RELATIVE SUSCEPTIBILITY OF POPULATION OF *Amrasca biguttula biguttula* (Ishida) INFESTING BITTERGOURD *Momordica charantia* L. COLLECTED FROM DIFFERENT LOCATIONS TO INSECTICIDES

By

SABITHA. R.

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur
Kerala

1992

DECLARATION

I hereby declare that this thesis entitled **"Relative susceptibility of population of Amrasca biguttula biguttula (Ishida) infesting bittergourd Momordica charantia L. collected from different locations to insecticides"** is a bonafide record of work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other University or Society.

Vellanikkara,
1.9.1992

Sabitha
SABITHA, R.

CERTIFICATE

Certified that this thesis entitled "Relative susceptibility of population of Amrasca biguttula biguttula (Ishida) infesting bitter-gourd Momordica charantia L. collected from different locations to insecticides" is a record of research work done independently by **Miss.Sabitha, R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. Sosamma Jacob
(Chairperson, Advisory Committee)
Associate Professor
Department of Entomology
College of Horticulture

Vellanikkara,
1.9.1992

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss. Sabitha, R.**, a candidate for the degree of Master of Science in Agriculture with major in Agricultural Entomology, agree that the thesis entitled "Relative susceptibility of population of *Amrasca biguttula biguttula* (Ishida) infesting bittergourd *Momordica charantia* L. collected from different locations to insecticides" may be submitted by Miss. Sabitha, R. in partial fulfilment of the requirements of the degree.

Chairperson — Dr.Sosamma Jacob, Associate Professor — 1-9-92

Members — Dr.T.S. Venkitesan, Professor and Head — 1-9-92

Dr.D. Sitarama Rao, Associate Professor — 1/9/92

Mr.V.K.G. Unnithan, Associate Professor

External Examiner

L. Nadarajan

ACKNOWLEDGEMENT

It gives me great pleasure to express my esteemed sense of gratitude to Dr.Sosamma Jacob, Associate Professor, Department of Entomology and Chairperson of my Advisory Committee for her exemplary and erudite guidance, ever willing help and constant encouragement during the course of research work and in preparation of this manuscript. I am greatly indebted to her.

I extend my sincere thanks to Dr.T.S.Venkitesan, Professor and Head, Department of Entomology for his valuable guidance.

I am greatly obliged to Dr.D. Sitarama Rao, Associate Professor, Department of Entomology for his critical appraisal of this manuscript and constructive suggestions for its betterment.

I acknowledge the help rendered by Mr.V.K.G. Unnithan for the suggestions in the preparation of this manuscript.

My gratefulness and personal obligation goes to all the members of the Department of Entomology for their help during the entire period of research.

Let me take this opportunity to thank my friend and classmate Mr.Unnimon, N.K. for all his help during the entire period of course work and research.

My profound sense of gratitude is due to my friends, Ms.Veenakumari,D., Ms.Beena, S., Ms.Veena, S.S., Ms.Sapheena, K.S., Ms.Prema, D. and Mr.Muralidharan, P. for all their acts of help during the course period.

I am forever beholden to my parents and sister who have been the source of inspiration for me at all critical junctures. I hope I have justified their unwavering confidence in me in some measure by this work.

I pay obeisance to the Almighty for helping me to make this venture a successful one.

The award of KAU Junior Fellowship is gratefully acknowledged.

SABITHA, R.

Dedicated to
my loving parents

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

Bittergourd (Momordica charantia L.) is one of the most popular cucurbitaceous vegetable crops commonly cultivated throughout India. It is considered as a valuable vegetable due to its high nutritive value and medicinal properties. It ranks first among cucurbits in respect of iron and vitamin C content.

The leaf hopper or jassid Amrasca biguttula biguttula (Ishida) (Homoptera:Cicadellidae) is one of the key pests infesting bittergourd causing serious damage to the plant. Being polyphagous, it has also been recorded feeding on a number of vegetable crops including brinjal, okra, cucurbits, beans and potato. Both the nymphs and adults suck cell sap from ventral surface of leaves and inject their toxic saliva into plant tissues. As a result, the feeding spots turn yellowish and the leaves start curling from margins inwardly; gradually the entire leaf shows yellow patches which turn red, dark brick-red or brown and ultimately dry and crumple.

Foliar applications of several insecticides belonging to different chemical groups were observed to be very effective against A. biguttula biguttula. The effectiveness of endosulfan (Krishnakumar and Srinivasan, 1987 and Yadav et al., 1989), quinalphos (Mohan, 1985; Jacob and Verma, 1985 and Kumar et al., 1988), monocrotophos (Kakar and Dogra, 1988 and Narke and Suryawanshi, 1987), phosalone

(Sidhu _et_ _al_., 1979 and Sidhu and Dhawan, 1987), carbaryl (Pareek and Noor, 1980; Tewari and Moorthy, 1983 and Kumar _et_ _al_., 1988), dimethoate and phosphamidon (Dhamdhere _et_ _al_., 1980) against _A. biguttula biguttula_ have been reported earlier.

During recent years, the attack of this leaf hopper has acquired serious dimensions and has become a major constraint in the cultivation of bittergourd crop in Kerala State. The cultivators often resort to over use of a variety of insecticides without following optimal dosage rates. The jassid populations in the State show a progressive increase in bittergourd crop with less susceptibility to insecticides. The heavy incidence of jassid populations in bitter-gourd crop and the noneffectiveness of commonly used insecticides has become a very serious concern in the State now. This situation in the field has necessitated to carry out an investigation on the susceptibility of _A. biguttula biguttula_ to commonly used insecticides in bittergourd crop.

The present study was, therefore, undertaken with the following objectives.

1. To determine the variations in the relative toxicity of commonly used insecticides against leaf hopper populations collected from different areas of the State.

2. To assess the susceptibility spectrum of populations of _A. biguttula biguttula_ collected from different areas to commonly used insecticides.

3. To bring out suggestions for any change in the existing field control recommendations against this pest.

4. To compare the susceptibility of leaf hopper populations collected from farmers' fields and homestead gardens to commonly used insecticides.

5. To compare the techniques of bioassay for susceptibility studies.

6. To study the persistent toxicity of the commonly used insecticides against *A. biguttula biguttula*.

Review of Literature

REVIEW OF LITERATURE

The important information pertaining to the investigations carried out are reviewed under the following heads.

2.1. Bioefficiency of endosulfan, quinalphos, monocrotophos, phosalone and carbaryl against the leaf hopper *Amrasca biguttula biguttula* (Ishida)

The leaf hopper *A. biguttula biguttula* has got a wide range of hosts viz. okra, cotton, cucurbits, brinjal, potato, sunflower, hollyhock, greengram, french beans, mesta etc. Literature on the bioefficiency of endosulfan, quinalphos, monocrotophos, phosalone and carbaryl to the leaf hopper *A. biguttula biguttula* in bittergourd is very scanty. Therefore, the efficiency of these insecticides against *A. biguttula biguttula* in other host crops are reviewed here.

2.1.1. Bioefficiency of endosulfan against *A. biguttula biguttula*

2.1.1.1. Okra

The effectiveness of endosulfan at 0.05 per cent (Sidhu and Simwat, 1973; Krishnakumar and Srinivasan, 1987 and Yadav *et al.*, 1989) and 0.07 per cent against *A. biguttula biguttula* in okra was reported (Srinivasan *et al.*, 1973 and Sidhu and Simwat, 1973). A combination of endosulfan at 0.05 per cent and aldicarb at 0.75 kg ai/ha was reported to be effective against *A. biguttula biguttula* by Uthamasamy and Balasubramanian (1978). Endosulfan at 0.6 kg ai/ha was observed to be very effective for the control of A. biguttula biguttula (Easwaramoorthy et al., 1976). In a relative toxicity study, Singh and Teotia (1978) found that endosulfan was 2.28 times as toxic as lindane to A. biguttula biguttula.

From the view point of residues in fruits, endosulfan at 0.035 per cent was preferred for the control of A. biguttula biguttula in okra. It was found to give a rapid knock down effect causing 84 per cent mortality to A. biguttula biguttula (Dhamdhere et al., 1980).

2.1.1.2. Cotton

Sequential application of endosulfan at 0.05 per cent with monocrotophos at 0.05 per cent was found to give 70 per cent control of Amrasca devastans Dist. on cotton (Agarwal and Katiyar, 1975). The effectiveness of endosulfan at 0.05 to 0.09 per cent against A. devastans in cotton was observed by Sidhu and Dhawan (1976) and Visvanathan and Abdul kareem (1983). According to Karuppachamy et al. (1986) the population of A. devastans was lowest with the treatment of endosulfan at 0.05 per cent in combination with carbofuran or aldicarb.

2.1.1.3. Brinjal

In brinjal, 0.025 per cent endosulfan was observed to be very effective against the nymphs of A. biguttula biguttula (Veeravel and Bhaskaran, 1976). But according to Tewari and Moorthy (1983), endosulfan at 0.05 per cent was more effective for the control of A. biguttula biguttula over that of synthetic pyrethroids.

2.1.1.4. Sunflower

In sunflower, a mixture of endosulfan at 0.05 per cent and sulphur at 2 g/l were found to be effective for the control of A. biguttula biguttula (Deshmukh, 1977). The effectiveness of endosulfan at 0.05 per cent applied at 25, 35 and 45 days after sowing of sunflower was also reported by Balasubramanian and Chelliah (1985).

2.1.1.5. Tomato

In tomato, 0.05 per cent endosulfan was observed to be effective against A. devastans (Agrawal and Kushwaha, 1979).

2.1.1.6. Ridge gourd

Sprays containing 0.05 per cent endosulfan were indicated to be effective for the control of A. biguttula biguttula in ridge gourd (Pareek and Noor, 1980).

2.1.2. Bioefficiency of quinalphos against A. biguttula biguttula

2.1.2.1. Okra

In okra, 0.025 per cent (Srinivasan et al., 1973) and 0.05 per cent quinalphos were observed to be effective against A. biguttula biguttula (Nair et al., 1977 and Mohan, 1985). But according to Dhamdhere et al. (1985) granules of quinalphos at 0.75, 1.00 and 1.50 kg ai/ha prevented an increase in the population of *A. biguttula biguttula*. The use of quinalphos at 0.03 per cent caused 57 per cent reduction in population of *A. biguttula biguttula* on okra while a higher dose of 0.05 per cent caused 68 per cent reduction in population (Jacob and Verma, 1985).

2.1.2.2. Cotton

The effectiveness of quinalphos at 0.3 kg ai/ha against *A. biguttula biguttula* on cotton was observed by Sidhu et al. 1979).

2.1.2.3. Brinjal

According to Subbaratnam and Butani (1984), 0.1 per cent quinalphos had a high persistent toxicity to second instar nymphs of *A. biguttula biguttula* on brinjal. Banerjee and Raychaudhari (1988) also observed the effectiveness of quinalphos for the control of *A. devastans*. According to Kumar et al. (1988) 0.05 per cent quinalphos was most effective against *A. biguttula biguttula* followed by 0.025 per cent in brinjal.

2.1.2.4. Ridge gourd

Sprays containing 0.025 per cent quinalphos was reported to be effective against *A. biguttula biguttula* on ridge gourd (Pareek and Noor, 1980).

2.1.3. Bioefficiency of monocrotophos against A. biguttula biguttula

2.1.3.1. Okra

The use of monocrotophos at 0.03 per cent was reported to give effective control of A. devastans on okra (Gupta and Dhari, 1978). Monocrotophos at 500 g ai/ha was observed to be effective in controlling A. biguttula biguttula (Patel et al., 1980; Krishnakumar and Srinivasan, 1987 and Kakar and Dogra, 1988). But the effectiveness of monocrotophos at a lower dose of 0.04 per cent against A. biguttula biguttula was indicated by Easwaramoorthy et al., 1976; Pareek et al., 1987; Narke and Suryawanshi, 1987 and Singh and Misra, 1988.

2.1.3.2. Cotton

Sidhu and Dhawan (1976) reported the effectiveness of monocrotophos at 0.5 kg ai/ha against A. biguttula biguttula. Agarwal and Katiyar (1975) observed that application of monocrotophos at 0.05 per cent with 0.05 per cent endosulfan and dimethoate at 0.03 per cent with monocrotophos at 0.05 per cent gave 70 per cent control of A. devastans on cotton. The application of monocrotophos at 0.3 kg ai/ha was reported to be effective in controlling A. biguttula biguttula (Sidhu et al., 1979) while the use of a lower dose of monocrotophos at 0.15 kg ai/ha was found to reduce the population of A. biguttula biguttula in cotton (Chakkaravarthy and Balasubramanian, 1986). According to Sidhu and Dhawan (1976) and Visvanathan and Abdul Kareem (1983) monocrotophos at 0.05 per cent effectively controlled _A_. _devastans_ on cotton. The effectiveness of monocrotophos at 100 g ai/ha against _A_. _biguttula biguttula_ was reported by Dhawan _et al_. (1988).

2.1.3.3. Potato

Good control of _A_. _biguttula biguttula_ was reported with monocrotophos at 0.25 kg ai/ha in potato by Mavi and Singh (1975). According to Misra and Lal (1981) monocrotophos applied at 0.05 per cent was effective against _A_. _devastans_ on potato.

2.1.3.4. Greengram

Gartoria and Singh (1984) reported sprays of monocrotophos at 0.4 kg ai/ha applied after four and eight weeks of sowing brought about 52 to 96 per cent reduction in the population of _A_. _biguttula biguttula_ within 10 days in greengram.

2.1.4. Bioefficiency of phosalone against _A_. _biguttula biguttula_

2.1.4.1. Cotton

Application of phosalone at 0.3 kg ai/ha was reported to be effective for the control of _A_. _biguttula biguttula_ in cotton (Sidhu _et al_., 1979). Effective control of _A_. _biguttula biguttula_ with phosalone at 0.5 kg ai/ha was indicated by Mundiwale _et al_., 1983; Sidhu and Dhawan, 1987 and Pawar _et al_., 1987.

2.1.5. Bioefficiency of carbaryl against A. biguttula biguttula

2.1.5.1. Okra

Carbaryl at 0.1 per cent has been reported to be effective against A. biguttula biguttula (Vijayaraghavan et al., 1965; David et al., 1967; Srinivasan et al., 1973; Chopra and Gera, 1976; Sidhu and Dhawan, 1981 and Mohan, 1985). Rawat and Jakhmola (1977) reported that carbaryl 10 per cent granules at the rate of 18.75 kg/ha gave effective control of A. devastans on okra. A mixture of 13 per cent carbaryl and 13 per cent lindane (Sevidol) was found to be effective in reducing the population of A. biguttula biguttula on okra when applied at 2 kg ai/ha (Sarma and Rao, 1979). The effectiveness of carbaryl at 0.15 per cent against A. biguttula biguttula in okra was indicated by Sidhu and Simwat, 1973; Gupta and Dhari, 1978; Dhamdhere et al., 1987; Pareek et al., 1987 and Yadav et al., 1989.

2.1.5.2. Cotton

The effectiveness of carbaryl at 0.2 per cent was indicated by Atwal and Singh (1969). Agarwal and Katiyar (1975) observed that sequential application of carbaryl at 0.2 per cent with dimethoate at 0.03 per cent brought about 70 per cent control of A. devastans on cotton. According to Thimmaiah (1977) there was 33.7 per cent reduction in the nymphal population of A. biguttula biguttula after application of six sprays of carbaryl at 0.2 per cent. A combination of carbaryl and HCH at a ratio of 1:1 applied at 20 kg/ha was found to be effective in controlling *A. biguttula biguttula* (Borle *et al.*, 1980). Application of carbaryl at 1.25 kg ai/ha was indicated to be effective against *A. biguttula biguttula* on cotton (Sidhu and Dhawan, 1987).

2.1.5.3. Brinjal

The effectiveness of carbaryl at 0.2 per cent (Tewari and Moorthy, 1983) and at 0.15 per cent (Kumar *et al.*, 1988) against *A. biguttula biguttula* was reported on brinjal.

2.1.5.4. Sunflower

Deshmukh (1977) reported that a mixture of carbaryl at 0.2 per cent and sulphur at 2 g/l was effective in reducing the infestation of *A. biguttula biguttula* on sunflower.

2.1.5.5. Ridge gourd

Pareek and Noor (1980) reported that sprays containing 0.2 per cent carbaryl were very effective in controlling *A. biguttula biguttula* infesting ridge gourd.

2.2. Susceptibility/resistance of sucking insect pests to endosulfan, quinalphos, monocrotophos, phosalone and carbaryl

No work has been reported on the susceptibility/resistance of *A. biguttula biguttula* to endosulfan, quinalphos, monocrotophos, phosalone and carbaryl. Therefore, susceptibility/resistance of other sucking pests to these insecticides are taken into consideration in this review.

2.2.1. Susceptibility/resistance of sucking pests to endosulfan

Field evidence of resistance to endosulfan in green peach potato aphid Myzus persicae Sulzer was reported by Fellowes and Ferguson (1974). A non-stable endosulfan resistance in M. persicae was detected by Bauernfeind and Chapman (1985). They found that endosulfan resistant aphid populations collected from fields were reverted to susceptibility after being maintained in green house insecticide free environments. Reversions to parathion susceptibility was paralleled by near - simultaneous reversions to endosulfan susceptibility. Katundu and Aliniazee (1990) reported development of 1.8 to 50 fold resistance to endosulfan in the filbert aphid Myzocallis coryli (Goetze) in Oregon.

Follet et al. (1985) observed 5-12 fold resistance to endosulfan in selected strains of the psyllid, Psylla pyricola Forester from pear orchards in Oregon. According to Ahmed et al. (1987) the resistance in adults of cotton whitefly Bemisia tabaci Genn. was 364 fold for endosulfan while it was 10 fold for a mixture of dimethoate with endosulfan.

2.2.2. Susceptibility/resistance of sucking pests to quinalphos

Fellowes and Ferguson (1974) detected the development of field resistance in green peach potato aphid *M. persicae* to quinalphos in Auckland. According to Dittrich and Ernst (1983), Sudanese field strains of *B. tabaci* were moderately resistant to quinalphos in cotton.

2.2.3. Susceptibility/resistance of sucking pests to monocrotophos

Wavte *et al.* (1977) reported the development of resistance to methyl parathion and monocrotophos in the banded wing whitefly *Trialeurodes abutilonea* (Haldeman) in Louisiana. Although low levels of resistance (X6) to monocrotophos was demonstrated in laboratory tests, it was still effective for the control of whitefly in the field.

Dittrich and Ernst (1983) reported that Sudanese field strains of *B. tabaci* were highly resistant to monocrotophos in cotton. The status of *B. tabaci* in cotton was found to be increased from secondary to primary pest level due to the increased resistance to monocrotophos, DDT and other organophosphates (Dittrich *et al.*, 1986).

Malathion resistant strains of the brown plant hopper *Nilaparvata lugens* Stal. were reported to show 5-26 fold resistance to monocrotophos while fenitrothion resistant strains showed 5-12 fold cross resistance to monocrotophos (Ozaki and Kassai, 1984). Resistance to monocrotophos was indicated in brown plant hoppers selected in the laboratory with carbaryl or propoxur (Kassai and Ożaki, 1984).

2.2.4. Susceptibility/resistance of sucking pests to phosalone

The cotton aphid, Aphis gossypii Glover was reported to have developed 70 fold resistance to phosalone in Tashkent region of the USSR (Abdullaev, 1984). Katundu and Aliniazee (1990) detected the development of resistance in filbert aphid M. coryli to phosalone. The resistance level was found to vary from 1.7 to 49,069 fold against phosalone.

2.2.5. Susceptibility/resistance of sucking pests to carbaryl

Several populations of the green leaf hopper Nephotettix cincticeps Uhler. were found to possess some degree of resistance to carbamate insecticides (Hama and Iwata, 1973). According to Hama (1975) increase in resistance to several organophosphorous insecticides seemed to have involved in the occurrence of carbamate resistance in rice green leaf hopper. Kao et al. (1981) reported that all populations of Nephotettix spp. in Taiwan showed the development of resistance to carbaryl with resistance ratios varying from 12 to 79.

According to Ozaki and Kassai (1984), malathion resistant strains of the brown plant hopper showed 5-26 fold resistance to carbaryl while fenitrothion resistant strains showed 5-32 fold cross resistance to carbaryl.

Evans (1973) observed considerable variations in the susceptibility of sugarcane frog hopper <u>Aeneolamia</u> <u>varia</u> <u>saccharina</u> Dist. to carbaryl. Resistance in frog hoppers to carbaryl was found to be present in several areas of Trinidad.

Aliniazee (1983) reported carbaryl resistance in the filbert aphid <u>M</u>. <u>coryli</u>. Populations exposed to carbaryl for 5 years required 17 to 22 times more chemical than a susceptible strain while populations exposed to carbaryl for 20 years required 78 to 145 times more chemical.

Materials and Methods

MATERIALS AND METHODS

The study was conducted at the College of Horticulture, Vellanikkara in the year 1991-92 using populations of the leaf hopper *Amrasca biguttula biguttula* (Ishida) in bittergourd collected from farmers' fields and homestead gardens of four different areas of Kerala State.

The leaf hoppers infesting bittergourd (*Momordica charantia* L.) was got identified from IARI, New Delhi as *Amrasca biguttula biguttula* (Ishida).

3.1. Selection of localities for the collection of leaf hopper populations in bittergourd

Four localities representing four districts of Kerala State were selected for collecting the leaf hopper populations to carry out the experiments. These districts were selected on the basis of the reports received from the farmers about the heavy incidence of jassid populations in bittergourd crop showing less susceptibility to insecticides. The localities selected are given in Table 1.

Table 1. Localities selected for collecting leaf hopper populations

Population No.	Locality	District
1	Kuruppanthara	Kottayam
2	Vellanikkara	Thrissur
3	Ottapalam	Palakkad
4	Angadippuram	Malappuram

3.4.1. Bioassay techniques

The spray-residue test method recommended by FAO (1979) was used for assessing the susceptibility of different populations of leaf hoppers against the five insecticides. Leaves of uniform size with petiole ends wrapped with moist cotton were collected from bittergourd plants and kept in petridishes (10 cm dia.). They were then sprayed with different concentrations of the insecticides under the Potter's tower at a pressure of 25 cm of mercury column. Both the dorsal and ventral surfaces of the leaves were sprayed each with one ml of spray material and the leaves were allowed to dry under an electric fan for ten minutes. Three replications were maintained for each treatment. An untreated control by spraying the leaf with water alone was also maintained.

Ten uniform sized nymphs of A. biguttula biguttula were then transferred to the sprayed leaves in the petridishes by using a camel hair brush and covered with the upper petridishes. The petridishes were kept in the laboratory at a temperature of 30 ± 1°C. Observations on the mortality of leaf hoppers were recorded after 24 hours of treatment. This procedure was adopted for testing the susceptibility of all the different populations of A. biguttula biguttula towards the five insecticides of endosulfan, quinalphos, monocrotophos, phosalone and carbaryl.

The leaf dip method of bioassay (FAO, 1979) using the leaf hopper population of Vellanikkara alone was also carried out with a view to compare the two bioassay methods. In the leaf dip test, uniform sized leaves of bittergourd plants were immersed in different concentrations of insecticides for 10 seconds, with gentle agitation. The leaves were then dried under a fan for 15 minutes and the rest of the procedure was same as that of the spray-residue test.

3.5. Persistent toxicity of different insecticides against Vellanikkara population of A. biguttula biguttula

An experiment was conducted to study the persistent toxicity of five different insecticides viz. endosulfan, quinalphos, monocrotophos, phosalone and carbaryl against the Vellanikkara population of A. biguttula biguttula in bittergourd. Bittergourd plants were raised in pots of size 27.5 x 26 cm. The five insecticides were sprayed at the recommended concentrations (KAU, 1989) on the plants 25 days after sowing. There were three replications for each treatment. A control was also maintained by spraying only water. Leaves of treated bittergourd plants were collected 1, 3, 5, 7, 14 and 21 days after application of insecticides. The leaves were then placed in petridishes (10 cm dia) with the petiole ends wrapped in moist cotton to prevent drying.

Ten uniform sized nymphs of A. biguttula biguttula collected from the field were then transferred to the sprayed leaves in the petridish by using a camel hair brush and covered with the upper petridishes. They were kept in the laboratory at a temperature of 30 ± 1°C. Observations on the mortality of leaf hoppers were recorded after 24 hours of treatment. The percentage mortality and persistent toxicity values were then calculated.

3.6. Interpretation of data

From the data on mortality of leaf hoppers recorded after 24 h of treatment, percentage mortality was calculated and corrected based on Abbots' formula (Abbot, 1925), wherever mortality in control was observed.

The data on dosage mortality response of different populations to the five insecticides were subjected to probit analysis according to Finney (1971).

Results

RESULTS

The results of the present investigations are presented as follows:

4.1. Relative toxicity of endosulfan, quinalphos, monocrotophos, phosalone and carbaryl against four different populations of A. biguttula biguttula collected from farmers' fields

The relative toxicity values of different insecticides against A. biguttula biguttula have been calculated by taking LC_{50} value of carbaryl as unity. Carbaryl has been selected as a standard to compare the toxicity values since it is mainly recommended for the control of pests in vegetable crops.

4.1.1. Relative toxicity of different insecticides to Kuruppanthara population of A. biguttula biguttula collected from farmers' fields

The mortality of the leaf hoppers obtained 24 hours after treatment were subjected to probit analysis and presented in Table 4 and graphically depicted in Fig. 1. It is evident that all the five insecticides tested were not equally effective against the Kuruppanthara population of leaf hoppers. All of them were found to be more toxic than carbaryl. Monocrotophos showed the highest toxicity value with the lowest LC_{50} value of 0.032587. It was proved to be 5.78 times more toxic than carbaryl. The order of toxicity of other insecticides was: endosulfan > quinalphos > phosalone.

Table 4. Relative toxicity of different insecticides to Kuruppanthara population of *A. biguttula biguttula* collected from farmers' fields

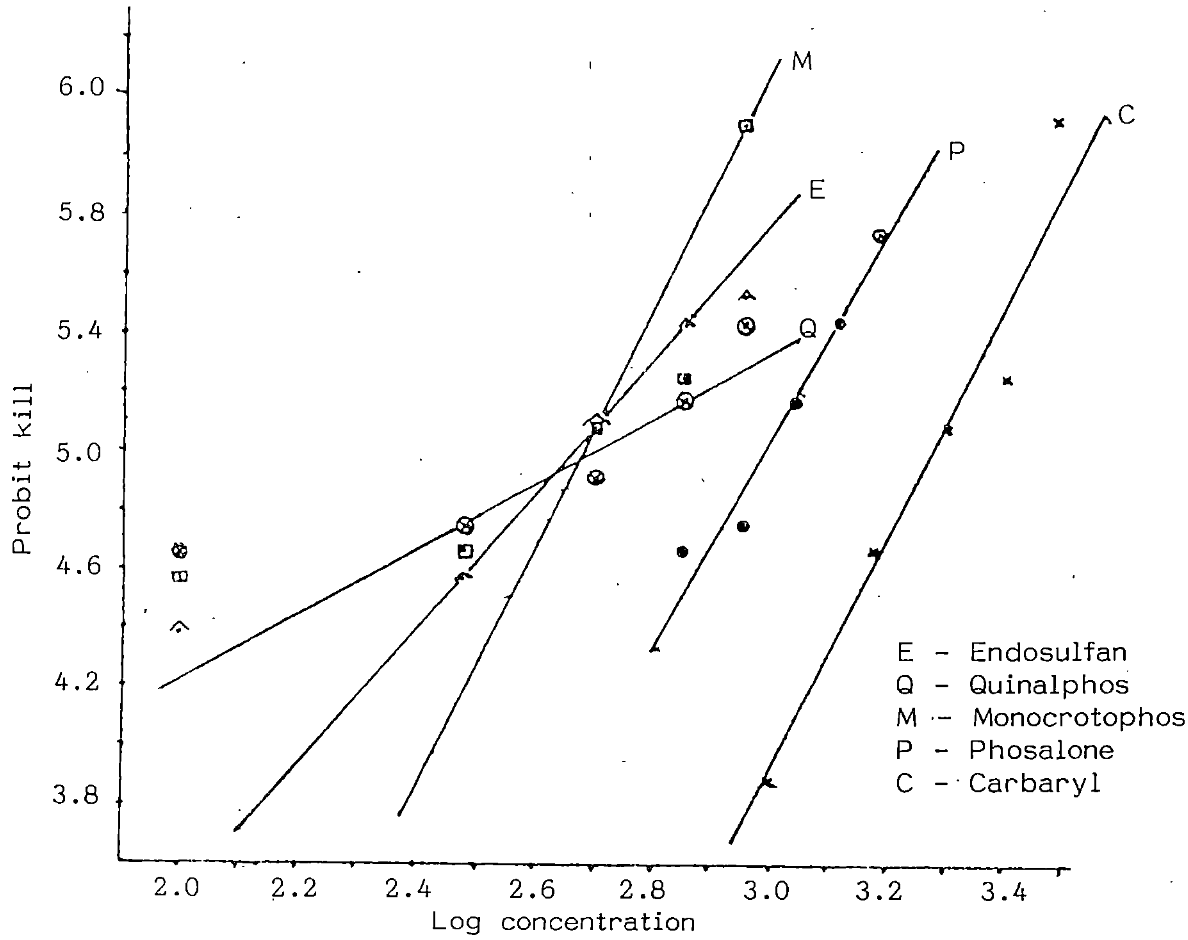
Insecticide	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	2.0484	Y = 6.802 + 1.288x	0.039916	0.02754 0.05783	4.72
2. Quinalphos	1.64337	Y = 6.0178 + 0.736x	0.041682	0.03410 0.05093	4.52
3. Monocrotophos	6.98154	Y = 6.8959 + 1.275x	0.032587	0.02209 0.04806	5.78
4. Phosalone	0.84901	Y = 8.3952 + 3.3394x	0.096228	0.08273 0.111916	1.96
5. Carbaryl	2.22155	Y = 7.970 + 4.0973x	0.188335	0.16663 0.21286	1.00

* In none of these cases, the data were found to be significantly heterogeneous at P = 0.05

Y = probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 1. Susceptibility of Kuruppanthara population of A. biguttula biguttula collected from farmers' fields to different insecticides



These insecticides were 4.72, 4.52 and 1.96 times as toxic as carbaryl respectively.

4.1.2. Relative toxicity of different insecticides to Ottapalam population of A. biguttula biguttula collected from farmers' fields

The results are presented in Table 5 and graphically depicted in Fig. 2. In Ottapalam population, endosulfan was found to have the highest relative toxicity value (8.72 times as toxic as carbaryl) and similar values for other insecticides were: monocrotophos 4.98, quinalphos 4.92 and phosalone 2.56. The order of toxicity of insecticides was endosulfan > monocrotophos > quinalphos > phosalone > carbaryl. Carbaryl was found to have the lowest toxicity against Ottapalam population of A. biguttula biguttula.

4.1.3. Relative toxicity of different insecticides to Angadippuram population of A. biguttula biguttula collected from farmers' fields

Perusal of Table 6 indicates that endosulfan showed highest relative toxicity value (5.84) followed by monocrotophos (4.08). The trend in the toxicity of different insecticides to Angadippuram population of leaf hoppers was observed to be similar to that of Ottapalam population (Fig. 3). The descending order of relative toxicity with values was endosulfan 5.84 > monocrotophos 4.08 > quinalphos 3.36 > phosalone 2.37 times as toxic as carbaryl. In both Ottapalam and Angadippuram populations, endosulfan was

Table 5. Relative toxicity of different insecticides to Ottapalam population of A. biguttula biguttula collected from farmers' fields

Insecticides	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	5.0242	Y = 7.211 + 1.379x	0.02491	0.01661 0.03736	8.72
2. Quinalphos	1.18142	Y = 6.7305 + 1.276x	0.04414	0.03033 0.06423	4.92
3. Monocrotophos	2.39868	Y = 7.1527 + 1.583x	0.04367	0.03213 0.05934	4.96
4. Phosalone	0.79449	Y = 9.638 + 4.331x	0.08491	0.07572 0.09522	2.56
5. Carbaryl	1.13237	Y = 6.968 + 2.969x	0.21736	0.183803 0.25706	1.00

* In none of these cases, the data was found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 2. Susceptibility of Ottapalam population of _A. biguttula biguttula_ collected from farmers' fields to different insecticides

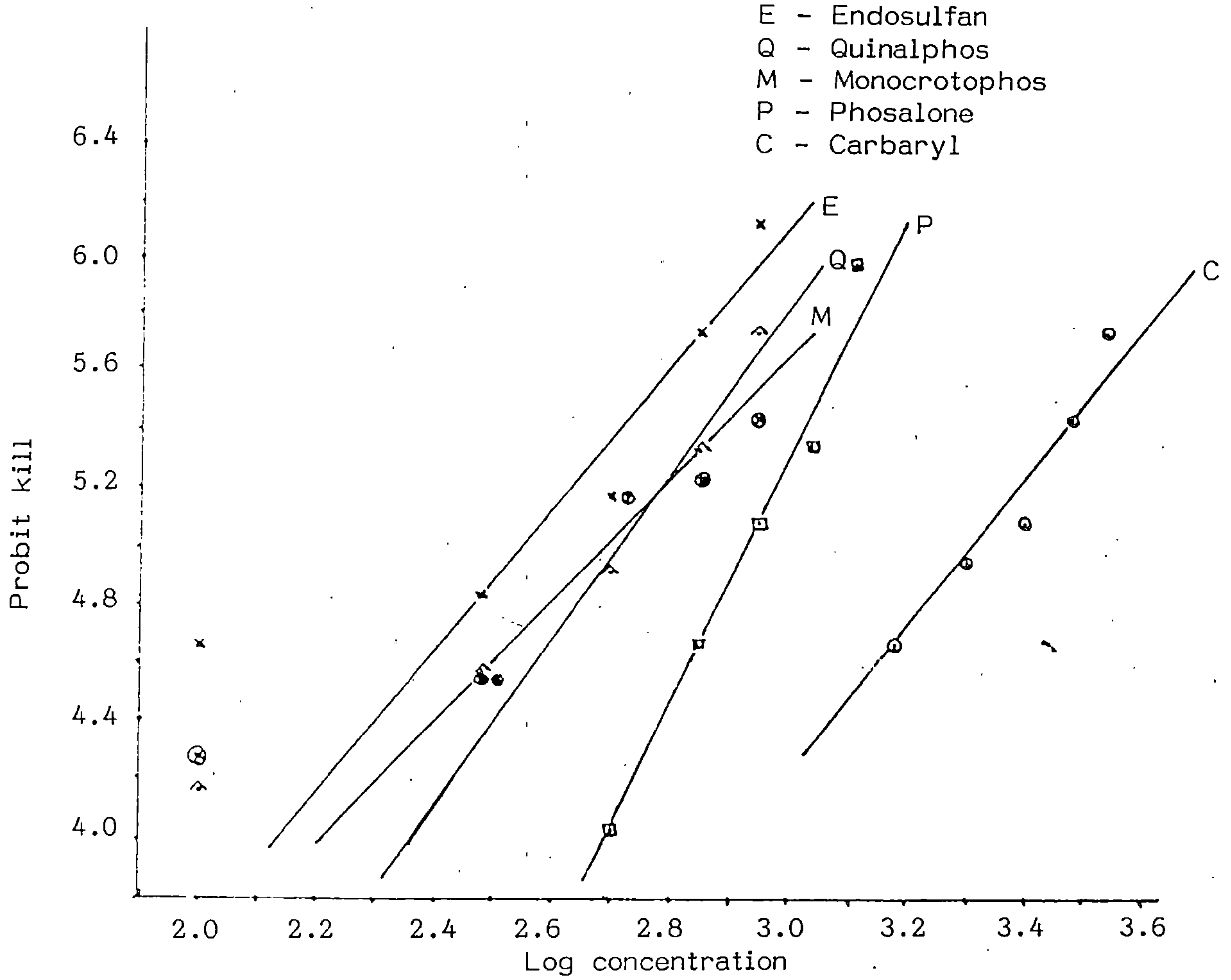


Table 6. Relative toxicity of different insecticides to Angadippuram population of *A. biguttula biguttula* collected from farmers' fields

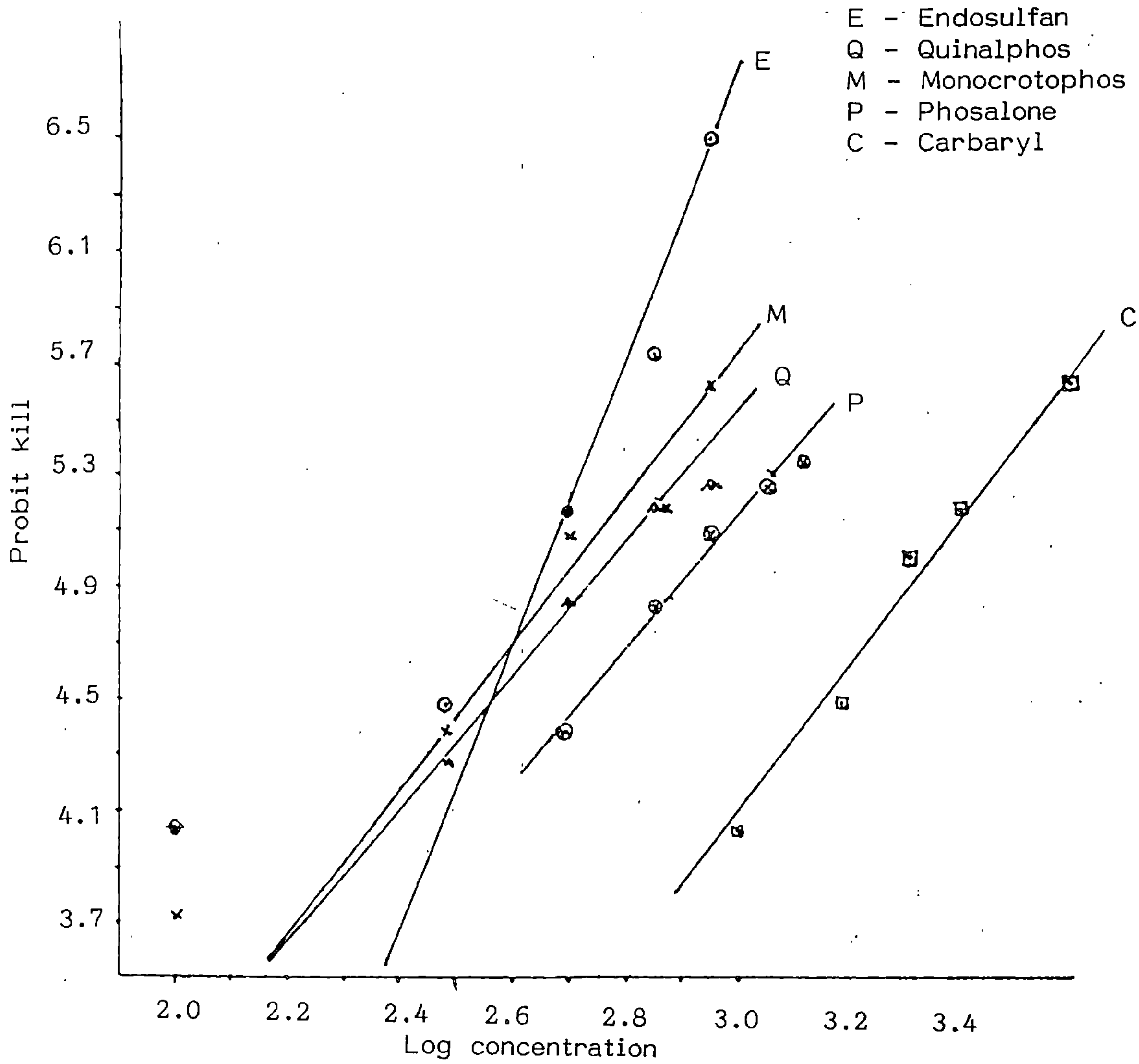
Insecticide	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	6.7476	Y = 8.441 + 2.37x	0.03533	0.0282 0.04426	5.84
2. Quinalphos	1.76028	Y = 6.721 + 1.419x	0.061350	0.04205 0.08949	3.36
3. Monocrotophos	1.29672	Y = 7.5901 + 1.997x	0.050537	0.03926 0.06505	4.08
4. Phosalone	0.246406	Y = 7.467 + 2.326x	0.087019	0.07103 0.10659	2.37
5. Carbaryl	0.5219	Y = 7.237 + 3.265x	0.206397	0.17516 0.2432	1.00

* In none of these cases, the data was found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 3. Susceptibility of Angadippuram population of A. biguttula biguttula collected from farmers' fields to different insecticides



found to have the highest toxicity against A. biguttula biguttula. The LC_{50} values of carbaryl in Ottapalam and Angadippuram populations were found to be 0.21736 and 0.206397 indicating the greater effectiveness of carbaryl against Angadippuram population than Ottapalam population of leaf hoppers.

4.1.4. Relative toxicity of different insecticides to Vellanikkara population of A. biguttula biguttula collected from farmers' fields

It is clear from Table 7 and Fig. 4 that quinalphos and monocrotophos were more toxic than carbaryl while endosulfan and phosalone were less toxic than carbaryl to Vellanikkara population of leaf hoppers. Quinalphos was observed to be the most effective insecticide and it was found to be 2.06 times more toxic than carbaryl. Phosalone was proved to be the least effective insecticide against Vellanikkara population. The descending order of toxicity of insecticides was quinalphos > monocrotophos > carbaryl > endosulfan > phosalone. Quinalphos and monocrotophos were 2.06 and 1.22 times more toxic than carbaryl while endosulfan and phosalone were 0.99 and 0.58 times less toxic than carbaryl.

An overall view (Table 8) of the relative toxicities of five insecticides tested against four populations of leaf hoppers collected from farmers' fields revealed the following.

Table 7. Relative toxicity of different insecticides to Vellanikkara population of *A. biguttula biguttula* collected from farmers' fields

Insecticide	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	1.6971	Y = 7.009 + 1.3845x	0.035382	0.02486 0.05035	0.99
2. Quinalphos	1.1303	Y = 6.821 + 1.028x	0. 016955	0.00863 0.03322	2.06
3. Monocrotophos	4.5813	Y = 7.001 + 1.298x	0.028736	0.0192 0.0428	1.22
4. Phosalone	1.4971	Y = 8.8952 + 3.2001x	0.0606418	0.05185 0.07092	0.58
5. Carbaryl	2.6521	Y = 7.7557 + 1.7561x	0.0349686	0.02598 0.04706	1.00

* In none of these cases, the data were found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 4. Susceptibility of Vellanikkara population of A. biguttula biguttula collected from farmers' fields to different insecticides

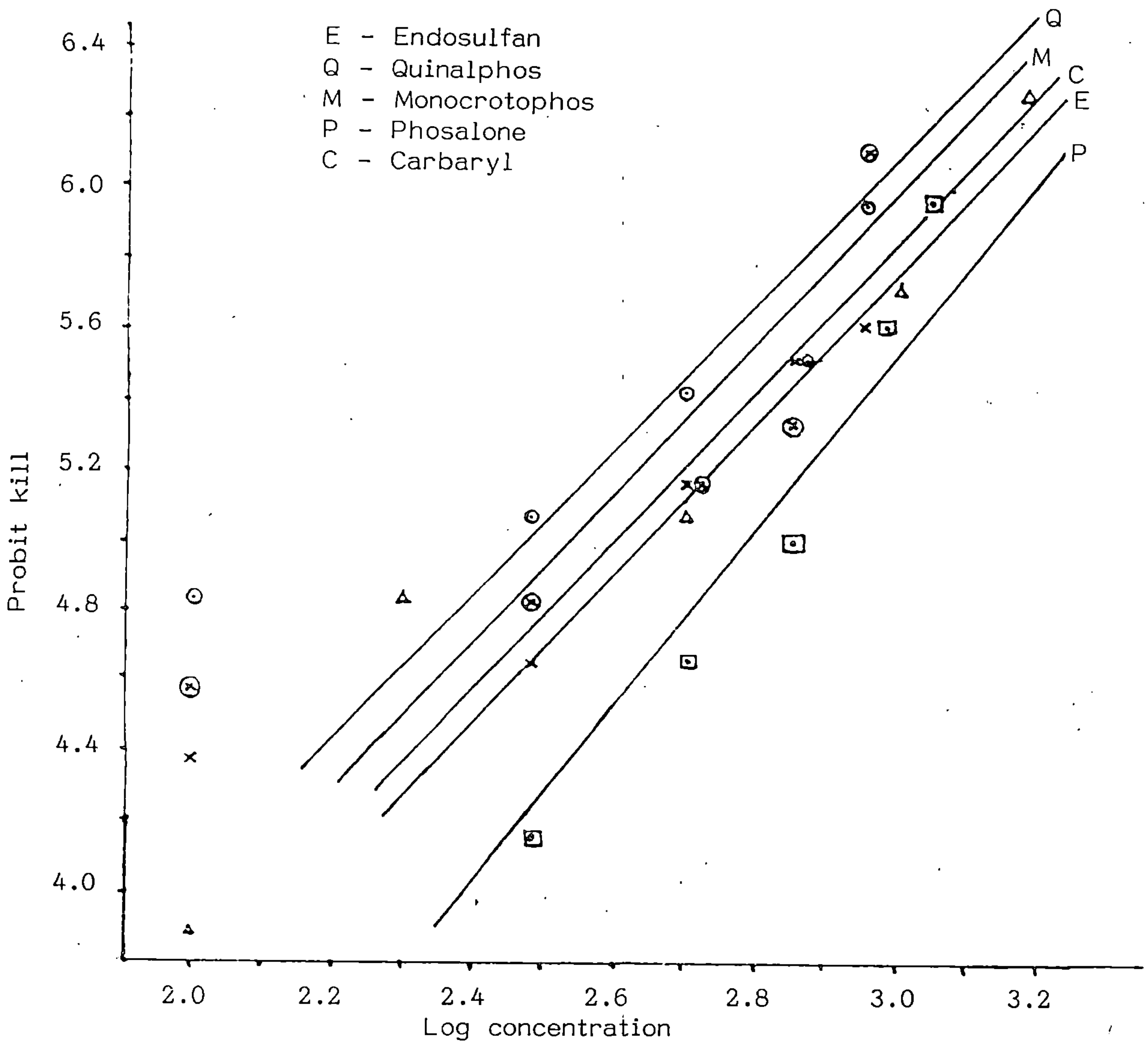


Table 8. Order of relative toxicity of five insecticides against four populations of A. biguttula biguttula collected from farmers' fields

Population	Order of relative toxicity of insecticides				
1. Kuruppanthara	Monocrotophos (5.78)	Endosulfan (4.72)	Quinalphos (4.52)	Phosalone (1.96)	Carbaryl (1.00)
2. Ottapalam	Endosulfan (8.72)	Monocrotophos (4.96)	Quinalphos (4.92)	Phosalone (2.56)	Carbaryl (1.00)
3. Angadippuram	Endosulfan (5.84)	Monocrotophos (4.08)	Quinalphos (3.36)	Phosalone (2.37)	Carbaryl (1.00)
4. Vellanikkara	Quinalphos (2.06)	Monocrotophos (1.22)	Carbaryl (1.00)	Endosulfan (0.99)	Phosalone (0.58)

Figures in parantheses indicate relative toxicity values

Among the five insecticides tested against A. biguttula biguttula, endosulfan was found to be most effective against Ottapalam and Angadippuram populations while monocrotophos was found to be most effective against Kuruppanthara population and quinalphos was most effective against Vellanikkara population. Carbaryl was least effective at all localities except Vellanikkara where phosalone was found to be least effective. The order of toxicity of insecticides was found to be similar against Ottapalam and Angadippuram populations. Monocrotophos was found to be the second best insecticide against all the populations except Kuruppanthara. Phosalone was proved less toxic to all the populations.

4.2. Relative toxicity of endosulfan, quinalphos, monocrotophos, phosalone and carbaryl against four different populations of A. biguttula biguttula collected from homestead gardens

The relative toxicities of different insecticides have been calculated by taking the LC_{50} values of carbaryl as unity.

4.2.1. Relative toxicity of different insecticides to Kuruppanthara population of A. biguttula biguttula collected from homestead gardens

From the results in Table 9 it is indicated that all the insecticides tested were found to be more toxic than carbaryl against the population of A. biguttula biguttula collected from homestead gardens (Fig. 5). Endosulfan was found to have the highest

Table 9. Relative toxicity of different insecticides to Kuruppanthara population of _A. biguttula biguttula_ collected from homestead gardens

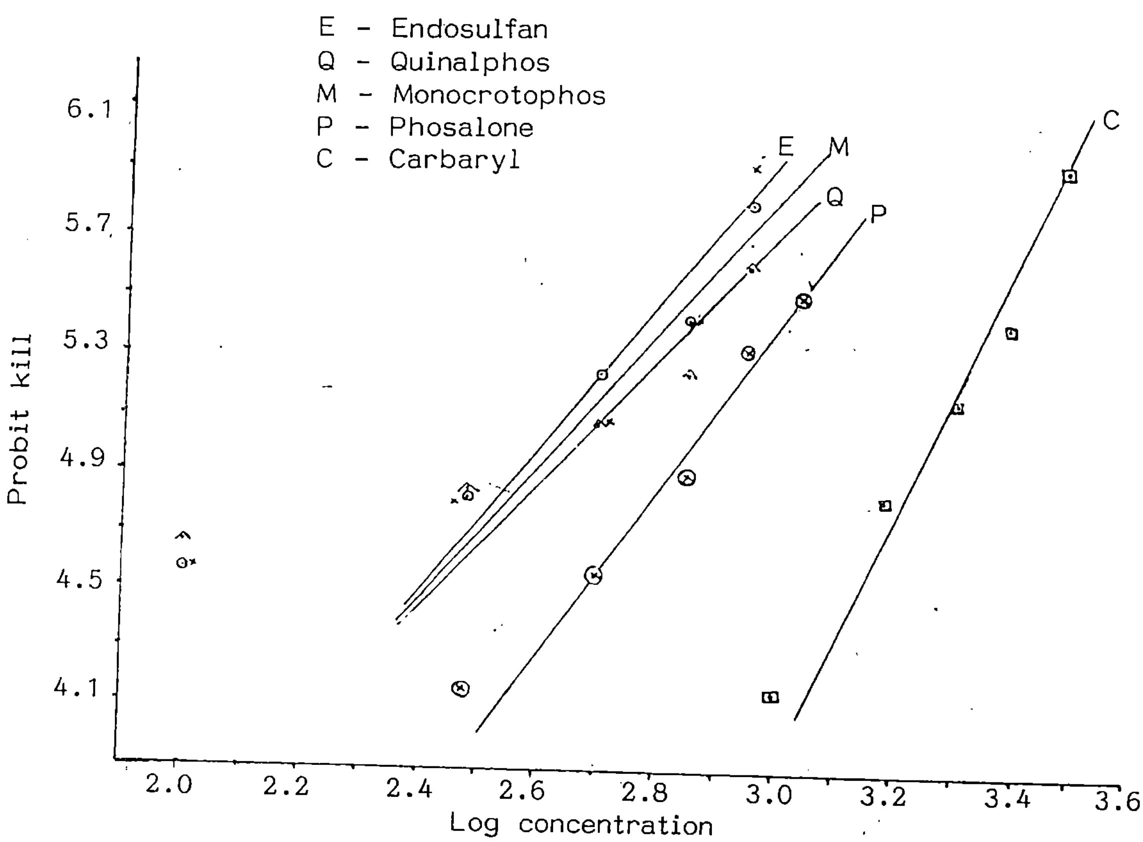
Insecticide	Heterogeneity* X^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	1.84762	Y = 6.909 + 1.233x	0.028340	0.0186 0.04327	6.14
2. Quinalphos	1.61166	Y = 6.351 + 0.9008x	0.031662	0.0290 0.03456	5.49
3. Monocrotophos	3.5667	Y = 6.929 + 1.2604x	0.029460	0.02393 0.03626	5.90
4. Phosalone	0.40384	Y = 7.8937 + 2.503x	0.069851	0.063245 0.077147	2.49
5. Carbaryl	0.61776	Y = 7.6601 + 3.5013x	0.163876	0.161631 0.187048	1.00

* In none of the cases, the data were found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = long (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 5. Susceptibility of Kuruppanthara population of A. biguttula biguttula collected from homestead gardens to different insecticides



toxicity. It was observed to show 6.14 times more toxicity than carbaryl. The next effective insecticide was monocrotophos which was 5.9 times more toxic than carbaryl. Phosalone was found to be 2.49 times as toxic as carbaryl. The descending order of toxicity of insecticides against the leaf hopper population from homestead gardens was endosulfan > monocrotophos > quinalphos > phosalone > carbaryl.

4.2.2. Relative toxicity of different insecticides to Ottapalam population of A. biguttula biguttula collected from homestead gardens

The results are presented in Table 10 and graphically depicted in Fig. 6. It is seen that all the insecticides were more effective than carbaryl against Ottapalam population. Endosulfan was the most effective insecticide against Ottapalam population. It was 9.27 times as toxic as carbaryl. Quinalphos was 5.3 times as toxic as carbaryl, while monocrotophos was 4.81 times as toxic as carbaryl. The descending order of toxicity of insecticides was endosulfan > quinalphos > monocrotophos > phosalone > carbaryl.

4.2.3. Relative toxicity of different insecticides to Angadippuram population of A. biguttula biguttula collected from homestead gardens

Endosulfan was observed to exhibit the highest relative toxicity value followed by quinalphos against A. biguttula biguttula (Table 11). It is also evident that the order of toxicity

Table 10. Relative toxicity of different insecticides to Ottapalam population of *A. biguttula biguttula* collected from homestead gardens

Insecticide	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	2.6322	Y = 6.7117 + 1.0163x	0.020690	0.015237 0.0281	9.27
2. Quinalphos	4.3441	Y = 6.9025 + 1.3196x	0.036172	0.02999 0.04361	5.30
3. Monocrotophos	2.505	Y = 6.80576 + 1.291x	0.039870	0.03301 0.048169	4.81
4. Phosalone	1.98465	Y = 8.3118 + 3.046x	0.0817719	0.07472 0.08948	2.35
4. Carbaryl	22.9777	Y = 7.0298 + 2.831x	0.191884	0.175946 0.209265	1.00

* The data were not found to be heterogeneous at P = 0.05 except in the case of carbaryl

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 6. Susceptibility of Ottapalam population of A. biguttula biguttula collected from homestead gardens to different insecticides

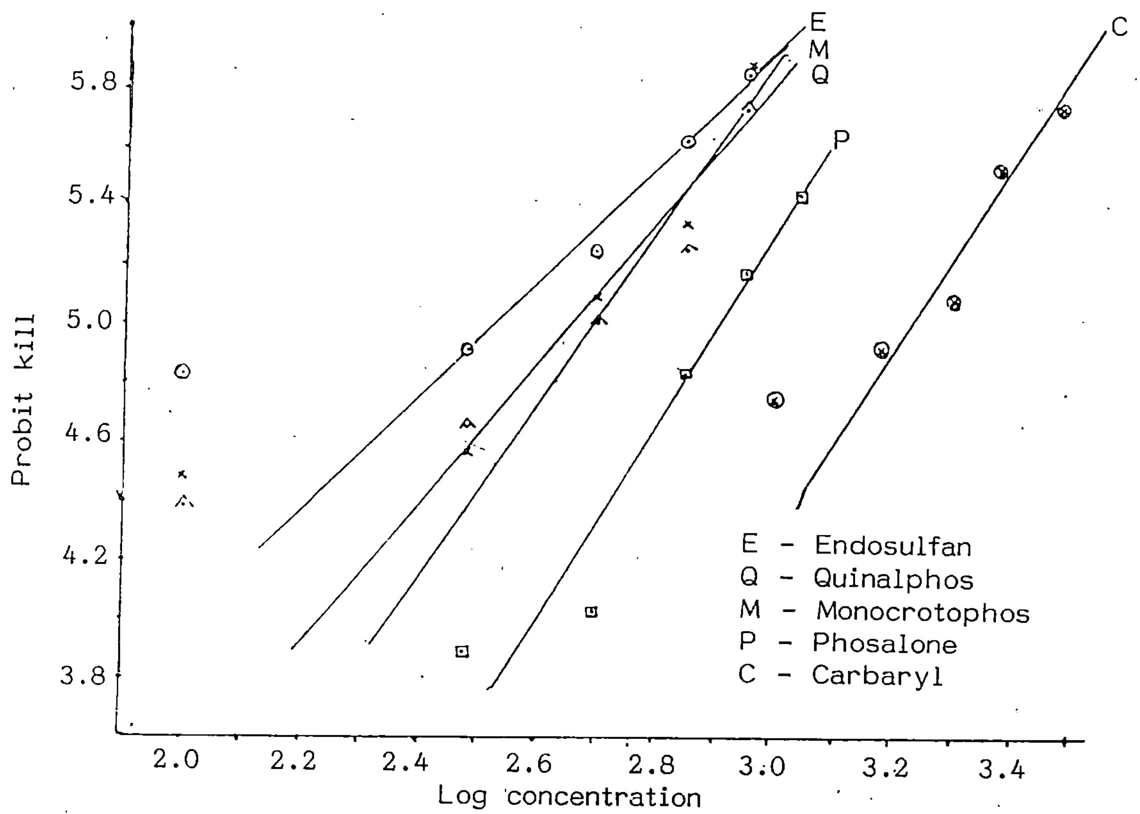


Table 11. Relative toxicity of different insecticides to Angadippuram population of A. biguttula biguttula collected from homestead gardens

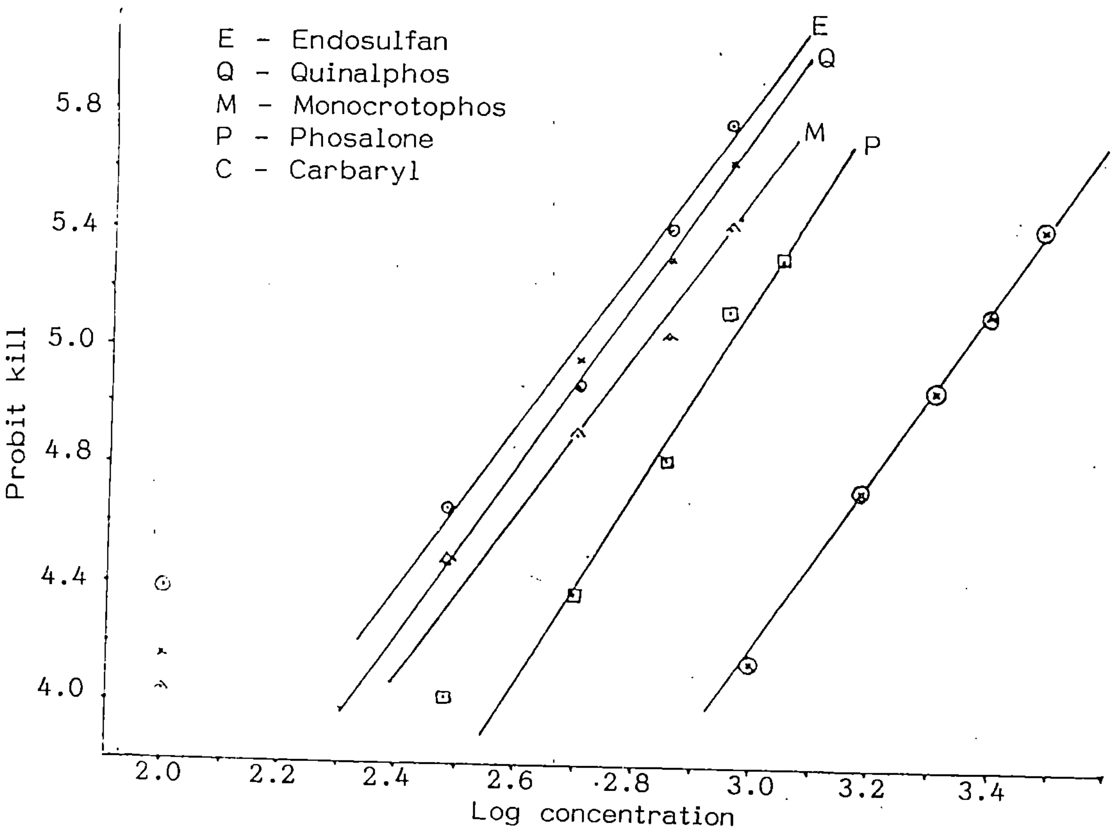
Insecticide	Heterogeneity* $\chi^2(3)$	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	4.04918	Y = 7.3763 + 1.6052x	0.03308	0.03361 0.03884	5.37
2. Quinalphos	3.09235	Y = 7.5594 + 1.8088x	0.038462	0.03344 0.04423	4.61
3. Monocrotophos	1.671464	Y = 7.1604 + 1.6459x	0.048667	0.04176 0.05671	3.65
4. Phosalone	1.00111	Y = 8.1998 + 2.8291x	0.073955	0.06754 0.080967	2.40
5. Carbaryl	0.338461	Y = 6.8013 + 2.399x	0.177499	0.160267 0.196582	1.00

* In none of the cases, the data were found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 7. Susceptibility of Angadippuram population of A. biguttula biguttula collected from homestead gardens to different insecticides



of insecticides tested against Angadippuram population was similar to that of Ottapalam population (Fig. 7). Their relative toxicity values are endosulfan 5.37 > quinalphos 4.61 > monocrotophos 3.65 > phosalone 2.4 times as toxic as carbaryl.

4.2.4. Relative toxicity of different insecticides against Vellanikkara population of _A. biguttula biguttula_ collected from homestead gardens

Perusal of Table 12 indicates that quinalphos was most effective with the highest relative toxicity value (13.55 times as toxic as carbaryl) against Vellanikkara population of _A. biguttula biguttula_ collected from homestead gardens. The next effective insecticide was monocrotophos. Carbaryl was found to be least effective insecticide as proved by its highest LC_{50} value. The descending order of toxicity of insecticides with relative toxicity values to Vellanikkara population was quinalphos 13.55 > monocrotophos 8.85 > endosulfan 7.33 > phosalone 3.52 > carbaryl 1.00 (Fig.8).

An overall view (Table 13) of the relative toxicities of five insecticides tested against four populations of leaf hoppers collected from homestead gardens revealed the following.

All the insecticides tested were found to be more effective than carbaryl against the four populations of leaf hoppers collected from homestead gardens. Endosulfan was found to be the most effective insecticide against all the leaf hopper populations except

Table 12. Relative toxicity of different insecticides to Vellanikkara population of *A. biguttula biguttula* collected from homestead gardens

Insecticide	Heterogeneity* χ^2 (3)	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
1. Endosulfan	3.21068	Y = 7.16019 + 1.3842x	0.027507	0.0226 0.03348	7.33
2. Quinalphos	3.18546	Y = 7.06997 + 1.1328x	0.014887	0.01338 0.01656	13.55
3. Monocrotophos	1.90241	Y = 6.7107 + 1.0418x	0.022796	0.02084 0.024925	8.85
4. Phosalone	2.03114	Y = 8.462 + 2.787x	0.05728	0.05224 0.06280	3.52
5. Carbaryl	0.27928	Y = 7.0606 + 2.9633x	0.20165	0.185399 0.219316	1.00

* In none of the cases, the data were found to be significantly heterogeneous at P = 0.05

Y = Probit kill; x = log (concentration x 10^4)

LC_{50} = Concentration calculated to give 50 per cent mortality

Fig. 8. Susceptibility of Vellanikkara population of A. biguttula biguttula collected from homestead gardens to different insecticides

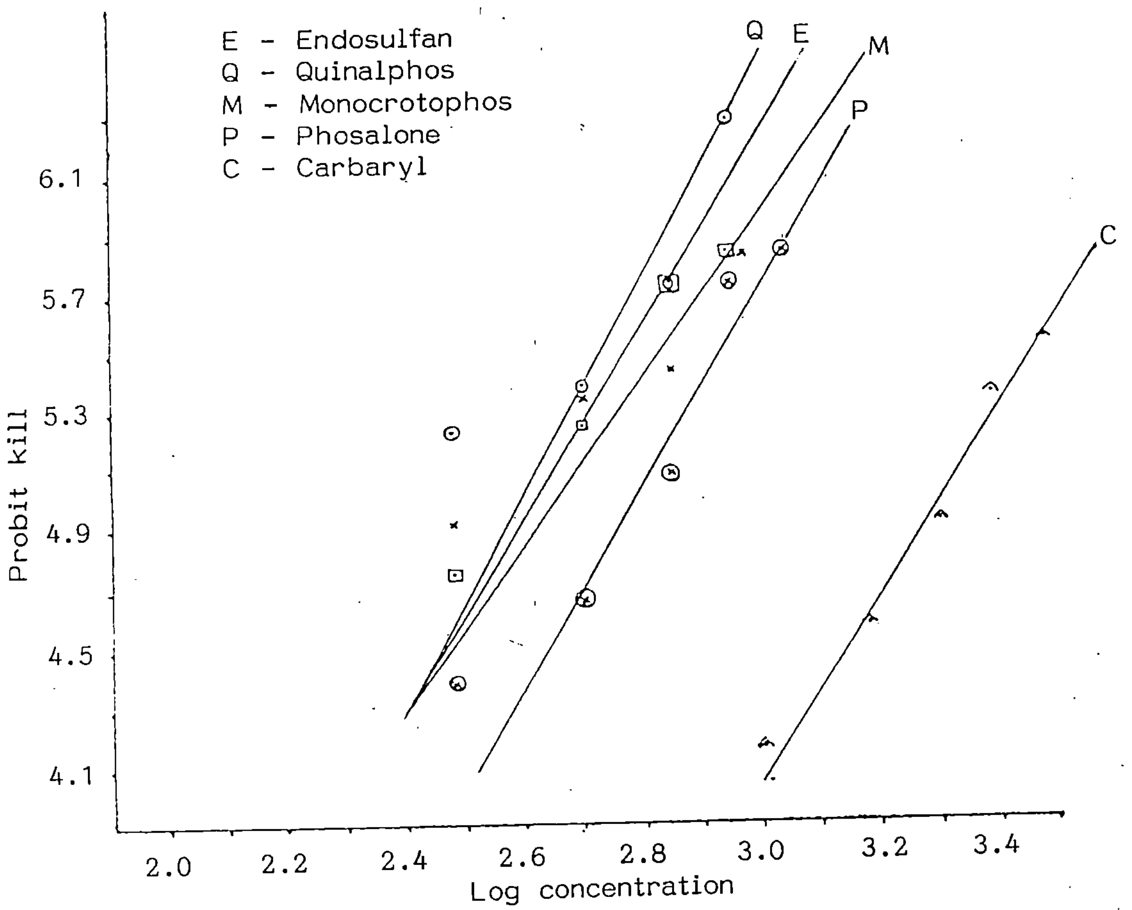


Table 13. Order of relative toxicity of five insecticides against the four populations of _A. biguttula biguttula_ collected from homestead gardens

Population	Order of relative toxicity of insecticides				
1. Kuruppanthara	Endosulfan (6.14)	Monocrotophos (5.90)	Quinalphos (5.49)	Phosalone (2.49)	Carbaryl (1.00)
2. Ottapalam	Endosulfan (9.27)	Quinalphos (5.30)	Monocrotophos (4.81)	Phosalone (2.38)	Carbaryl (1.00)
3. Angadippuram	Endosulfan (5.37)	Quinalphos (4.61)	Monocrotophos (3.65)	Phosalone (2.40)	Carbaryl (1.00)
4. Vellanikkara	Quinalphos (13.55)	Monocrotophos (8.85)	Endosulfan (7.33)	Phosalone (3.52)	Carbaryl (1.00)

Figures in parantheses indicate relative toxicity values against Vellanikkara population wherein quinalphos was most effective. Carbaryl was found to be the least effective insecticide in all the four localities. All the five insecticides indicated the same trend in toxicity against Ottapalam and Angadippuram populations of A. biguttula biguttula. Monocrotophos was found to be the second effective insecticide in Kuruppanthara and Vellanikkara populations while quinalphos was the second effective insecticide against Ottapalam and Angadippuram populations. Phosalone was observed to have a very low toxicity against all the four different leaf hopper populations in homestead gardens.

4.3. Comparative susceptibility of different populations of A. biguttula biguttula to different insecticides

4.3.1. Comparative susceptibility of different populations of A. biguttula biguttula collected from farmers' fields to different insecticides

The relative susceptibility of different populations was calculated by taking LC_{50} values of the Vellanikkara population as the standard for comparison.

It is evident from Table 14 that out of the four populations of A. biguttula biguttula tested for susceptibility, the Ottapalam population was found to show the maximum susceptibility to endosulfan than Vellanikkara population. Lowest susceptibility to endosulfan was seen in Kuruppanthara population. The susceptibility of Angadippuram population of A. biguttula biguttula to endosulfan was almost

Table 14. Relative susceptibility of different populations of A. biguttula biguttula collected from farmers' fields to different insecticides

Population	LC_{50} values					Relative susceptibility values				
	Endosulfan	Quinalphos	Monocrotophos	Phosalone	Carbaryl	Endosulfan	Quinalphos	Monocrotophos	Phosalone	Carbaryl
Kuruppanthara	0.039916	0.041682	0.032587	0.096228	0.188335	0.886	0.407	0.881	0.630	0.186
Ottapalam	0.024913	0.044142	0.043670	0.084910	0.217360	1.419	0.384	0.658	0.714	0.161
Angadippuram	0.035330	0.061350	0.050537	0.087019	0.206397	1.001	0.276	0.569	0.697	0.169
Vellanikkara	0.035382	0.016955	0.028736	0.060641	0.034967	1.000	1.000	1.000	1.000	1.000

equal to that of Vellanikkara population being 1.001 times as susceptible as Vellanikkara population. The Kuruppanthara population was 0.886 times less susceptible to endosulfan than Vellanikkara population.

Highest susceptibility to quinalphos was observed in Vellanikkara population of A. biguttula biguttula. All the other three populations were found to be less susceptible to quinalphos as compared with Vellanikkara population. The Kuruppanthara population was 0.41 times less susceptible to quinalphos than the Vellanikkara population followed by the Ottapalam population which was 0.38 times less susceptible than the Vellanikkara population. The Angadippuram population was 0.28 times less susceptible than the Vellanikkara population. Lowest susceptibility to quinalphos was seen in Angadippuram population of A. biguttula biguttula.

The Vellanikkara population of A. biguttula biguttula was found to have the highest susceptibility to monocrotophos and all the other three populations were found to have lesser susceptibility to monocrotophos. The Kuruppanthara population was found to be 0.88 times less susceptible to monocrotophos than the Vellanikkara population followed by the Ottapalam population being 0.66 times less susceptible than the Vellanikkara population and the Angadippuram population was 0.57 times less susceptible than Vellanikkara population to monocrotophos. Among the four populations, the

Vellanikkara population was found to exhibit the highest susceptibility to phosalone. The order of susceptibility of four populations to phosalone was Vellanikkara > Ottapalam > Angadippuram > Kuruppanthara.

The Vellanikkara population was again proved to have the highest susceptibility to carbaryl also followed by the Kuruppanthara population. The Ottapalam population was seen to have the lowest susceptibility to carbaryl.

4.3.2. Comparative susceptibility of different populations of *A. biguttula biguttula* collected from homestead gardens to different insecticides

The relative susceptibility values were calculated using the LC_{50} values of the Vellanikkara population as the standard for comparison and the results are presented in Table 15.

The Ottapalam population of *A. biguttula biguttula* was found to have the highest susceptibility to endosulfan as it was 1.33 times more susceptible than the Vellanikkara population. The Kuruppanthara and Angadippuram populations were less susceptible than the Vellanikkara population with relative susceptibility values of 0.97 and 0.83.

The Vellanikkara population was observed to show the highest susceptibility to quinalphos with the lowest LC_{50} value. The

Table 15. Relative susceptibility of different populations of <u>A</u>. <u>biguttula</u> <u>biguttula</u> collected from homestead gardens to different insecticides

Population	LC_{50} values					Relative susceptibility values				
	Endosulfan	Quinalphos	Monocrotophos	Phosalone	Carbaryl	Endosulfan	Quinalphos	Monocrotophos	Phosalone	Carbaryl
Kuruppanthara	0.028340	0.031662	0.029460	0.069851	0.173876	0.971	0.470	0.774	0.823	1.16
Ottapalam	0.020690	0.036172	0.039870	0.081772	0.191884	1.327	0.412	0.572	0.700	1.05
Angadippuram	0.033080	0.038463	0.048667	0.073955	0.177499	0.831	0.387	0.468	0.775	1.14
Vellanikkara	0.027507	0.014887	0.022796	0.057280	0.20165	1.000	1.000	1.000	1.000	1.000

increasing order of susceptibility of different populations to quinalphos was Angadippuram < Ottapalam < Kuruppanthara < Vellanikkara with relative susceptibility values of 0.387, 0.412 and 0.470 respectively.

A similar trend was observed in the susceptibility towards monocrotophos also. The Vellanikkara population was observed to have the highest susceptibility towards monocrotophos. All the other three populations of Kuruppanthara, Ottapalam and Angadippuram were found to be less susceptible than Vellanikkara population and their relative susceptibility values were 0.774, 0.572 and 0.468.

Highest susceptibility to phosalone was exhibited by Vellanikkara population. The Kuruppanthara population was 0.823 times less susceptible than Vellanikkara population followed by the Angadippuram and Ottapalam populations which were 0.78 and 0.70 times less susceptible than Vellanikkara population respectively.

All the populations of <u>A. biguttula biguttula</u> from the four localities were found to show more or less equal susceptibility to carbaryl. However, lowest susceptibility was observed in Vellanikkara population. The Kuruppanthara population had the highest susceptibility being 1.16 times more susceptible than Vellanikkara population followed by Angadippuram and Ottapalam populations with relative susceptibility values of 1.14 and 1.05.

4.4. Comparison of response of four different populations of *A. biguttula biguttula* collected from farmers' fields and homestead gardens to different insecticides

The response of different populations of *A. biguttula biguttula* collected from farmers' fields and homestead gardens to different insecticides were compared and presented in Table 16.

No significant difference was observed in the response of populations of *A. biguttula biguttula* collected from farmers' fields and homestead gardens towards the different insecticides, when analysed statistically.

4.5. Comparison of two bioassay techniques for the toxicity of different insecticides against Vellanikkara population of *A. biguttula biguttula* collected from farmers' fields

The spray-residue and leaf-dip techniques of bioassay were evaluated using the five insecticides against Vellanikkara population of *A. biguttula biguttula* collected from farmers' field.

It is evident from Table 17 that the LC_{50} values of the five different insecticides against Vellanikkara population of *A. biguttula biguttula* were higher in the case of the spray-residue method than the leaf-dip method. To cause the same level of mortality in leaf hoppers, 1.17 times higher doses of endosulfan and phosalone were required by spray-residue method as compared to leaf-dip method.

Table 16. Comparison of response of different populations of *A. biguttula biguttula* from farmers' fields and homestead gardens to different insecticides

Insecticides	Populations LC_{50}							
	Kuruppanthara		Ottapalam		Angadippuram		Vellanikkara	
	FF*	HG**	FF	HG	FF	HG	FF	HG
1. Endosulfan	0.039916	0.028340	0.024913	0.020690	0.035330	0.033080	0.035382	0.027507
2. Quinalphos	0.041682	0.031662	0.044142	0.036172	0.061350	0.038463	0.016955	0.014887
3. Monocrotophos	0.032587	0.029460	0.043670	0.039870	0.050537	0.048667	0.028736	0.022796
4. Phosalone	0.096228	0.069851	0.084910	0.081772	0.087019	0.073955	0.060642	0.057280
5. Carbaryl	0.188335	0.173876	0.217360	0.191884	0.206397	0.177499	0.034969	0.201650

* FF - Farmers' field
** HG - Homestead gardens

Table 17. Toxicity of different insecticides against Vellanikkara population of A. biguttula biguttula from farmer's fields using two bioassay techniques

Insecticide	Method of bioassay	Hetero-geneity(*) X^2 (3)	Regression equation	Regression coefficient	LC_{50}	Fiducial limits
1. Endosulfan	SR*	1.6971	Y = 7.009 + 1.3845x	1.3845 ± 0.329	0.035382	0.02486 0.05035
	LD**	3.8253	Y = 7.3281 + 1.529x	1.529 ± 0.331	0.030068	0.021419 0.042211
2. Quinalphos	SR	1.1303	Y = 6.821 + 1.028x	1.028 ± 0.315	0.016955	0.00863 0.03322
	LD	1.3354	Y = 7.508 + 1.347x	1.347 ± 0.328	0.013758	0.016555 0.011438
3. Monocrotophos	SR	4.5813	Y = 7.001 + 1.298x	1.298 ± 0.323	0.028736	0.0192 0.0428
	LD	2.6271	Y = 6.735 + 1.019x	1.019 ± 0.314	0.019888	0.016385 0.024139
4. Phosalone	SR	1.4971	Y = 8.895 + 3.20x	3.20 ± 0.588	0.060642	0.05185 0.07092
	LD	1.2252	Y = 8.243 + 2.521x	2.521 ± 0.567	0.051710	0.041678 0.0641571
5. Carbaryl	SR	2.6521	Y = 7.7557 + 1.756x	1.756 ± 0.277	0.034968	0.02598 0.04706
	LD	0.4726	Y = 7.9596 + 1.833x	1.833 ± 0.294	0.024260	0.017682 0.033307

* SR - Spray-residue technique
** LD - Leaf-dip technique

Y = Probit kill; x = log (concentration x 10^4)
(*) = In none of the cases the data were found to be significantly heterogeneous at P = 0.05

In quinalphos, 1.23 times higher dose was required to cause same level of mortality of the leaf hoppers in case of spray-residue technique as compared to leaf-dip method.

The LC_{50} values of monocrotophos obtained by the two methods were compared and it was found that 1.44 times higher dose of monocrotophos was needed to cause the same level of mortality in A. biguttula biguttula by the spray-residue technique. In carbaryl also 1.44 times higher dose was required by spray-residue technique to cause the same level of mortality.

A comparison of the two methods indicated that the toxicity of insecticides to A. biguttula biguttula was more by leaf-dip technique than spray-residue method.

4.6. Persistent toxicity of different insecticides to Vellanikkara population of A. biguttula biguttula

From the results of the study conducted on persistent toxicity of five insecticides against Vellanikkara population of A. biguttula biguttula (Table 18), it is clear that carbaryl was the most persistent insecticide with the highest persistent toxicity value of 1474.2. It was observed to cause 86.66 per cent mortality after one day of application and a mortality of 46.66 per cent was found in leaf hoppers even after 21 days of application. Among the five insecticides tested only carbaryl was found to cause 50 per cent mortality after 14 days of application.

Table 18. Persistent toxicity of different insecticides to Vellanikkara population A. biguttula biguttula

Insecticide	Dose (Per cent)	Percentage mortality – Days after application 1	3	5	7	14	21	P	T	PT	ORE
1. Endosulfan	0.05	66.66	63.33	43.33	20.00	10.00	0.00	14	40.7	569.8	5
2. Quinalphos	0.05	73.33	60.00	53.33	43.33	33.33	26.66	21	48.3	1014.3	4
3. Monocrotophos	0.05	70.00	53.33	50.00	40.00	36.66	30.00	21	50.2	1054.2	2
4. Phosalone	0.07	56.66	53.33	46.66	43.33	40.00	30.00	21	48.5	1018.5	3
5. Carbaryl	0.2	86.66	76.66	76.66	63.33	50.00	46.66	21	70.2	1474.2	1

P = Period
T = Average toxicity
PT = Index based on persistent toxicity
ORE = Order of relative efficacy based on PT indices

The second persistent insecticide was found to be monocrotophos with a persistent toxicity value of 1054.2. Phosalone and quinalphos had nearly equal persistent toxicity values of 1018.5 and 1014.3 respectively. Both monocrotophos and phosalone recorded 30 per cent mortality 21 days after application.

Endosulfan had the lowest persistent toxicity value of 569.8. Though it caused 66.66 per cent mortality on the first day after application no mortality was observed 21 days after application.

After one day of application of insecticides, highest mortality was caused by carbaryl followed by quinalphos and monocrotophos. Phosalone was found to produce only 56.66 per cent mortality one day after application while endosulfan brought about 66.66 per cent mortality.

Discussion

DISCUSSION

5.1. Relative toxicity of five insecticides against four different populations of A. biguttula biguttula collected from farmers' fields

Among the five insecticides tested against four different populations of A. biguttula biguttula collected from farmers' fields, it was found that endosulfan was most toxic against Ottapalam and Angadippuram populations. The high effectiveness of endosulfan against A. biguttula biguttula in cucurbits (Pareek and Noor, 1980) and many other crops like okra, cotton and brinjal was already well documented by many workers (Sidhu and Simwat, 1973; Krishnakumar and Srinivasan, 1987; Yadav et al., 1989; Sidhu and Dhawan, 1976; Tewari and Moorthy, 1983). Endosulfan was 8.72 and 5.84 times as toxic as carbaryl against Ottapalam and Angadippuram populations, respectively. Singh and Teotia (1978) observed that endosulfan was 2.28 times as toxic as lindane against A. biguttula biguttula on okra.

Monocrotophos was found to be most toxic to Kuruppanthara population. It was the second best toxic insecticide to the other three populations from Vellanikkara, Ottapalam and Angadippuram. The efficacy of monocrotophos against A. biguttula biguttula has been reported on okra (Patel et al., 1980; Krishnakumar and Srinivasan, 1987 and Kakar and Dogra, 1988), on cotton (Sidhu and Dhawan, 1976) and on potato (Misra and Lal, 1981).

Quinalphos had the highest toxicity against Vellanikkara population of A. biguttula biguttula. Effectiveness of quinalphos against A. biguttula biguttula on various crops like cucurbits (Pareek and Noor, 1980), okra (Nair et al., 1977; Mohan, 1985) and brinjal (Subbaratnam and Butani, 1984 and Kumar et al., 1988) has already been reported. Phosalone was least toxic to Vellanikkara population. But effective control of A. biguttula biguttula in cotton with phosalone at 0.5 kg ai/ha was indicated by Mundiwale et al., 1983; Sidhu and Dhawan, 1987 and Pawar et al., 1987.

Carbaryl was found to be least toxic to all different populations of A. biguttula biguttula collected from farmers' fields except Vellanikkara. Carbaryl at 0.1 per cent in okra (Vijayaraghavan et al., 1965; Sidhu and Dhawan, 1981; Mohan, 1985), 0.2 per cent in cotton (Atwal and Singh, 1969) and ridge gourd (Pareek and Noor, 1980) has been reported to be highly effective for the control of A. biguttula biguttula. But the present findings are in disagreement with these reports which might be due to the continuous increased exposure of the pest to carbaryl in these areas. Carbaryl was stated to be the most dominantly used insecticide at Kuruppanthara and Angadippuram areas on local enquiries made with the farmers.

5.2. Relative toxicity of five insecticides against four different populations of A. biguttula biguttula collected from homestead gardens

Perusal of results on the relative toxicity of five insecticides against the four populations of A. biguttula biguttula collected from homestead gardens clearly revealed that carbaryl was least toxic to all the four different leaf hopper populations. Therefore, it is indicated that among the five insecticides tested, carbaryl was least toxic to leaf hoppers in both farmers' fields and homestead gardens.

Endosulfan showed highest toxicity to leaf hopper populations collected from homestead gardens of Kuruppanthara, Ottapalam and Angadippuram. The high effectiveness of endosulfan was thus clearly observed in leaf hopper populations collected from both farmers' fields and homestead gardens of Ottapalam and Angadippuram. Similarly the toxicity of quinalphos was highest against A. biguttula biguttula from both farmers' fields and homestead gardens of Vellanikkara. Therefore, it can be concluded that endosulfan is the most effective insecticide against A. biguttula biguttula in Ottapalam and Angadippuram areas. Quinalphos was the most toxic insecticide at Vellanikkara. But in Kuruppanthara, the toxicity of endosulfan was highest followed by monocrotophos against homestead garden population while in farmers' fields monocrotophos was most effective followed by endosulfan.

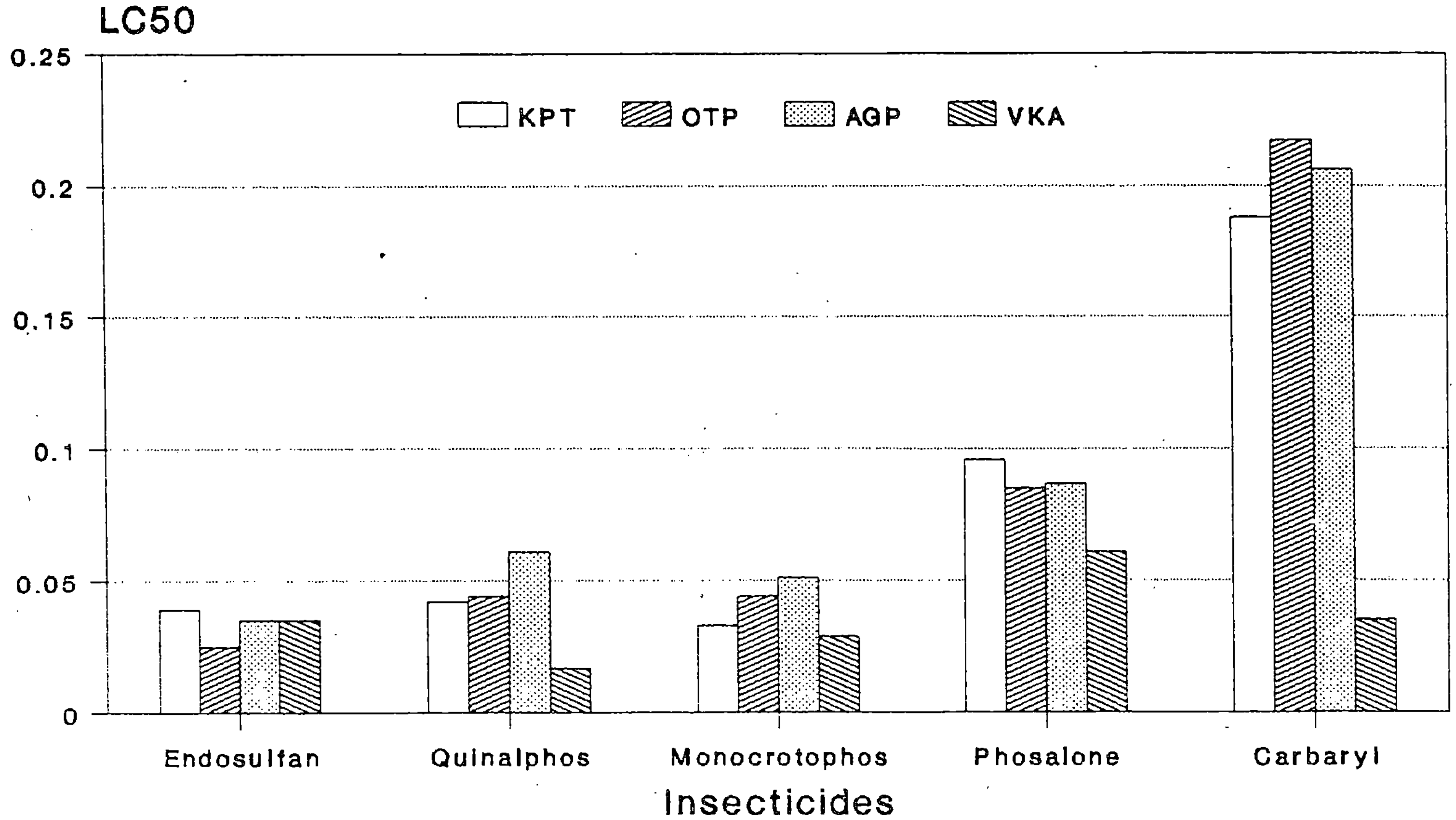
The relative toxicity studies have thus clearly revealed that the toxicity of insecticides vary with leaf hopper populations from different areas. Out of the five insecticides tested, endosulfan, quinalphos and monocrotophos were highly effective while phosalone and carbaryl were less effective in these selected areas. The variation in toxicity of insecticides might be due to the difference in the weather conditions, insecticide use pattern, strain/type of the pest, practices adopted by farmers etc.

5.3. Comparative susceptibility of different populations of A. biguttula biguttula to different insecticides

Considerable variations were observed in the susceptibility pattern among the populations of A. biguttula biguttula collected from four different locations (Fig. 9 and 10) to different insecticides. The leaf hoppers collected from farmers' fields in Ottapalam were found to show highest susceptibility to endosulfan as compared to those from Vellanikkara. The leaf hoppers collected from both farmers' fields and homestead gardens in Vellanikkara area exhibited the highest susceptibility to quinalphos, monocrotophos, phosalone and carbaryl. The Ottapalam population from both farmers' fields and homestead gardens manifested highest susceptibility to endosulfan while the susceptibility was lowest in Kuruppanthara population from farmers' fields. From the enquiries made with the local farmers of Ottapalam, it was understood that organophosphorus insecticides were being used continuously against A. biguttula biguttula and other pests. The highest susceptibility to endosulfan in Ottapalam might have been due to the less exposure of A. biguttula biguttula to endosulfan.

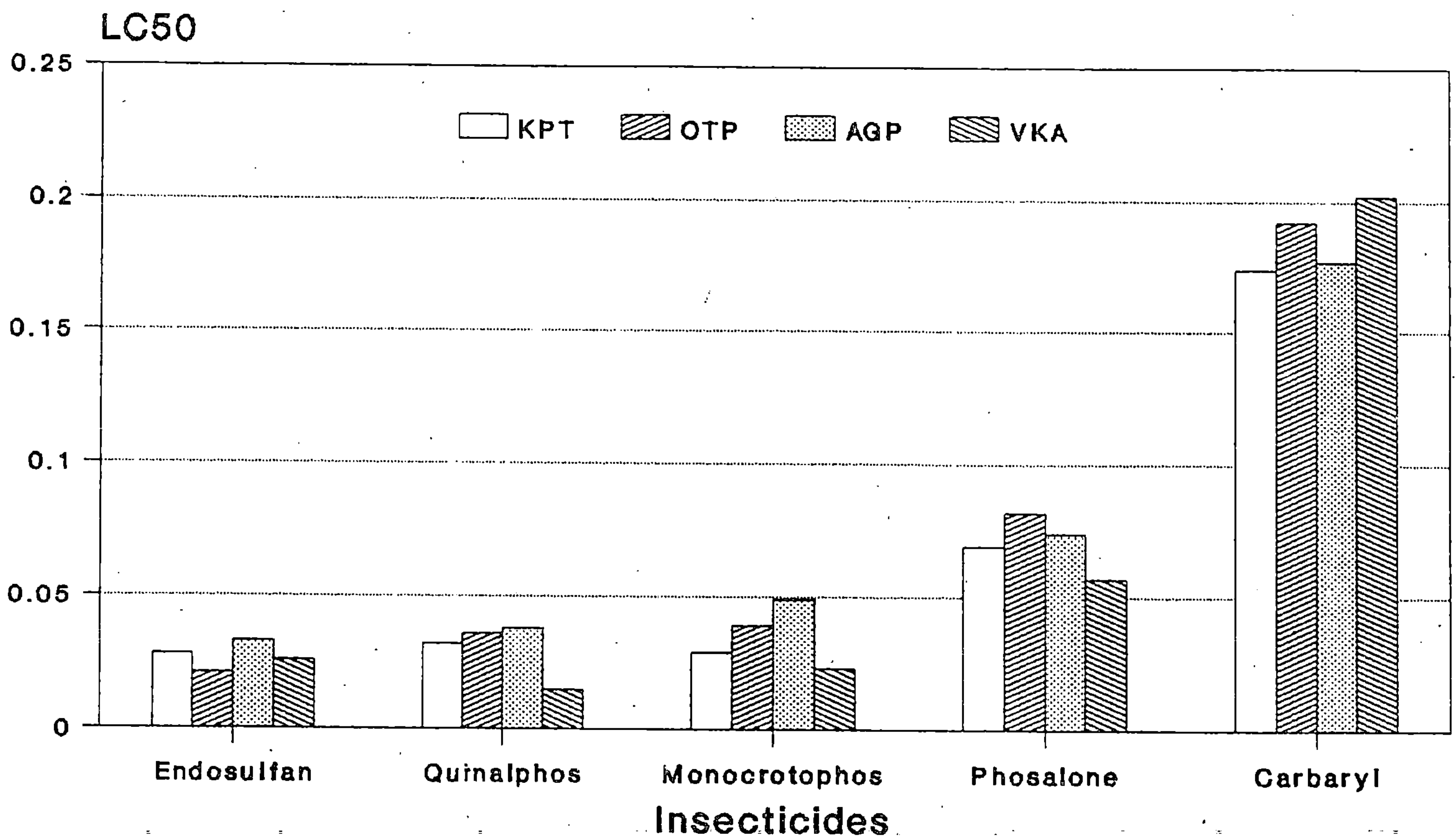
The leaf hopper populations collected from both farmers' fields and homestead gardens of Angadippuram were least susceptible

Fig. 9 Susceptibility of populations of *A. biguttula biguttula* from farmers' fields to different insecticides



KPT-Kuruppanthara; OTP-Ottapalam
AGP-Angadippuram; VKA-Vellanikkara

Fig.10 Susceptibility of populations of *A. biguttula biguttula* from homestead gardens to different insecticides



KPT-Kuruppanthara; OTP-Ottapalam
AGP-Angadippuram; VKA-Vellanikkara

towards quinalphos and monocrotophos. The susceptibility to phosalone was lowest in Kuruppanthara population of _A_. _biguttula_ _biguttula_ from farmers' fields.

A difference in susceptibility pattern was noticed in leaf hoppers collected from farmers' fields and homestead gardens to carbaryl. In populations from farmers' fields, susceptibility to carbaryl was highest in Vellanikkara while the population from homestead gardens in Vellanikkara recorded lowest susceptibility. The leaf hoppers from farmers' fields of Ottapalam indicated a lowest susceptibility while a high susceptibility was noticed in homestead gardens.

It can be concluded that a variation in susceptibility pattern was noticed in leaf hopper populations collected from different localities to different insecticides. Variations in susceptibility pattern has been reported in other insects also. Saxena _et_ _al_. (1989) reported the development of resistance in different strains of _Plutella xylostella_ (L.) collected from different states of India. The difference in susceptibility of _P_. _xylostella_ in various districts of Punjab also has been reported by Deshmukh and Saramma (1973) and Chawla and Kalra (1976). _Heliothis_ _armigera_ Hb. was also reported to cause difference in susceptibility to insecticides in different districts of Andhra Pradesh (Reddy _et_ _al_., 1991).

None of the populations of *A. biguttula biguttula* used in the present study was a known susceptible population i.e., a population with no previous exposure to insecticides. Insecticide resistance in field populations of insects can only be confirmed by comparing their response to the toxicant with the base line toxicity values. Owing to the lack of baseline toxicity studies, the magnitude of susceptibility/resistance in *A. biguttula biguttula* could not be obtained in the present investigations. Insecticide resistance development can be attributed to widespread application of insecticides, past selection with insecticides, alteration in the life history of the insect, the timing, dosage and formulation of insecticides (Georghiou and Taylor, 1976, 1977a).

Since the present study was only a preliminary one and restricted to only four districts of Kerala, no definite conclusions on the susceptibility spectrum of *A. biguttula biguttula* in bittergourd could be brought about. Detailed investigations on the susceptibility pattern of *A. biguttula biguttula* to other insecticides from all other districts in the State have to be carried out along with base line toxicity studies so that the susceptibility/resistance of *A. biguttula biguttula* in bittergourd can be well understood. The development of resistance/reduced susceptibility in *A. biguttula biguttula* towards insecticides can be confirmed only after conducting an exhaustive study on the susceptibility spectrum of leaf hopper populations all throughout the State and by comparing it with a purely susceptible strain. Based on the results of this preliminary study alone, it is not possible to suggest any changes in the existing recommendations against this pest.

5.4. Comparison of response of four different populations of *A. biguttula biguttula* collected from farmers' fields and homestead gardens to different insecticides

Two populations of leaf hoppers were collected from each locality to compare their responses to insecticides. One population from farmers' fields which was subjected to continuous exposure of insecticides due to scheduled sprayings and the other from homestead gardens which was less exposed to insecticides generally. The LC_{50} values of all insecticides were found to be less in the homestead gardens than those from farmers' fields which indicated a higher susceptibility of leaf hopper populations in homestead gardens due to the obvious reason of less application of insecticides in homestead gardens. Eventhough the estimated LC_{50} values of insecticides in homestead gardens were lesser than those of farmers' fields, no significant difference was observed in the response of leaf hoppers to insecticides, when analysed statistically. This indicates that leaf hoppers from farmers' fields might have migrated to homestead gardens and hence no significant difference in susceptibility was observed. Another reason that can be attributed is the proximity of the farmers' fields and homestead gardens which might have made the migration easier.

Georghiou and Taylor (1977b) reported the influence of migration as a factor for the development of insecticide resistance in insects.

5.5. Comparison of two bioassay techniques for the toxicity of different insecticides against Vellanikkara population of A. biguttula biguttula collected from farmers' fields

An evaluation of the two bioassay techniques revealed that the toxicity of all insecticides against A. biguttula biguttula was more by leaf-dip method than the spray-residue technique. Thus, to cause the same level of mortality in A. biguttula biguttula, a lower dose of all insecticides was required by leaf-dip method as compared to spray-residue method. This is in agreement with the earlier findings of Senapati and Satpathy (1982) who reported higher toxicity of carbaryl to Epilachna sparsa (Hbst.) with leaf-dip method. The differential rate of entry of insecticide in the different bioassay techniques through different parts of body surface of insects, according to them, was the main reason for the phenomenon in E. sparsa.

Eventhough leaf-dip method of bioassay was observed to produce more toxicity in leaf hoppers, the spray residue technique was adopted throughout the present investigations because the studies were more of practical rather than academic importance. In fields, the farmers generally adopt the technique of spraying the crop to control leaf hoppers and, therefore, the same technique was adopted in the present studies to investigate the toxicity of different insecticides against A. biguttula biguttula.

5.6. Persistent toxicity of different insecticides to Vellanikkara population of A. biguttula biguttula

Among the five insecticides tested, carbaryl at 0.2 per cent was found to cause the highest mortality followed by quinalphos after one day of application. After 14 days of application, only carbaryl was found to bring about 50 per cent mortality and even after 21 days it could bring about 46.6 per cent mortality of A. biguttula biguttula. Thus, carbaryl at 0.2 per cent was found to be the most effective and persistent insecticide. The persistence and toxicity of carbaryl were already reported by Senapati and Satpathy (1982). But this highest toxicity of carbaryl was not evident to any population of A. biguttula biguttula collected from four locations. The excessive and continuous use of carbaryl in these localities for a long period might have reduced the toxicity and susceptibility of these populations of A. biguttula biguttula.

The second best persistent insecticide was found to be monocrotophos with a persistent toxicity value of 1054.2. In the relative toxicity studies also, monocrotophos was proved to be the second best effective insecticide against Vellanikkara population. Though the mortality of leaf hoppers after one day of application was higher in quinalphos (73.3 per cent) as compared to monocrotophos (70 per cent), the persistent toxicity was found to be higher for monocrotophos. The highest toxicity of quinalphos was also found in relative toxicity studies. In okra, monocrotophos at 500 g ai/ha was reported to be effective in controlling A. biguttula biguttula (Patel et al., 1980; Krishnakumar and Srinivasan, 1987 and Kakar and Dogra, 1988). Endosulfan showed the lowest persistent toxicity (569.8) causing no mortality after 21 days of application. But Dhamdhere et al. (1980) observed 26.6 per cent mortality after 21 days of application. Though phosalone caused only 56.7 per cent mortality on the first day of application, it occupied third position in persistent toxicity values. But phosalone was observed to be least toxic towards Vellanikkara population in relative toxicity studies. However, phosalone at 0.5 kg ai/ha was reported to be effective against A. biguttula biguttula in cotton (Sidhu and Dhawan, 1981).

Summary

SUMMARY

The leaf hopper Amrasca biguttula biguttula (Ishida) is one of the key pests of bittergourd causing much damage by sucking cell sap from the plant. Recently, the incidence of A. biguttula biguttula has posed a serious problem in bittergourd cultivation in Kerala state with less susceptibility to insecticides. Therefore, an investigation was carried out to determine the variations in the susceptibility pattern of leaf hopper populations from different areas of the State towards the commonly used insecticides.

The study was conducted at the College of Horticulture, Vellanikkara in the year 1991-92 using different populations of leaf hoppers infesting bittergourd collected from four different areas of Kerala viz., Kuruppanthara (Kottayam district), Vellanikkara (Thrissur district), Ottapalam (Palakkad district) and Angadippuram (Malappuram district). The spray - residue technique of bioassay was adopted to assess the susceptibility of five commonly used insecticides from three major chemical groups viz., endosulfan (organo-chlorine), quinalphos, monocrotophos and phosalone (organophosphorous) and carbaryl (carbamate). Two populations of leaf hoppers from farmers' fields (subjected to regular spraying) and homestead gardens (less exposed to insecticides) of each locality were used for the studies.

From the relative toxicity studies conducted it was found that endosulfan was most toxic against Ottapalam and Angadippuram

populations of A. biguttula biguttula collected from farmers' fields. Monocrotophos was most effective against Kuruppanthara population and quinalphos was most effective against Vellanikkara population. Carbaryl was least effective at all localities except Vellanikkara where phosalone was found to be least effective. The toxicity of endosulfan, monocrotophos, quinalphos, phosalone and carbaryl towards the populations of A. biguttula biguttula in Ottapalam and Angadippuram were found to be in the same order.

The relative toxicity of five insecticides tested against four populations collected from homestead gardens revealed that endosulfan was the most effective against all leaf hopper populations except Vellanikkara population. Quinalphos was most effective against Vellanikkara population. Carbaryl was the least effective insecticide in all the four localities. As in the case of farmers' fields, the toxicity of five insecticides against Ottapalam and Angadippuram populations collected from homestead gardens was observed to be in a similar order. Phosalone was found to have a very low toxicity against all four populations of A. biguttula biguttula collected from homestead gardens.

Studies on the susceptibility of the four different populations of A. biguttula biguttula collected from farmers' fields to the five insecticides revealed that among the four populations, the Vellanikkara population showed the highest susceptibility to quinalphos, monocrotophos, phosalone and carbaryl. Ottapalam population had the highest susceptibility to endosulfan. Kuruppanthara population was proved to show lowest susceptibility to endosulfan and phosalone.

An overall comparison of susceptibility of the different populations of A. biguttula biguttula collected from homestead gardens to the five insecticides indicated that Vellanikkara population exhibited the highest susceptibility to quinalphos, monocrotophos and phosalone and lowest susceptibility to carbaryl. Ottapalam and Kuruppanthara populations were proved to have highest and lowest susceptibility to endosulfan and carbaryl respectively. It was evident from the susceptibility studies that considerable variations were seen in the susceptibility of leaf hopper populations from four different areas to the five insecticides which might mainly be due to the excessive continuous use of insecticides in different regions. None of the populations of A. biguttula biguttula was known to be a purely susceptible one without any exposure to insecticides. The magnitude of susceptibility by comparing with the susceptible population could not be carried out in the present studies due to lack of baseline toxicity studies. The present study was only a preliminary one and restricted to only four districts of Kerala. There is much scope to conduct an extensive investigation on the susceptibility spectrum of leaf hopper populations from all the districts of the State towards different insecticides which would help to detect any development of resistance of A. biguttula biguttula. Therefore, it is not possible to bring about suggestions for any change in the existing field control recommendations against this pest with the result of the study.

The LC_{50} values of insecticides against farmers' field populations were found to be higher than those of homestead gardens. However no significant difference was observed in response of populations of A. biguttula biguttula collected from farmers' fields and homestead gardens towards the different insecticides when analysed statistically. This indicates the possibility of migration of the leaf hoppers from farmers' fields to homestead gardens.

The results obtained from a comparison of two bioassay techniques for the toxicity of different insecticides against Vellanikkara population indicated that the leaf-dip method of bioassay required a lesser dose of insecticides to cause the same level of toxicity in A. biguttula biguttula when compared to the spray-residue method. To cause the same level of mortality, 1.17 times higher doses of endosulfan and phosalone, 1.23 times quinalphos and 1.44 times monocrotophos and carbaryl were required by the spray-residue method.

The study conducted on the persistent toxicity of the five insecticides against Vellanikkara population of A. biguttula biguttula showed that carbaryl was the most persistent insecticide giving 46.66 per cent mortality even after 21 days of application. Endosulfan proved to be the least persistent insecticide registering no mortality of leaf hoppers after 21 days of application. Phosalone and quinalphos had nearly equal persistent toxicity values of 1018.5 and 1014.3 respectively. Monocrotophos and phosalone recorded 30 per cent mortality at 21 days after application.

Deshmukh, S.N. and Saramma, P.U. 1973. Comparative susceptibility of Plutella maculipennis (Curtis) collected from Ludhiana and Jullundur districts to some insecticides. Pesticides **7**(1):21.

Dhamdhere, S.V., Bahadur, J. and Misra, U.S. 1985. Relative efficacy of granular insecticides for the control of Amrasca biguttula biguttula. PKV Res. J. **9**(2):37-40.

Dhamdhere, S.V., Bahadur, J. and Misra, U.S. 1987. Studies on persistence and toxicity of carbamate insecticides against Amrasca biguttula biguttula Ishida infesting okra. PKV Res. J. **11**(1):97-99.

Dhamdhere, S.V., Deole, J.Y. and Odak, S.C. 1980. Insecticidal control of Amrasca biguttula biguttula on okra. Indian J. Pl. Prot. **8**(2):147-150.

Dhawan, A.K., Simwat, G.S. and Sidhu, A.S. 1988. Field evaluation of monocrotophos for the control of sucking pests on cotton. Pesticides **22**(6):25-28.

*Dittrich, V. and Ernst, G.H. 1983. The resistance pattern in white-flies of Sudanese cotton. Mitteilungen der Deutschen Gessellshaft fur Allegemeine und Angewandte Entomologie. **4**(1/3): 96-97.

*Dittrich, V., Hassan, S.O. and Ernst, G.H. 1986. Development of a new primary pest of cotton in the Sudan : Bemisia tabaci the whitefly. Agric. Ecosyst. Environ. **17**(1/2):137-142.

Easwaramoorthy, S., Chelliah, S. and Uthamasamy, S. 1976. Efficacy of certain insecticides against the sucking pests of bhendi, Abelmoschus esculentus (L.) Moench. Madras agric. J. **63**(4): 254-256.

Evans, D.E. 1973. Resistance to carbamate insecticides in Aeneolamia varia saccharina (Dist.). Trop. Agric. **50**(2):153-163.

FAO, 1979. FAO method No.17. Method for adult aphids. Recommended methods for the detection and measurement of resistance of agricultural pests to pesticides. FAO Pl. Prot. Bull. **27**(2):29-32.

*Fellowes, R.W. and Ferguson, A.M. 1974. Field evidence for resistance to certain insecticides by green peach potato aphid in South Auckland. N. Z. J. exp. Agric. **2**(1):83-88.

Finney, D.J. 1971. Probit Analysis 3rd ed. Cambridge Univ. Press, London. pp.333.

Follett, P.A., Croft, B.A. and Westigard, P.H. 1985. Regional resistance to insecticides in Psylla pyricola from pear orchards in Oregon. Can. Entomol. **117**(5):565-573.

Gartoria, G.S. and Singh, H. 1984. Effect of insecticidal and fertiliser applications on the jassid complex in green gram, Vigna radiata. J. ent. Res. **8**(2):154-158.

*Georghiou, G.P. and Taylor, C.E. 1976. Pesticide resistance as an evolutionary phenomenon. Proc. XV Int. Congrl. Entomol., Washington, D.C. 759-785.

KAU, 1989. Package of Practices Recommendations. Kerala Agricultural University, Directorate of Extension, Mannuthy, Kerala.

Karuppachamy, P., Uthamasamy, S. and Kumar, M.G. 1986. Chemical control of pests of rice fallow cotton in Cauvery delta region. Madras agric. J. **73**(3):178-180.

Kassai, T. and Ozaki, K. 1984. Resistance patterns in rice brown planthopper Nilaparvata lugens Stal. (Hemiptera:Delphacidae) after selection with carbaryl and propoxur. Jap. J. appl. Ent. Zool. **28**(1):20-24.

Katündu, J.M. and Aliniazee, M.T. 1990. Variable resistance of filbert aphid (Homoptera:Aphididae) to insecticides in the Willamette Valley, Oregon. J. econ. Ent. **83**(1):41-47.

Krishnakumar, N.K. and Srinivasan, K. 1987. Efficacy and economics of pest control in okra with conventional and synthetic pyrethroid insecticides. Indian J. Pl. Prot. **15**(1):81-83.

Kumar, S., Jain, P.C. and Kumawat, S.R. 1988. Comparative efficacy of insecticides against jassid Amrasca biguttula biguttula Ishida of brinjal under field conditions. Indian J. Ent. **50**(4):449-453.

*Mavi, G.S. and Singh, H. 1975. Comparative efficacy of some insecticides for the control of jassid on potato. Pl. Prot. Bull. **23**(4):40-43.

Misra, S.S. and Lal, L. 1981. Evaluation of foliar systemic insecticides against leaf hopper Amrasca devastans on potato. Entomon **6**(3):201-205.

Georghiou, G.P. and Taylor, C.E. 1977a. Genetic and biological influences in the evolution of insecticide resistance. J. econ. Ent. **70**(3):319-323.

Georghiou, G.P. and Taylor, C.E. 1977b. Operational influences in the evolution of insecticide resistance. J. econ. Ent. **70**(5):653-658.

Gupta, R.N. and Dhari, K. 1978. Evaluation of some insecticides for the control of shoot and fruit borer (Earias sp.) and jassid (Amrasca devastans Dist.) on rainfed okra crop. Pesticides **12**(11):21-24.

Hama, H. and Iwata, T. 1973. Resistance to carbamate insecticides and its mechanism in the green rice leaf hopper Nephotettix cincticeps. Jap. J. Appl. Ent. Zool. **17**(3):154-161.

Hama, H. 1975. Resistance to insecticides in the green rice leaf hopper. Jap. Pestic. Infor. **23**:9-12.

Jacob, S. and Verma, S. 1985. Biological efficacy of methamidophos, quinalphos and malathion against the jassid Amrasca biguttula biguttula on okra. Indian J. Pl. Prot. **13**(1):15-19.

*Kakar, K.L. and Dogra, G.S. 1988. Insect pests of okra and their control under mild hill conditions. J. Insect Sci. **1**(2): 195-198.

Kao, H.I., Liu, M.Y. and Sun, C.N. 1981. Green rice leaf hopper resistance to malathion, methyl parathion, carbaryl, permethrin and fenvalerate in Taiwan. Int. Rice Res. Newsl. **6**(5):19.

Mohan, N.J. 1985. Control of major pests of okra. Pesticides **19**(7):35-37.

Mundiwale, S.K., Men, U.B., Govindwar, V.S. and Borle, M.N. 1983. Efficacy of five insecticides alone and in combination with DDT against cotton pests. Indian J. Ent. **45**(3):282-285.

Nair, M.R.G.K., Christudas, B.P. and Mathai, S. 1977. On the control of the jassid *Amrasca biguttula biguttula* Ishida on bhindi using some new insecticides. Agric. Res. J. Kerala. **14**(2):171-172.

Narke, C.G. and Suryawanshi, D.S. 1987. Chemical control of major pests of okra. Pesticides **21**(1):37-39.

*Ozaki, K. and Kassai, T. 1984. Cross resistance patterns in malathion and fenitrothion resistant strains of rice brown plant hopper. J. Pestic. Sci. **9**(1):151-154.

Pareek, B.L. and Noor, A. 1980. Evaluation of some insecticides against *Amrasca biguttula biguttula* Ishida infesting ridge gourd. Entomon. **5**(1):55-57.

*Pareek, B.L., Sharma, G.R. and Bhatnagar, K.N. 1987. Field evaluation and economics of insecticides against the major pests of okra. Trop. Pest Mgmt **33**(3):192-195.

Patel, J.R., Patel, R.C. and Amin, P.R. 1980. Field evaluation of some insecticides for the control of *Amrasca biguttula biguttula* Ishida and *Aphis gossypii* Glover on okra. Indian J. Ent. **42**(4):776-779.

Pawar, D.B., Kale, P.N., Ajri, D. and Lawande, K.E. 1987. Chemical control of jassid, aphid and fruit borer of brinjal by synthetic pyrethroids. J. Maharashtra agric. Univ. **12**(2):211-213.

Rawat, R.R. and Jakhmola, S.S. 1977. Relative efficacy of some granular insecticides in the control of Amrasca devastans Dist. on okra. Indian J. Ent. **38**(3):293-295.

Reddy, G.P.V., Prasad, V.D., Satyavani, P. and Murthy, M.M.K. 1991. Comparative assessment of pyrethroid-resistance in certain populations of Heliothis armigera Hbn. in Andhra Pradesh. Entomon. **16**(3):233-235.

Sarma, P.V. and Rao, P.V.R. 1979. Studies on the effect of certain granular insecticides in the control of bhendi jassid Amrasca biguttula biguttula Ishida. Indian J. Pl. Prot. **6**(2):35-39.

Saxena, J.D., Rai, S., Srivastava, K.M. and Sinha, S.R. 1989. Resistance in the field populations of the diamond back moth to some commonly used synthetic pyrethroids. Indian J. Ent. **51**(3):265-268.

Senapati, B. and Satpathy, J.M. 1982. Development of carbaryl resistance in Epilachna sparsa (Hbst.) and its cross resistance characteristics. J. ent. Res. **6**(2):150-156.

Sidhu, A.S. and Dhawan, A.K. 1976. Field evaluation of monocrotophos and dicarbam for control of cotton pests. Pesticides **10**(9):15-17.

Sidhu, A.S. and Dhawan, A.K. 1981. Evaluation of some new insecticides against foliage feeding pests of cotton. Pesticides **15**(6):20-22.

Sidhu, A.S. and Dhawan, A.K. 1987. Testing of phosalone and phenthoate for the control of the sucking pests and pink bollworm of cotton. Pesticides **21**(3):37-39.

Sidhu, A.S., Dhawan, A.K. and Singh, K. 1979. Testing of new chemicals for control of cotton pests. Pesticides **13**(11): 7-11.

Sidhu, A.S. and Simwat, G.S. 1973. Evaluation of new insecticides for the control of Amrasca devastans (Dist.) infesting okra. Indian J. Ent. **35**(4):297-299.

Singh, S. and Misra, P.N. 1988. Efficacy of new insecticides for control of insect pests of spring okra. Indian J. agric. Sci. **58**(10):783-785.

Singh, R. and Teotia, T.P.S. 1978. Relative toxicity of some insecticides to the adults of cotton jassid Amrasca biguttula biguttula (Ishida). Indian J. Ent. **40**(1):82-85.

Srinivasan, P.M., Venkatanarayanan, D., Gopalan, M. and Uthamasamy, S. 1973. Control of major pests of bhendi (Abelmoschus esculentus) with new insecticides. Madras agric. J. **60**(7): 601-602.

Subbaratnam, G.V. and Butani, D.K. 1984. Persistent toxicity of certain insecticides to jassid Amrasca biguttula biguttula on brinjal. Entomon **9**(1):15-17.

Tewari, G.C. and Moorthy, P.N.K. 1983. Effectiveness of synthetic pyrethroids against the pest complex of brinjal. Entomon **8**(4):365-368.

Thimmaiah, G. 1977. Chemical control of leaf hoppers and boll-worms on Varalaxmi hybrid cotton by soil and foliar applications. Mysore J. agric. Sci. **11**(3):386-391.

Uthamasamy, S. and Balasubramanian, M. 1978. Efficacy of some insecticides in controlling the pests of bhendi *Abelmoschus esculentus* (L.) Moench. Pesticides **12**(2):39-41.

Veeravel, R. and Bhaskaran, P. 1976. Efficacy of quinalphos and other insecticide sprays against insect pests of brinjal. Madras agric. J. **63**(5-7):338-340.

Vijayaraghavan, S., Sivagami, R., Menon, P.P.V. and Basheer, M. 1965. A schedule of treatments against pests of cotton. Madras agric. J. **52**(11):486.

Visvanathan, T. and Abdul kareem, A. 1983. Field evaluation of some insecticides against jassids on cotton. Pesticides **17**(7): 33-34.

Wavte, C.M., Clower, D.F. and Graves, J.B. 1977. Resistance to methyl parathion and monocrotophos in the banded wing whitefly in Louisiana. J. econ. Ent. **70**(2):263-266.

Yadav, P.R., Jaipal, S. and Singh, Z. 1989. Field evaluation of some modern insecticides against jassid in okra crop. Indian J. Ent. **50**(1):5-11.

* Originals not seen

References

REFERENCES

Abbot, W.S. 1925. A method of computing the effectiveness of an insecticide. J. econ. Ent. **18**(2):265-267.

*Abdullaev, E. 1984. Susceptibility of the cotton aphid to aphicides. Zashchita Rastenii **12**:39.

Agarwal, R.A. and Katiyar, K.M. 1975. Effect of insecticides against jassid (Amrasca devastans Dist.) and pink bollworm (Pectinophora gossypiella Saunders) in cotton. Pesticides **9**(3):30-33.

Agrawal, S.C. and Kushwaha, K.S. 1979. Efficacy of insecticidal control schedules against aphids and jassids on tomato. Indian J. Pl. Prot. **6**(2):40-43.

Ahmed, A.H.M., Elhag, E.A. and Bashir, N.H.H. 1987. Insecticide resistance in the cotton whitefly Bemisia tabaci Genn. in the Sudan Gezira. Trop. Pest Mgmt **33**(1):67-72.

Aliniazee, M.T. 1983. Carbaryl resistance in the filbert aphid (Homoptera:Aphididae). J. econ. Ent. **76**(5):1002-1004.

Atwal, A.S. and Singh, K. 1969. Chemical control of cotton jassid (Empoasca devastans Dist.) and whitefly (Bemisia tabaci Genn.). J. Res. Punjab agric. Univ. **6**(1):237-240.

Balasubramanian, G. and Chelliah, S. 1985. Chemical control of pests of sunflower. Pesticides **19**(4):21-22.

Banerjee, T.K. and Raychaudhari, D. 1988. Effect of some insecticides on population of leaf hoppers Amrasca devastans and Cestius phycitis infesting egg plant. Indian J. agric. Sci. **58**(6):500-501.

Bauernfeind, R.J. and Chapman, R.K. 1985. Nonstable parathion and endosulfan resistance in green peach aphids (Homoptera: Aphididae). J. econ. Ent. **78**(3):516-522.

Borle, M.N., Upalanchiwar, A.R. and Deshmukh, S.D. 1980. Efficacy of insecticidal mixtures in dust formulations for the control of cotton jassid in dryland cultivation. Indian J. Ent. **42**(1):130-132.

Chakkaravarthy, G. and Balasubramanian, M. 1986. Control of cotton jassid Amrasca biguttula biguttula Ishida (Homoptera:Cicadellidae). Pesticides **20**(2):21-22.

Chawla, R.P. and Kalra, R.L. 1976. Studies on insecticide resistance in Plutella xylostella. Indian J. Pl. Prot. **4**(2):170-180.

*Chopra, N.P. and Gera, R. 1976. Relative effectiveness of some insecticides on three varieties of cotton. Cotton Development 6(1):17.

David, B.V., Srinivasan, P.M. and Janagarajan, A. 1967. The control of major pests of irrigated cotton in the southern districts of Madras state. Madras agric. J. **54**(2):343-352.

Deshmukh, S.D. 1977. Field trials to evaluate the efficacy of insecticides against pests of sunflower. Pesticides **11**(4): 32-38.

ABSTRACT

A study was undertaken at the College of Horticulture, Vellanikkara during 1991-92 to determine the relative susceptibility of four different populations of leaf hopper _Amrasca biguttula biguttula_ (Ishida) on bittergourd to five insecticides. The four populations were collected from Vellanikkara (Thrissur district), Kuruppanthara (Kottayam district), Angadippuram (Malappuram district) and Ottapalam (Palakkad district) from farmers' fields and homestead gardens. The five insecticides tested represented three major chemical groups viz., endosulfan (organochlorine), quinalphos, monocrotophos and phosalone (organophosphorous) and carbaryl (carbamate).

Based on relative toxicity study, endosulfan was proved to be most toxic against Ottapalam and Angadippuram populations of leaf hoppers collected from farmers' fields. Monocrotophos was found to be most effective against Kuruppanthara population and quinalphos was most effective against Vellanikkara population. Phosalone and carbaryl were found to have very low effectiveness on the four populations. In the homestead gardens endosulfan proved to be most effective against all populations except that of Vellanikkara where quinalphos was most effective. Carbaryl and phosalone showed very low toxicity against the leaf hopper populations collected from homestead gardens.

Susceptibility studies revealed that Vellanikkara population of leaf hoppers showed highest susceptibility to quinalphos, monocrotophos and phosalone in both farmers' fields and homestead gardens. Carbaryl had the highest susceptibility in farmers' fields while lowest susceptibility was exhibited in homestead gardens. The Ottapalam and Kuruppanthara populations exhibited highest susceptibility to endosulfan and carbaryl respectively.

There was no significant difference in the LC_{50} values of insecticides obtained against leaf hopper populations from farmers' fields and homestead gardens. No significant difference was thus observed in response of leaf hopper populations from farmers' fields and homestead gardens towards insecticides.

The leaf-dip method of bioassay was found to be superior in toxicity than that of the spray-residue method. All insecticides required a lower dose in the leaf-dip method than spray residue technique to cause the same level of mortality in A. biguttula biguttula.

Carbaryl proved to be the most persistent insecticide in the persistent toxicity studies against Vellanikkara population of A. biguttula biguttula. Endosulfan was found to be the least persistent insecticide. The second best persistent insecticide was monocrotophos followed by phosalone and quinalphos.