water									
female	2	e	(1)	2	e	(1)	2	d	(1)
mixed sexes	26	d	(2)	25	d	(2)	26	c	(2)
10% sucrose									
female	24	d	(2)	25	d	(2)	24	c	(2)
mixed sexes	49	bc	(2)	50	bc	(2)	50	bc	(2)
20% sucrose									
female	31	cd	(2)	31	cd	(2)	31	c	(2)
mixed sexes	61	ab	(2)	54	abc	(2)	61	ab	(2)
30% sucrose									
female	86	a	(2)	80	a	(2)	82	a	(2)
mixed sexes	76	ab	(2)	76	ab	(2)	73	ab	(2)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day								
	19			20			21		
water									
female	2	e	(1)	2	e	(1)	2	d	(1)
mixed sexes	26	cd	(2)	26	d	(2)	26	c	(2)
10% sucrose									
female	24	d	(2)	24	d	(2)	24	c	(2)
mixed sexes	48	bc	(2)	50	bc	(2)	50	b	(2)
20% sucrose									
female	30	cd	(2)	31	cd	(2)	31	c	(2)
mixed sexes	57	ab	(2)	58	ab	(2)	57	ab	(2)
30% sucrose									
female	79	a	(2)	77	a	(2)	79	a	(2)
mixed sexes	71	ab	(2)	71	ab	(2)	70	ab	(2)

	Day								
	22			23			24		
water									
female	2	d	(1)	2	d	(1)	2	d	(1)
mixed sexes	26	c	(2)	26	c	(2)	26	c	(2)
10% sucrose									
female	24	c	(2)	24	c	(2)	24	c	(2)
mixed sexes	50	ab	(2)	50	ab	(2)	50	ab	(2)
20% sucrose									
female	32	bc	(2)	31	bc	(2)	31	bc	(2)
mixed sexes	56	ab	(2)	58	a	(2)	58	a	(2)
30% sucrose									
female	70	a	(2)	78	a	(2)	78	a	(2)
mixed sexes	73	a	(2)	73	a	(2)	73	a	(2)

Totals for female only sex group (8 females) have been halved so that valid comparisons can be made with the mixed sex group (4 females).
Numbers with the same letter within each day are not significantly different (P>0.01).
Figures in parenthesis are the number of cages for which eggs were counted.
The cumulative sum of eggs shows a decline in some cases because of counting inaccuracies. See page 157.

continued . . .

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day					
	7		8		9	
water						
female	0	(1)	0	(1)	0 a	(1)
mixed sexes	0	(2)	0	(2)	3 a	(2)
10% sucrose						
female	0	(2)	0	(2)	4 a	(2)
mixed sexes	0	(2)	0	(2)	0 a	(2)
20% sucrose						
female	0	(2)	0	(2)	0 a	(2)
mixed sexes	0	(2)	0	(2)	0 a	(2)
30% sucrose						
female	0	(2)	0	(2)	0 a	(2)
mixed sexes	0	(2)	0	(2)	0 a	(2)

	Day					
	10		11		12	
water						
female	0 b	(1)	1 c	(1)	1 c	(1)
mixed sexes	11 a	(2)	16 a	(2)	18 a	(2)
10% sucrose						
female	11 a	(2)	15 ab	(2)	16 ab	(2)
mixed sexes	9 a	(2)	21 a	(2)	22 a	(2)
20% sucrose						
female	0 a	(2)	2 c	(2)	5 bc	(2)
mixed sexes	0 a	(2)	4 bc	(2)	11 ab	(2)
30% sucrose						
female	0 a	(2)	0 c	(2)	0 c	(2)
mixed sexes	0 a	(2)	0 c	(2)	0 c	(2)

continued . . .

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day								
	13			14			15		
water									
female	1	c	(1)	1	c	(1)	1	d	(1)
mixed sexes	21	ab	(2)	20	ab	(2)	20	abc	(2)
10% sucrose									
female	19	ab	(2)	16	ab	(2)	18	bc	(2)
mixed sexes	31	a	(2)	34	a	(2)	39	ab	(2)
20% sucrose									
female	9	bc	(2)	9	bc	(2)	9	c	(2)
mixed sexes	19	a	(2)	27	a	(2)	33	ab	(2)
30% sucrose									
female	0	c	(2)	7	bc	(2)	15	c	(2)
mixed sexes	0	c	(2)	2	c	(2)	12	c	(2)

	Day								
	16			17			18		
water									
female	1	d	(1)	1	d	(1)	1	e	(1)
mixed sexes	20	abc	(2)	19	bc	(2)	20	bc	(2)
10% sucrose									
female	19	bc	(2)	19	bc	(2)	19	cd	(2)
mixed sexes	37	ab	(2)	40	a	(2)	40	ab	(2)
20% sucrose									
female	9	cd	(2)	10	c	(2)	10	d	(2)
mixed sexes	40	a	(2)	40	a	(2)	43	a	(2)
30% sucrose									
female	22	abc	(2)	30	ab	(2)	35	abc	(2)
mixed sexes	15	c	(2)	21	abc	(2)	20	bcd	(2)

continued . . .

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

i. Experiment 2-2/1.

	Day 19			Day 20			Day 21		
water									
female	1	e	(1)	1	d	(1)	1	e	(1)
mixed sexes	20	bc	(2)	20	bcd	(2)	20	b	(2)
10% sucrose									
female	18	cd	(2)	18	cd	(2)	18	cd	(2)
mixed sexes	37	abc	(2)	40	ab	(2)	39	ab	(2)
20% sucrose									
female	10	d	(2)	10	d	(2)	10	d	(2)
mixed sexes	42	a	(2)	43	a	(2)	42	a	(2)
30% sucrose									
female	38	ab	(2)	36	ab	(2)	36	abc	(2)
mixed sexes	22	abcd	(2)	23	ab	(2)	22	abcd	(2)

	Day 22			Day 23			Day 24		
water									
female	1	d	(1)	1	d	(1)	1	d	(1)
mixed sexes	20	abc	(2)	20	bc	(2)	20	bc	(2)
10% sucrose									
female	18	bc	(2)	18	c	(2)	18	c	(2)
mixed sexes	38	a	(2)	38	ab	(2)	38	ab	(2)
20% sucrose									
female	10	c	(2)	10	c	(2)	10	c	(2)
mixed sexes	40	a	(2)	41	a	(2)	41	a	(2)
30% sucrose									
female	37	ab	(2)	37	abc	(2)	37	abc	(2)
mixed sexes	25	abc	(2)	23	abc	(2)	23	abc	(2)

Totals for female only sex group (8 females) have been halved so that valid comparisons can be made with the mixed sex group (4 females).
Numbers with the same letter within each day are not significantly different ($P>0.01$).
Figures in parenthesis are the number of cages for which larvae were counted.
The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies. See page 157.

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 1			Day 2			Day 3		
water									
female	10	cd	(8)	60	d	(8)	174	d	(8)
mixed sexes	21	bc	(8)	96	bc	(8)	205	cd	(8)
15% sucrose									
female	5	d	(8)	89	bcd	(8)	198	cd	(8)
mixed sexes	18	b	(8)	113	b	(8)	238	bc	(8)
20% sucrose									
female	28	ab	(8)	167	a	(8)	293	ab	(8)
mixed sexes	27	ab	(8)	166	a	(8)	321	a	(8)
25% sucrose									
female	47	a	(8)	175	a	(8)	314	a	(8)
mixed sexes	32	ab	(8)	168	a	(8)	293	a	(8)

	Day 4			Day 5			Day 6		
water									
female	222	d	(8)	224	c	(8)	227	c	(8)
mixed sexes	243	d	(8)	249	c	(8)	253	c	(8)
15% sucrose									
female	275	cd	(8)	334	b	(8)	353	b	(8)
mixed sexes	316	bc	(8)	371	ab	(8)	395	ab	(8)
20% sucrose									
female	376	ab	(8)	417	a	(8)	454	a	(8)
mixed sexes	401	a	(8)	444	a	(8)	459	a	(8)
25% sucrose									
female	389	a	(8)	408	a	(8)	438	a	(8)
mixed sexes	351	ab	(8)	377	ab	(8)	412	ab	(8)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 7			Day 8			Day 9		
water									
female	229	c	(8)	229	d	(8)	229	d	(8)
mixed sexes	253	c	(8)	253	d	(8)	253	d	(8)
15% sucrose									
female	365	b	(8)	375	c	(8)	382	c	(8)
mixed sexes	400	a	(8)	406	bc	(8)	404	bc	(8)
20% sucrose									
female	469	a	(8)	489	a	(8)	493	a	(8)
mixed sexes	474	a	(8)	495	a	(8)	500	a	(8)
25% sucrose									
female	452	a	(8)	470	ab	(8)	461	ab	(8)
mixed sexes	426	ab	(8)	442	abc	(8)	443	abc	(8)

	Day 10			Day 11			Day 12		
water									
female	229	d	(8)	229	d	(8)	229	c	(8)
mixed sexes	253	d	(8)	253	d	(8)	253	c	(8)
15% sucrose									
female	386	c	(8)	391	c	(8)	398	b	(8)
mixed sexes	417	bc	(8)	424	bc	(8)	434	b	(8)
20% sucrose									
female	497	a	(8)	501	ab	(8)	502	a	(8)
mixed sexes	509	a	(8)	505	a	(8)	508	a	(8)
25% sucrose									
female	465	ab	(8)	474	ab	(8)	472	ab	(8)
mixed sexes	443	abc	(8)	449	abc	(8)	452	ab	(8)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 13			Day 14			Day 15		
water									
female	229	d	(8)	229	d	(8)	229	c	(8)
mixed sexes	254	d	(8)	253	d	(8)	253	c	(8)
15% sucrose									
female	395	c	(8)	404	c	(8)	401	b	(8)
mixed sexes	429	bc	(8)	429	bc	(8)	421	b	(8)
20% sucrose									
female	510	a	(8)	501	ab	(8)	514	a	(8)
mixed sexes	510	a	(8)	512	a	(8)	447	ab	(7)
25% sucrose									
female	476	ab	(8)	473	abc	(8)	464	ab	(8)
mixed sexes	459	abc	(8)	458	abc	(8)	456	ab	(8)

	Day 16			Day 17			Day 18		
water									
female	219	d	(8)	221	d	(8)	213	d	(8)
mixed sexes	236	d	(8)	238	d	(8)	241	d	(8)
15% sucrose									
female	394	c	(8)	340	b	(7)	381	c	(8)
mixed sexes	419	bc	(8)	408	b	(8)	402	bc	(8)
20% sucrose									
female	505	a	(8)	503	a	(8)	494	a	(8)
mixed sexes	429	abc	(7)	424	b	(7)	424	abc	(7)
25% sucrose									
female	474	ab	(8)	471	ab	(8)	465	ab	(8)
mixed sexes	452	abc	(8)	451	ab	(8)	447	abc	(8)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day								
	19			20			21		
water									
female	221	d	(8)	211	c	(8)	213	c	(8)
mixed sexes	258	d	(8)	247	c	(8)	250	c	(8)
15% sucrose									
female	380	c	(8)	373	b	(8)	364	b	(8)
mixed sexes	394	bc	(8)	391	ab	(8)	371	b	(8)
20% sucrose									
female	507	a	(8)	464	a	(8)	476	a	(8)
mixed sexes	416	bc	(7)	392	ab	(7)	391	b	(7)
25% sucrose									
female	456	ab	(8)	436	ab	(8)	433	ab	(8)
mixed sexes	460	ab	(8)	432	ab	(8)	431	ab	(8)

	Day								
	22			23			24		
water									
female	212	e	(8)	215	d	(8)	22		(1)
mixed sexes	257	e	(8)	250	d	(8)	.		(0)
15% sucrose									
female	357	d	(8)	370	c	(8)	328		(7)
mixed sexes	371	cd	(8)	388	bc	(8)	355		(7)
20% sucrose									
female	483	a	(8)	491	ab	(8)	270		(4)
mixed sexes	404	bcd	(7)	413	bc	(7)	433		(7)
25% sucrose									
female	447	ab	(8)	451	ab	(8)	160		(3)
mixed sexes	435	abc	(8)	428	abc	(8)	176		(3)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day					
	25		26		27	
water						
female	79	(3)	24	(1)	24	(1)
mixed sexes	37	(1)	.	(0)	.	(0)
15% sucrose						
female	329	(7)	330	(7)	291	(6)
mixed sexes	363	(7)	362	(7)	356	(7)
20% sucrose						
female	316	(5)	260	(4)	265	(4)
mixed sexes	419	(7)	425	(7)	421	(7)
25% sucrose						
female	233	(4)	112	(2)	117	(2)
mixed sexes	270	(5)	182	(3)	168	(3)

	Day					
	28		29		30	
water						
female	110	(4)	24	(1)	.	(0)
mixed sexes	.	(0)	38	(1)	.	(0)
15% sucrose						
female	365	(8)	280	(6)	181	(4)
mixed sexes	395	(8)	223	(4)	158	(3)
20% sucrose						
female	496	(8)	221	(4)	224	(4)
mixed sexes	435	(7)	54	(1)	.	(0)
25% sucrose						
female	455	(8)	389	(7)	122	(2)
mixed sexes	442	(8)	110	(2)	.	(0)

continued . . .

Table A2-2/5 continued.

(1) Cumulative sum of eggs for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 31		Day 32		Day 33	
15% sucrose						
female	173	(4)	181	(4)	197	(4)
mixed sexes	236	(4)	241	(4)	243	(4)
20% sucrose						
female	56	(1)	56	(1)	57	(1)
mixed sexes	.	(0)	.	(0)	.	(0)

	Day 34		Day 35		Day 36	
15% sucrose						
female	.	(0)	.	(0)	.	(0)
mixed sexes	43	(1)	43	(1)	43	(1)

	Day 37	
15% sucrose		
female	.	(0)
mixed sexes	50	(1)

Totals for female only sex group (8 females) have been halved so that valid comparisons can be made with the mixed sex group (4 females).
Numbers with the same letter within each day are not significantly different (P>0.01).
Figures in parenthesis are the number of cages for which eggs were counted.
The cumulative sum of eggs shows a decline in some cases because of counting inaccuracies (see page 157) or a reduction in the number of cages.

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 10		Day 11		Day 12	
water						
female	0	(8)	0	(8)	2 b	(8)
mixed sexes	0	(8)	0	(8)	13 a	(8)
15% sucrose						
female	0	(8)	0	(8)	0 b	(8)
mixed sexes	0	(8)	0	(8)	0 b	(8)
20% sucrose						
female	0	(8)	0	(8)	0 b	(8)
mixed sexes	0	(8)	0	(8)	0 b	(8)
25% sucrose						
female	0	(8)	0	(8)	0 b	(8)
mixed sexes	0	(8)	0	(8)	0 b	(8)

	Day 13		Day 14		Day 15	
water						
female	11 b	(8)	53 b	(8)	99 b	(8)
mixed sexes	37 a	(8)	86 a	(8)	145 a	(8)
15% sucrose						
female	0 c	(8)	10 c	(8)	46 cd	(8)
mixed sexes	0 c	(8)	16 c	(8)	57 c	(8)
20% sucrose						
female	0 c	(8)	1 d	(8)	28 de	(8)
mixed sexes	0 c	(8)	1 d	(8)	17 e	(7)
25% sucrose						
female	0 c	(8)	0 d	(8)	0 f	(8)
mixed sexes	0 c	(8)	0 d	(8)	2 f	(8)

	Day 16		Day 17		Day 18	
water						
female	132 ab	(8)	144 a	(8)	148 bc	(8)
mixed sexes	165 a	(8)	176 a	(8)	178 ab	(8)
15% sucrose						
female	112 bc	(8)	133 a	(7)	201 a	(8)
mixed sexes	115 bc	(8)	152 a	(8)	213 a	(8)
20% sucrose						
female	90 c	(8)	148 a	(8)	227 a	(8)
mixed sexes	82 c	(7)	150 a	(7)	230 a	(7)
25% sucrose						
female	6 d	(8)	36 b	(8)	124 cd	(8)
mixed sexes	5 d	(8)	33 b	(8)	100 d	(8)

continued . . .

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 19			Day 20			Day 21		
water									
female	158	c	(8)	151	d	(8)	159	d	(8)
mixed sexes	201	bc	(8)	197	cd	(8)	196	cd	(8)
15% sucrose									
female	224	ab	(8)	234	bc	(8)	249	abc	(8)
mixed sexes	233	ab	(8)	249	abc	(8)	246	abc	(8)
20% sucrose									
female	282	a	(8)	295	a	(8)	305	a	(8)
mixed sexes	259	a	(7)	276	ab	(7)	283	a	(7)
25% sucrose									
female	197	b	(8)	244	abc	(8)	258	ab	(8)
mixed sexes	166	c	(8)	212	c	(8)	221	bc	(8)

	Day 22			Day 23			Day 24		
water									
female	160	e	(8)	157	e	(8)	19		(1)
mixed sexes	202	de	(8)	199	de	(8)	.		(0)
15% sucrose									
female	247	bcd	(8)	255	bc	(8)	225		(7)
mixed sexes	250	bcd	(8)	261	bc	(8)	233		(7)
20% sucrose									
female	326	a	(8)	333	a	(8)	200		(4)
mixed sexes	302	ab	(7)	315	ab	(7)	336		(7)
25% sucrose									
female	286	abc	(8)	294	abc	(8)	113		(3)
mixed sexes	238	cd	(8)	249	cd	(8)	99		(3)

	Day 25		Day 26		Day 27	
water						
female	57	(3)	20	(1)	21	(1)
mixed sexes	25	(1)	.	(0)	.	(0)
15% sucrose						
female	229	(7)	231	(7)	199	(6)
mixed sexes	233	(7)	241	(7)	234	(7)
20% sucrose						
female	228	(5)	200	(4)	198	(4)
mixed sexes	328	(7)	334	(7)	333	(7)
25% sucrose						
female	164	(4)	91	(2)	89	(2)
mixed sexes	141	(5)	100	(3)	95	(3)

continued . . .

Table A2-2/5 continued.

(2) Cumulative sum of larvae for sex groups within sucrose concentrations over time.

ii. Experiment 2-2/2.

	Day 28		29		30	
water						
female	78	(4)	17	(1)	.	(0)
mixed sexes	38	(1)	27	(1)	.	(0)
15% sucrose						
female	257	(8)	196	(6)	130	(4)
mixed sexes	272	(8)	144	(4)	144	(4)
20% sucrose						
female	347	(8)	148	(4)	153	(4)
mixed sexes	340	(7)	45	(1)	.	(0)
25% sucrose						
female	313	(8)	272	(7)	83	(2)
mixed sexes	258	(8)	65	(2)	36	(1)

	Day 31		32		33	
15% sucrose						
female	120	(4)	131	(4)	144	(4)
mixed sexes	159	(4)	164	(4)	164	(4)
20% sucrose						
female	41	(1)	44	(1)	42	(1)
mixed sexes	.	(0)	.	(0)	.	(0)
25% sucrose						
female	.	(0)	.	(0)	.	(0)
mixed sexes	.	(0)	.	(0)	.	(0)

	Day 34		35		36	
15% sucrose						
female	.	(0)	.	(0)	.	(0)
mixed sexes	20	(1)	20	(1)	20	(1)
20% sucrose						
female	.	(0)	.	(0)	.	(0)
mixed sexes	.	(0)	.	(0)	.	(0)

Totals for female only sex group (8 females) have been halved so that valid comparisons can be made with the mixed sex group (4 females).
Numbers with the same letter within each day are not significantly different (P>0.01).
Figures in parenthesis are the number of cages for which larvae were counted.
The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies (see page 157) or a reduction in the number of cages.

Table A2-2/6

(1) Cumulative sum of eggs and sucrose concentration over time.

i. Experiment 2-2/1.

a. Comparison of sucrose concentrations.

	Day 1			Day 2			Day 3		
water	3	c	(3)	22	c	(3)	23	c	(3)
10% sucrose	29	b	(4)	63	b	(4)	72	b	(4)
20% sucrose	13	bc	(4)	43	b	(4)	69	b	(4)
30% sucrose	54	a	(4)	127	a	(4)	180	a	(4)

	Day 4			Day 5			Day 6		
water	28	c	(3)	30	c	(3)	29	c	(3)
10% sucrose	76	b	(4)	86	b	(4)	91	b	(4)
20% sucrose	95	b	(4)	100	b	(4)	108	b	(4)
30% sucrose	211	a	(4)	224	a	(4)	237	a	(4)

	Day 7			Day 8			Day 9		
water	29	c	(3)	31	c	(3)	31	c	(3)
10% sucrose	99	b	(4)	95	b	(4)	98	b	(4)
20% sucrose	121	b	(4)	121	b	(4)	115	b	(4)
30% sucrose	237	a	(4)	235	a	(4)	244	a	(4)

	Day 10			Day 11			Day 12		
water	30	c	(3)	30	c	(3)	30	c	(3)
10% sucrose	91	b	(4)	93	b	(4)	91	b	(4)
20% sucrose	111	b	(4)	117	b	(4)	123	b	(4)
30% sucrose	232	a	(4)	250	a	(4)	235	a	(4)

continued . . .

Table A2-2/6 continued.

(1) Cumulative sum of eggs and sucrose concentration over time.

i. Experiment 2-2/1.

a. Comparison of sucrose concentration.

	Day 13			Day 14			Day 15		
water	31	c	(3)	31	c	(3)	30	c	(3)
10% sucrose	96	b	(4)	91	b	(4)	101	b	(4)
20% sucrose	122	b	(4)	112	b	(4)	118	b	(4)
30% sucrose	246	a	(4)	243	a	(4)	249	a	(4)

	Day 16			Day 17			Day 18		
water	30	c	(3)	28	c	(3)	29	c	(3)
10% sucrose	97	b	(4)	99	b	(4)	97	b	(4)
20% sucrose	122	b	(4)	115	b	(4)	123	b	(4)
30% sucrose	247	a	(4)	236	a	(4)	237	a	(4)

	Day 19			Day 20			Day 21		
water	29	c	(3)	29	c	(3)	29	c	(3)
10% sucrose	96	b	(4)	97	b	(4)	97	b	(4)
20% sucrose	117	b	(4)	119	b	(4)	118	b	(4)
30% sucrose	229	a	(4)	224	a	(4)	228	a	(4)

	Day 22			Day 23			Day 24		
water	29	c	(3)	29	c	(3)	29	c	(3)
10% sucrose	98	b	(4)	98	b	(4)	98	b	(4)
20% sucrose	119	b	(4)	119	b	(4)	119	b	(4)
30% sucrose	233	a	(4)	228	a	(4)	228	a	(4)

Figures in parenthesis are the number of valid observations. The cumulative sum of eggs shows a decline in some cases because of counting inaccuracies. See page 157.
Numbers with the same letter within each day are not significantly different (P>0.01).

continued . . .

Table A2-2/6 continued.

(2) Cumulative sum of larvae and sucrose concentration over time.
i. Experiment 2-2/1.

a. Comparison of sucrose concentrations.

	Day 7		Day 8		Day 9	
water	0	(2)	0	(2)	3 ab	(3)
10% sucrose	0	(2)	0	(2)	8 a	(4)
20% sucrose	0	(2)	0	(2)	0 b	(4)
30% sucrose	0	(2)	0	(2)	0 b	(4)

	Day 10		Day 11		Day 12	
water	11 b	(3)	18 b	(3)	20 b	(3)
10% sucrose	30 a	(4)	50 a	(4)	53 a	(4)
20% sucrose	0 c	(4)	7 b	(4)	21 b	(4)
30% sucrose	0 c	(4)	0 c	(4)	0 c	(4)

	Day 13		Day 14		Day 15	
water	23 b	(3)	22 b	(3)	22	(3)
10% sucrose	68 a	(4)	66 a	(4)	74 a	(4)
20% sucrose	36 b	(4)	44 a	(4)	50 ab	(4)
30% sucrose	0 c	(4)	16 b	(4)	41 bc	(4)

	Day 16		Day 17		Day 18	
water	22 b	(3)	20 b	(3)	21 b	(3)
10% sucrose	74 a	(4)	77 a	(4)	77 a	(4)
20% sucrose	57 a	(4)	59 a	(4)	63 a	(4)
30% sucrose	59 a	(4)	81 a	(4)	90 a	(4)

	Day 19		Day 20		Day 21	
water	21 c	(3)	21 c	(3)	21 b	(3)
10% sucrose	73 ab	(4)	75 b	(4)	74 a	(4)
20% sucrose	62 b	(4)	63 b	(4)	62 a	(4)
30% sucrose	97 a	(4)	95 a	(4)	93 a	(4)

	Day 22		Day 23		Day 24	
water	21 c	(3)	21 c	(3)	21 c	(3)
10% sucrose	74 ab	(4)	74 ab	(4)	74 ab	(4)
20% sucrose	60 b	(4)	60 b	(4)	60 b	(4)
30% sucrose	99 a	(4)	97 a	(4)	97 a	(4)

Figures in parenthesis are the number of valid observations. The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies. See page 157.
Numbers with the same letter within each day are not significantly different (P>0.01).

Table A2-2/6 continued.

(2) Cumulative sum of larvae within sucrose concentration over time.

i. Experiment 2-2/1.

b. Comparison of cumulative sum of larvae over time.

	water		10% sucrose		20% sucrose		30% sucrose	
Day								
8	0	(3)	0	(4)	0	(4)	0	(4)
9	3 ab	(3)	8 a	(4)	0	(4)	0	(4)
10	11 b	(3)	30 b	(4)	0	(4)	0	(4)
11	18 c	(3)	50 bc	(4)	7 a	(4)	0	(4)
12	20 c	(3)	53 bc	(4)	21 b	(4)	0	(4)
13	23 c	(3)	68 c	(4)	36 bc	(4)	0	(4)
14	22 c	(3)	66 c	(4)	44 cd	(4)	16 a	(4)
15	22 c	(3)	74 c	(4)	50 cd	(4)	41 b	(4)
16	22 c	(3)	74 c	(4)	57 cd	(4)	59 b	(4)
17	20 c	(3)	77 c	(4)	59 cd	(4)	81 c	(4)
18	21 c	(3)	77 c	(4)	63 d	(4)	90 c	(4)
19	21 c	(3)	73 c	(4)	62 d	(4)	97 c	(4)
20	21 c	(3)	75 c	(4)	63 d	(4)	95 c	(4)
21	21 c	(3)	74 c	(4)	62 d	(4)	93 c	(4)
22	21 c	(3)	74 c	(4)	60 d	(4)	99 c	(4)
23	21 c	(3)	74 c	(4)	60 d	(4)	97 c	(4)
24	21 c	(3)	74 c	(4)	60 d	(4)	97 c	(4)

Figures in parenthesis are the number of cages for which larvae were counted.
The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies. See page 157.
Numbers with the same letter within each sucrose concentration are not significantly different (P>0.01).

continued . . .

Table A2-2/6 continued.

(1) Cumulative sum of eggs and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

	Day 1			Day 2			Day 3		
water	31	bc	(16)	156	b	(16)	379	b	(16)
15% sucrose	23	c	(16)	202	b	(16)	436	b	(16)
20% sucrose	55	ab	(16)	333	a	(16)	614	a	(16)
25% sucrose	79	a	(16)	343	a	(16)	607	a	(16)

	Day 4			Day 5			Day 6		
water	465	c	(16)	473	c	(16)	480	c	(16)
15% sucrose	591	b	(16)	705	b	(16)	748	b	(16)
20% sucrose	777	a	(16)	861	a	(16)	913	a	(16)
25% sucrose	740	a	(16)	785	ab	(16)	850	ab	(16)

	Day 7			Day 8			Day 9		
water	482	c	(16)	482	c	(16)	482	c	(16)
15% sucrose	765	b	(16)	781	b	(16)	786	b	(16)
20% sucrose	943	a	(16)	984	a	(16)	993	a	(16)
25% sucrose	878	a	(16)	912	a	(16)	904	a	(16)

	Day 10			Day 11			Day 12		
water	482	c	(16)	482	c	(16)	482	c	(16)
15% sucrose	803	b	(16)	815	b	(16)	832	b	(16)
20% sucrose	1006	a	(16)	1006	a	(16)	1010	a	(16)
25% sucrose	908	ab	(16)	923	ab	(16)	924	ab	(16)

	Day 13			Day 14			Day 15		
water	483	c	(16)	482	c	(16)	482	c	(16)
15% sucrose	824	b	(16)	833	b	(16)	822	b	(16)
20% sucrose	1020	a	(16)	1013	a	(16)	961	a	(15)
25% sucrose	935	a	(16)	931	ab	(16)	920	ab	(16)

continued . . .

Table A2-2/6 continued.

(1) Cumulative sum of eggs and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

	Day 16		Day 17		Day 18	
water	455 c	(16)	459 c	(16)	454 c	(16)
15% sucrose	813 b	(16)	748 b	(15)	783 b	(16)
20% sucrose	934 a	(15)	927 a	(15)	918 a	(15)
25% sucrose	926 a	(16)	922 a	(16)	912 a	(16)

	Day 19		Day 20		Day 21	
water	479 c	(16)	458 b	(16)	463 c	(16)
15% sucrose	774 b	(16)	764 a	(16)	735 b	(16)
20% sucrose	923 a	(15)	856 a	(15)	867 a	(15)
25% sucrose	916 a	(16)	868 a	(16)	864 a	(16)

	Day 22		Day 23		Day 24	
water	469 c	(16)	465 c	(16)	22	(1)
15% sucrose	728 b	(16)	758 b	(16)	683	(14)
20% sucrose	887 a	(15)	904 a	(15)	703	(11)
25% sucrose	882 a	(16)	879 a	(16)	336	(6)

	Day 25		Day 26		Day 27	
water	116	(4)	24	(1)	24	(1)
15% sucrose	692	(14)	692	(14)	647	(13)
20% sucrose	735	(12)	685	(11)	686	(11)
25% sucrose	503	(9)	294	(5)	285	(5)

	Day 28		Day 29		Day 30	
water	110	(4)	62	(2)	.	(0)
15% sucrose	760	(16)	503	(10)	339	(7)
20% sucrose	931	(15)	275	(5)	224	(4)
25% sucrose	897	(16)	499	(9)	122	(2)

continued . . .

Table A2-2/6 continued.

(1) Cumulative sum of eggs and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of cumulative sum of eggs over time.

	Day 31		Day 32		Day 33	
water	.	(0)	.	(0)	.	(0)
15% sucrose	409	(8)	422	(8)	440	(8)
20% sucrose	56	(1)	56	(1)	57	(1)
25% sucrose	.	(0)	.	(0)	.	(0)

	Day 34		Day 35		Day 36	
water	.	(0)	.	(0)	.	(0)
15% sucrose	43	(1)	43	(1)	43	(1)
20% sucrose	.	(0)	.	(0)	.	(0)
25% sucrose	.	(0)	.	(0)	.	(0)

Figures in parenthesis are the number of cages for which eggs were counted.
The cumulative sum of eggs shows a decline in some cases because of counting inaccuracies (see page 157) or a reduction in the number of cages.
Numbers with the same letter within each sucrose concentration are not significantly different (P>0.01).

continued . . .

Table A2-2/6 continued.

(2) Cumulative sum of larvae and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of cumulative sum of larvae over time.

	Day 10		Day 11		Day 12	
water	0	(16)	0	(16)	16 a	(16)
15% sucrose	0	(16)	0	(16)	0 b	(16)
20% sucrose	0	(16)	0	(16)	0 b	(16)
25% sucrose	0	(16)	0	(16)	0 b	(16)

	Day 13		Day 14		Day 15	
water	59 a	(16)	192 a	(16)	342 a	(16)
15% sucrose	0 b	(16)	35 b	(16)	148 b	(16)
20% sucrose	0 b	(16)	3 c	(16)	72 c	(15)
25% sucrose	0 b	(16)	0 c	(16)	2 d	(16)

	Day 16		Day 17		Day 18	
water	429 a	(16)	464 a	(16)	473 b	(16)
15% sucrose	339 b	(16)	417 a	(15)	614 a	(16)
20% sucrose	262 c	(15)	446 a	(15)	683 a	(15)
25% sucrose	17 d	(16)	104 b	(16)	348 c	(16)

	Day 19		Day 20		Day 21	
water	516 c	(16)	499 c	(16)	514 c	(16)
15% sucrose	681 b	(16)	716 b	(16)	743 b	(16)
20% sucrose	822 a	(15)	866 a	(15)	892 a	(15)
25% sucrose	559 c	(16)	700 b	(16)	737 b	(16)

	Day 22		Day 23		Day 24	
water	521 c	(16)	512 c	(16)	38	(1)
15% sucrose	744 b	(16)	771 b	(16)	683	(14)
20% sucrose	954 a	(15)	980 a	(15)	735	(11)
25% sucrose	809 b	(16)	836 b	(16)	325	(6)

continued . . .

Table A2-2/6 continued.

(2) Cumulative sum of larvae and sucrose concentration over time.

ii. Experiment 2-2/2.

a. Comparison of sucrose concentrations.

	Day 25		26		27	
water	138	(4)	40	(1)	42	(1)
15% sucrose	691	(14)	702	(14)	632	(13)
20% sucrose	783	(12)	733	(11)	728	(11)
25% sucrose	469	(9)	281	(5)	272	(5)

	Day 28		29		30	
water	194	(5)	61	(2)	.	(0)
15% sucrose	786	(16)	536	(10)	403	(8)
20% sucrose	1034	(15)	340	(5)	305	(4)
25% sucrose	884	(16)	608	(9)	202	(3)

	Day 31		32		33	
water	.	(0)	.	(0)	.	(0)
15% sucrose	399	(8)	426	(8)	452	(8)
20% sucrose	82	(1)	87	(1)	83	(1)
25% sucrose	.	(0)	.	(0)	.	(0)

	Day 34		35	
water	.	(0)	.	(0)
15% sucrose	20	(1)	20	(1)
20% sucrose	.	(0)	.	(0)
25% sucrose	.	(0)	.	(0)

Figures in parenthesis are the number of cages for which larvae were counted.
The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies (see page 157) or a reduction in the number of cages.
Numbers with the same letter within each day are not significantly different (P>0.01).

continued . . .

Table A2-2/6 continued.

(2) Cumulative sum of larvae within sucrose concentration over time.

ii. Experiment 2-2/2.

b. Comparison of cumulative sum of larvae over time.

Day	water		15% sucrose		20% sucrose		25% sucrose	
12	16 a	(16)	0	(16)	0	(16)	0	(16)
13	59 b	(16)	0	(16)	0	(16)	0	(16)
14	192 c	(16)	35 a	(16)	3 a	(16)	0	(16)
15	342 d	(16)	148 b	(16)	72 b	(15)	2 a	(16)
16	429 e	(16)	339 c	(16)	262 c	(15)	17 b	(16)
17	464 ef	(16)	417 d	(15)	446 d	(15)	104 c	(16)
18	473 ef	(16)	614 e	(16)	683 e	(15)	348 d	(16)
19	516 f	(16)	681 ef	(16)	822 f	(15)	559 e	(16)
20	499 f	(16)	716 f	(16)	866 fg	(15)	700 f	(16)
21	514 f	(16)	743 f	(16)	892 fgh	(15)	737 fg	(16)
22	521 f	(16)	744 f	(16)	954 gh	(15)	809 g	(16)
23	512 f	(16)	771 f	(16)	980 h	(15)	836 g	(16)
24	38	(1)	683	(14)	735	(11)	325	(6)
25	138	(4)	691	(14)	783	(12)	469	(9)
26	40	(1)	702	(14)	733	(11)	281	(5)
27	42	(1)	632	(13)	728	(11)	272	(5)
28	194	(5)	786	(16)	1034	(15)	884	(16)
29	61	(2)	536	(10)	340	(5)	608	(9)
30	.	(0)	403	(8)	305	(4)	202	(3)
31	.		399	(8)	82	(1)	.	(0)
32	.		426	(8)	87	(1)	.	
33	.		452	(8)	83	(1)	.	
34	.		20	(1)	.	(0)	.	
35	.		20	(1)	.		.	
36	.		20	(1)	.		.	
37	.		29	(1)	.		.	

Figures in parenthesis are the number of cages for which larvae were counted.
The cumulative sum of larvae shows a decline in some cases because of counting inaccuracies. See page 157.
Numbers with the same letter within each sucrose concentration are not significantly different (P>0.01).

Table A2-2/7

Maximum eggs laid, number and percent eggs hatched and sucrose concentration.

	Maximum total eggs	Maximum hatched eggs	Percent hatched eggs
Experiment 2-2/1			
water	31 f	21 u	68% x
10% sucrose	101 e	77 t	76% x
20% sucrose	123 e	63 t	51% xy
30% sucrose	250 d	99 t	40% y
Experiment 2-2/2			
water	680 c	521 s	77% x
15% sucrose	1127 b	771 r	68% x
20% sucrose	1395 a	980 p	70% x
25% sucrose	1329 a	836 q	63% xy

Numbers with the same letter are not significantly different (P>0.01).
No eggs hatched for the sucrose concentrations not listed.

Table A2-2/8

Sum of eggs per day for light intensities
for Experiment 2-2/3.

	Day			
	1	2	3	4
Light intensity				
0.025	34 fg	269 a	52 def	98 b
21	9 hi	68 cd	89 bc	102 b
53	17 h	59 cdef	74 bcd	88 bc
150	18 gh	78 bcd	90 bc	62 cde
630	3 i	36 fg	67 cd	40 ef

Light intensity was measured in microeinsteins per metre squared per second.
Numbers with the same letter are not significantly different (P>0.01).

Table A2-2/9

Sum of eggs at 4 days for light intensities
for both experiments.

	Experiment	
	2-2/3	2-2/4
Light intensity		
0.025	449 a	418 a
21	268 bc	225 bcd
53	237 bcd	275 b
150	245 bcd	217 cd
630	133 e	193 d

Light intensity was measured in microeinsteins per metre squared per second.
Numbers with the same letter are not significantly different (P>0.01).

Table A2-2/10

i. Sum of whiteflies alive at day 4 for light intensities.

	Experiment	
	2-2/3	2-2/4
Light intensity		
0.025	72 a	76 a
21	78 a	72 a
53	79 a	73 a
150	75 a	73 a
630	54 a	52 a
Adults at start	80 a	80 a

Light intensity was measured in microeinsteins per metre squared per second.
Numbers with the same letter are not significantly different (P>0.01).

ii. Sum of whiteflies alive per day for light intensities for Experiment 2-2/3.

	Day			
	1	2	3	4
Light intensity				
0.025	78 a	77 a	75 a	72 a
21	80 a	78 a	78 a	78 a
53	79 a	79 a	79 a	79 a
150	79 a	77 a	75 a	75 a
630	78 a	77 a	72 a	54 a
Adults at start	80 a	80 a	80 a	80 a

Light intensity was measured in microeinsteins per metre squared per second.
Numbers with the same letter are not significantly different (P>0.01).

Table A2-2/11

Sum of eggs laid during previous 24 hours for light/dark regimes.

	Day 1		Day 2		Day 3		Day 4	
Light/dark regimes								
0/24 hours	106	defg	308	a	76	ghi	303	a
4/20 hours	200	b	318	a	113	def	98	efg
8/16 hours	110	defg	204	b	168	bc	55	hi
12/12 hours	4	j	76	ghi	118	de	82	efgh
16/8 hours	6	j	62	hi	106	defg	55	hi
24/0 hours	5	j	79	fghi	138	cd	51	i

Numbers are totals for 9 cages.
Numbers with the same letter are not significantly different (P>0.01).

Table A2-2/12

Cumulative sum of eggs laid each day for light/dark regimes.

	Day 1	Day 2	Day 3	Day 4
Light/dark regimes				
0/24 hours	106 b	414 b	490 b	793 a
4/20 hours	200 a	518 a	631 a	729 a
8/16 hours	110 b	314 c	482 b	537 b
12/12 hours	4 c	80 d	198 c	280 c
16/8 hours	6 c	68 d	174 c	229 c
24/0 hours	5 c	84 d	222 c	273 c

Numbers are totals for 9 cages.
Numbers with the same letter within the same day are not significantly different (P>0.01).

Table A2-2/13

Oviposition and light/dark regimes.

Mean eggs per female per hour for previous time period.

	Light/dark regimes (hours)					
	0/24	4/20	8/16	12/12	16/8	24/0
Day 1						
Hours						
4	2.22 a	.50 b	.28 c			
8	2.50 a	.	3.94 b			
12	3.75 a	.	.	.25 a	.25 a	
16	4.85 a	.	.	.	.28 a	.75 a
24	4.91 a	11.80 a	6.75 a	.33 a	.79 a	.53 a
Day 2						
Hours						
28	7.02 a	3.97 b	7.20 a	-.25 a		3.11 a
32	9.20 a	.	12.90 a	2.62 a	1.08 a	2.53 a
36	7.49 a	.	.	4.82 a	3.69 a	.00 a
40	8.44 a	.	.	.	4.43 a	3.84 a
48	9.70 a	16.83 a	10.06 a	4.97 a	4.55 a	7.75 a
Day 3						
Hours						
52	8.48 a	1.03 a	2.96 b	3.23 a	-1.30 a	6.94 a
56	8.72 a	.	40.98 a	6.69 a	6.28 a	7.87 a
60	9.33 a	.	.	8.28 a	8.02 a	8.48 a
64	7.82 a	.	.	.	2.95 a	5.28 a
72	7.66 a	6.04 a	1.66 b	6.56 a	7.50 a	5.88 a
Day 4						
Hours						
76	8.10 a	13.15 a	5.18 a	8.98 a	2.60 a	4.51 a
80	8.63 a	.	5.72 a	10.58 a	6.73 a	9.75 a
84	7.40 a	.	.	6.86 a	5.90 a	.42 a
88	10.28 a	.	.	.	5.19 a	4.69 a
96	.	2.82 a	1.32 a	.	.	.

Numbers X100.
Numbers with the same letter within the light/dark regimes and days are not significantly different (P>0.01).

Table A2-2/14

Oviposition and light/dark regimes.

Mean eggs per female per hour laid in light and dark periods.

	Light/dark regimes (hours)			
	4/20	8/16	12/12	16/8
Day 1				
Light	.50 b	2.11 b	.08 a	.13 b
Darkness	11.80 a	6.75 a	.33 a	.79 a
Day 2				
Light	3.97 b	10.05 a	2.40 a	2.30 a
Darkness	16.83 c	10.06 a	4.97 a	4.55 a
Day 3				
Light	1.03 a	21.97 a	6.07 a	3.99 a
Darkness	6.04 a	1.66 b	6.56 a	7.50 a
Day 4				
Light	13.15 a	5.45 a	8.81	5.11
Darkness	2.82 a	1.32 a	.	.

Numbers with the same letter within each light/dark regime are not significantly different (P>0.01).

Table A2-2/15

Oviposition and light/dark regimes.

Sum of females alive

	Light/dark regimes (hours)					
	0/24	4/20	8/16	12/12	16/8	24/0
Day 1						
Hours						
4	90	87	86	88	90	89
8	90		86	88	90	89
12	90			88	89	89
16	90				88	88
24	90	87	86	87	86	87
Day 2						
Hours						
28	79	87	85	86	84	86
32	90		85	85	84	85
36	90			82	83	85
40	90				82	84
48	89	86	84	78	79	82
Day 3						
Hours						
52	89	86	82	76	78	80
56	88		82	76	78	79
60	89			76	78	79
64	88				77	78
72	88	86	82	74	76	74
Day 4						
Hours						
76	89	85	82	72	76	71
80	88		81	72	76	69
84	79			71	74	66
88	87				74	65
96		76	80			

Numbers are totals for 9 cages.
There are no significant differences ($P>0.01$) within any of the light/dark regimes.