RELATIVE SUSCEPTIBILITY OF POPULATIONS OF *Amrasca biguttula biguttula* (ISHIDA) INFESTING BITTER-GOURD (*Momordica charantia* L.) COLLECTED FROM DIFFERENT LOCATIONS TO INSECTICIDES PART II

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

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DECLARATION

I hereby declare that the thesis entitled **RELATIVE SUSCEPTIBILITY OF POPULATIONS OF *Amrasca biguttula biguttula* (ISHIDA) INFESTING BITTERGOURD (*Momordica charantia* L.) COLLECTED FROM DIFFERENT LOCATIONS TO INSECTICIDES PART II** is a bonafide record of research 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, fellowship or other similar title of any other university or society.

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We, the undersigned members of the Advisory Committee of Ms. Jyothi P. Bindu a candidate for the degree of Master of Science in Agriculture with major in Entomology, agree that this thesis entitled **RELATIVE SUSCEPTIBILITY OF POPULATIONS OF *Amrasca biguttula biguttula* (ISHIDA) INFESTING BITTERGOURD (*Momordica charantia* L.) COLLECTED FROM DIFFERENT LOCATIONS TO INSECTICIDES PART II** may be submitted by Ms. Jyothi P. Bindu is partial fulfilment of the requirement for the degree.

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Introduction

I. INTRODUCTION

Gourds form an important group of vegetables under the broad classification of cucurbits. Among them, bittergourd (Momordica charantia L.) ranks first with regard to nutritive value and unique medicinal properties. It occupies a prominent position among the vegetables cultivated during the summer season in Kerala.

The leafhopper or jassid Amrasca biguttula biguttula (Ishida) (Homoptera : Cicadellidae) is one of the key pests infesting bittergourd and other vegetable crops. The adult is wedge-shaped, about 2 mm long and pale green in colour. The nymphs are wingless, pale green in colour and are found in large numbers on the lower surface of the leaves.

The nymphs and adults of A. biguttula biguttula pierce the leaf tissues and suck the cell sap by their mouth parts. The injury is caused due to the toxaemia of the insect's saliva which is injected into the leaf tissues during feeding. The infested leaves crinkle severely. Their edges turn pale green, then yellow and finally brick red or brown in colour and lead to the drying of leaves ultimately. This symptom is called 'Hopper burn'. The vigour of the attacked plants is impaired and they become stunted in growth and hence fail to bear fruits. The symptoms of leafhopper attack on bittergourd are shown in plates (1 — 3).

The adult female leafhopper inserts about 15 to 30 eggs in the leaf veins and the minute nymphs emerge out of the eggs in 4 to 11 days. The nymphs moult five times. The life cycle is completed in 14 to 30 days.

Being polyphagous, this hopper has been recorded feeding on a number of vegetable and other crops including brinjal, okra, cowpea, cucurbits, beans, potato, tomato, sunflower, mesta, groundnut, castor, hollyhock etc. It is a major pest on cotton.

Foliar applications of several insecticides belonging to different chemical groups were observed to be very effective against A. biguttula biguttula. The effectiveness of endosulfan (Pareek and Noor, 1980; Krishnakumar and Srinivasan, 1987 and Yadav et al., 1989), quinalphos (Jacob and Verma, 1985; Mohan, 1985 and Kumar et al., 1988), monocrotophos (Narke and Suryawanshi, 1987; Kakar and Dogra., 1988, Singh and Mishra, 1988 and Krishnaiah et al. 1976), phosphamidon (Patel et al., 1980; Hasabe and Moholkar, 1981 and Bhamburkar, 1986) and deltamethrin (Dhamdhere et al., 1981; Rai, 1985 and Satpute et al., 1989) in controlling this leafhopper have been documented earlier.

Plate 1. Starting stage of hopper infestation on bittergourd plant

Plate 2. Marginal yellowing and crinkling of bittergourd leaves due to hopper infestation

Plate 3. Final stage of hopper infestation on bittergourd plant

Recently the leafhopper, A. biguttula biguttula has emerged as a dominant pest of bittergourd crop causing enormous loss to the cultivators in different parts of Kerala state. Although a variety of foliar insecticides were reported to be very effective in controlling this pest, many local reports were being received from the cultivators on the non-effectiveness of commonly used insecticides by the cultivators which probably have led to a reduced susceptibility in leafhopper populations to the commonly used insecticides. Sabitha (1992) also observed considerable variations in the susceptibility of leafhopper populations from different districts of the state to different insecticides. In the context of this serious problem in the field, it is felt quite necessary to investigate and confirm the susceptibility variations of field populations of A. biguttula biguttula to different insecticides. The studies will be useful to determine the toxicity of common insecticides against different leaf-hopper populations in the field.

Five commonly used insecticides belonging to three different chemical groups, chlorinated hydrocarbons, organophosphorus compounds and synthetic pyrethroids, were selected for testing their toxicity to A. biguttula biguttula. Along with these common insecticides a new insecticide, ethofenprox, based on CHO whose action is similar to the synthetic pyrethroids, was also included for testing because of its very low mammalian toxicity. Ethofenprox was reported to be highly effective against the leafhoppers and planthoppers by Krishnaiah and Kalode (1993).

The present study was undertaken with the following objectives:

To investigate the variations in the susceptibility status of different populations of A. biguttula biguttula infesting bittergourd collected from eight locations of four districts of Kerala state to the commonly used insecticides.

To study the toxicity variations of the commonly used insecticides against these different populations of A. biguttula biguttula in each district and thereby to assess the development of any reduction in toxicity against this pest in these districts.

Review of Literature

II. REVIEW OF LITERATURE

The jassid _Amrasca biguttula biguttula_ (Ishida) is one of the important destructive pests causing serious damage to a wide range of crops viz. okra, brinjal, cotton, cucurbits, potato, sunflower, greengram, french bean, groundnut, mesta etc. In spite of the use of various methods of pest control, insecticides continue to be the main tools for reducing the pest populations. Effective control of _A. biguttula biguttula_ has been reported with a variety of insecticides belonging to different chemical groups in many crops. The efficacy of quinalphos, monocrotophos, phosphamidon, endosulfan, deltamethrin and ethofenprox in controlling _A. biguttula biguttula_ is briefly reviewed here. An attempt has also been made to review the studies on the susceptibility/resistance of other hemipteran pest populations towards these insecticides.

2.1 Bioefficacy of different insecticides against _A. biguttula biguttula_ in various crops

2.1.1 Bioefficacy of quinalphos

Quinalphos was reported to be quite effective in controlling _A. biguttula biguttula_ in many crops at different concentrations.

2.1.1.1 Bioefficacy of quinalphos against *A. biguttula biguttula* in okra

Srinivasan *et al*. (1973) observed effective control of *A. biguttula biguttula* in okra with 0.025 per cent quinalphos. The use of quinalphos at 0.03 per cent caused 57 per cent reduction in population of *A. biguttula biguttula* in okra while a higher dose of 0.05 per cent caused 68 per cent reduction in the leaf hopper population (Jacob and Verma, 1985). Quinalphos at 0.05 per cent was earlier reported to be effective against. *A. biguttula biguttula* by Nair *et al*. (1977).

But Waryam Singh *et al*. (1991) observed that quinalphos was relatively ineffective against *A. biguttula biguttula* at 0.05 per cent concentration.

At a lower dose of 0.25 kg ai/ha, quinalphos indicated poor control of *A. biguttula biguttula* and caused resurgence of this pest in okra (Nagia *et al*., 1992). But at a higher dose of 0.5 kg ai/ha, it was observed to give good control of this pest (Mohan, 1985).

Dhamdhere *et al*. (1985) tested the efficiency of quinalphos at three concentrations of 0.75, 1.00 and 1.5 kg ai/ha against *A. biguttula biguttula* and observed that all these treatments prevented an increase in the number of leaf hoppers four weeks after application and remained effective upto 8 weeks.

2.1.1.2 Bioefficacy of quinalphos against *A. biguttula biguttula* in brinjal

According to Kumar *et al*. (1988), 0.05 per cent quinalphos was most effective against *A. biguttula biguttula* in brinjal followed by 0.025 per cent. Need based application of quinalphos at 0.05 per cent was found to be effective in controlling *A. biguttula biguttula* (Reghunath *et al*., 1989). Thanki and Patel (1991) found that quinalphos 0.05 per cent was the most effective dose in controlling hemipteran pests of brinjal.

Subbaratnam and Butani (1984) observed a high persistent toxicity to second instar nymphs of A. *biguttula biguttula* by the application of 0.1 per cent quinalphos.

2.1.1.3 Bioefficacy of quinalphos against *A. biguttula biguttula* in cotton

Sidhu *et al*. (1979) observed the effectiveness of quinalphos at 0.3 kg ai/ha against *A. biguttula biguttula* in cotton.

2.1.1.4 Bioefficacy of quinalphos against *A. biguttula biguttula* in ridgegourd

Sprays containing 0.025 per cent quinalphos were observed to be effective against *A. biguttula biguttula* in ridgegourd (Pareek and Noor, 1980).

2.1.2 Bioefficacy of monocrotophos

2.1.2.1 Bioefficacy of monocrotophos against *A. biguttula biguttula* in okra

With monocrotophos at 0.03 per cent, good control of *A. devastans* could be achieved by Gupta and Dhari (1978) in okra. Effective control of *A. biguttula biguttula* in okra with 0.04 per cent monocrotophos was noticed by Easwaramoorthy *et al.* (1976); Patel *et al.*(1980); Narke and Suryawanshi (1987); Pareek *et al.* (1987) and Singh and Mishra (1988).

Verma (1988) reported a 50 per cent reduction in the population of *A. biguttula biguttula* in okra within seven days by the application of monocrotophos at 0.05 per cent. The same dose was found to be significantly superior in controlling the insect in okra by Patel *et al.* (1980).

Monocrotophos at 0.5 kg ai/ha gave good control of *A. biguttula biguttula* (Krishnakumar and Srinivasan, 1987 and Kakar and Dogra, 1988).

Hasabe and Moholkar (1981) recommended seed dressing with monocrotophos at 4 per cent of the seed weight in okra to control *A. biguttula biguttula*.

2.1.2.2 Bioefficacy of monocrotophos against *A. biguttula biguttula* in brinjal

Mote (1981) recommended spraying of monocrotophos at 0.05 per cent to control *A. biguttula biguttula* in brinjal. The same dose was also reported by Naik *et al.* (1993) for controlling the nymphs of *A. devastans* for more than 20 days in brinjal.

2.1.2.3 Bioefficacy of monocrotophos against *A. biguttula biguttula* in cotton

Shah *et al.* (1990) observed that 0.036 per cent monocrotophos was the most effective chemical for controlling the cotton jassid. According to Viswanathan and Abdul Kareem (1983) monocrotophos at 0.05 per cent effectively controlled *A. devastans* on cotton. Spraying with monocrotophos 40 EC at 0.1 per cent and use of granular formulation of monocrotophos 5 G gave effective control of *A. biguttula biguttula* (Raju and Reddy, 1988). Dhawan *et al.* (1988) stated the effectiveness of monocrotophos at 0.1 kg ai/ha against *A. biguttula biguttula*. At 0.15 kg ai/ha, monocrotophos was found to reduce the population of *A. biguttula biguttula* on cotton (Chakkaravarthy and Balasubramanian, 1986). Nagia *et al.* (1992) reported the effective use of monocrotophos against *A. biguttula biguttula* at a still higher dose of 0.175 kg ai/ha sprayed 4 times at 20-22 days interval on 85 day old cotton crop. At 0.3 kg ai/ha monocrotophos was found to give good control of the same pest in cotton (Sidhu *et al*., 1979). A still higher dose of 0.5 kg ai/ha was reported to be effective against *A. biguttula biguttula* by Sidhu and Dhawan (1976).

Based on the study conducted by Senapathi and Behera (1989) it was found that spraying twice with demeton-methyl and subsequently with monocrotophos 5 times at 0.5 kg ai/ha, at 20 days interval commencing 30 days after sowing, afforded excellent control of *A. biguttula biguttula*.

Use of monocrotophos as skip row application was also found to have the same effect as full coverage for controlling the hopper *A. biguttula biguttula* (Surulivelu and Kumaraswami, 1989).

2.1.2.4 Bioefficacy of monocrotophos against *A. biguttula biguttula* in potato

For controlling *A. devastans* on potato, monocrotophos at 0.05 per cent was found to be good (Misra and Lal, 1981). Against *A. biguttula biguttula* on potato, monocrotophos at 0.25 kg ai/ha was reported to be effective (Mavi and Singh, 1975).

2.1.2.5 Bioefficacy of monocrotophos against *A. biguttula biguttula* in greengram

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 (Gartoria and Singh, 1984).

2.1.2.6 Bioefficacy of monocrotophos against *A. biguttula biguttula* in french bean

Lal (1992) reported the effectiveness of monocrotophos at 0.05 per cent against *Amrasca* spp.

2.1.2.7 Bioefficacy of monocrotophos against *A. biguttula biguttula* in groundnut

Monocrotophos at 0.05 per cent was reported to cause reduction in the population of leaf hopper in groundnut (Kennedy *et al.*, 1992).

2.1.2.8 Bioefficacy of monocrotophos against *A. biguttula biguttula* in cowpea

Verma and Dikshit (1990) reported the efficacy of 0.03 per cent monocrotophos against *A. biguttula biguttula* in cowpea for 22 days.

2.1.2.9 Bioefficacy of monocrotophos against *A. biguttula biguttula* in pigeon pea

In pigeon pea monocrotophos at 0.04 per cent was found to be effective against *A. biguttula biguttula* (Mishra and Saxena, 1982).

2.1.3 Bioefficacy of phosphamidon

2.1.3.1 Bioefficacy of phosphamidon against *A. biguttula biguttula* in okra

Alternate weekly spraying of 0.03 per cent phosphamidon and 0.05 per cent endosulfan gave increased yield in okra (Chaudhary and Dadheech, 1989). Dhamdhere _et al._ (1980) reported that phosphamidon was toxic to _A. biguttula biguttula_ at 0.05 per cent and its toxicity persisted upto 21 days.

2.1.3.2 Bioefficacy of phosphamidon against _A. biguttula biguttula_ in cotton

According to Raju and Reddy (1988) phosphamidon 0.05 per cent gave effective control of _A. biguttula biguttula_ in cotton. The effectiveness of the same dose was also reported by Singh and Lakra (1989). Bhamburkar (1986) reported that phosphamidon at 0.34 kg ai/ha applied on the crop at 15 and 18 days after sowing gave significant reduction of the population of _A. biguttula biguttula_ with maximum seed yield.

2.1.3.3 Bioefficacy of phosphamidon in potato

Misra and Lal (1981) stated the effectiveness of foliar application of phosphamidon against _A. devastans_ at 0.05 per cent and found out that it was the most effective one among the other tested chemicals.

2.1.3.4 Bioefficacy of phosphamidon against _A. biguttula biguttula_ in sunflower

Phosphamidon at 0.02 per cent was found to be most effective in reducing the jassid infestation in sunflower (Deshmukh, 1977).

2.1.3.5 Bioefficacy of phosphamidon against *A. biguttula biguttula* in french bean

Phosphamidon at 0.05 per cent gave the best level of control of *Amrasca* spp. in french bean (Lal, 1992).

2.1.3.6 Bioefficacy of phosphamidon against *A. biguttula biguttula* in tomato

Agrawal and Kushwaha (1979) reported that for the control of *A. devastans* two applications of phosphamidon at biweekly interval followed by an application of mevinphos two weeks after proved most effective.

2.1.4 Bioefficacy of endosulfan

2.1.4.1 Bioefficacy of endosulfan against *A. biguttula biguttula* in okra

The efficacy of endosulfan in controlling *A. biguttula biguttula* was reported at different concentrations in okra. Endosulfan was found to give rapid knock down effect with 84 per cent mortality in *A. biguttula biguttula* at 0.035 per cent concentration. This dosage was preferred by Dhamdhere *et al*. (1980) to avoid the residue problem in okra fruits.

The effectiveness of endosulfan at 0.05 per cent against *A. biguttula biguttula* in okra has been well documented by many workers. According to Krishnakumar and Srinivasan, 1987 and Yadav *et al*., 1989, endosulfan gave good control of the jassid at 0.05 per cent. But Uthamasamy and Balasubramanian (1978) observed a combined use of endosulfan at 0.05 per cent with aldicarb at 0.75 kg ai/ha for a good control of A. biguttula biguttula. Another combination of endosulfan 0.05 per cent with phosphamidon 0.03 per cent was suggested by Chaudhary and Dadheech (1989). Alternate weekly spraying of this combination of insecticides was reported to produce an increase in the yield also by controlling the pest complex.

Srinivasan et al. (1973) and Sidhu and Simwat (1973) stated a higher dose of 0.07 per cent against A. biguttula biguttula on okra. The same dose was observed to be the most effective by Rao et al. (1991) also against A. biguttula biguttula .

Combinations of endosulfan with malathion, dimethoate, oxydemeton methyl and monocrotophos all at 0.5 kg ai/ha was observed to be effective against A. biguttula biguttula (Singh and Singh, 1991). According to Easwaramoorthy et al. (1976), endosulfan at 0.6 kg ai/ha was effective against A. biguttula biguttula.

Endosulfan was reported to be 2.28 times more toxic than lindane to A. biguttula biguttula (Singh and Teotia, 1978). High volume spray of endosulfan was found to be the most effective treatment in reducing the population of A. biguttula biguttula (Harcharan Singh and Chhaneja, 1987).

Thus in okra, endosulfan was observed to bring about effective control of A. biguttula biguttula at concentration ranging from 0.035 to 0.07 per cent.

2.1.4.2 Bioefficacy of endosulfan against A. biguttula biguttula in brinjal

In brinjal A. biguttula biguttula could be effectively controlled with 0.025 per cent endosulfan (Veeravel and Baskaran, 1976). But according to Tewari and Moorthy (1983), 0.05 per cent endosulfan was more effective than synthetic pyrethroids. A higher dose of 0.07 per cent was stated to give good control of all the hemipteran pests in brinjal (Thanki and Patel, 1991). The same concentration was suggested by Singh and Kavadia (1989) for the protection of nursery plants of brinjal. Endosulfan at 0.025 to 0.07 per cent was thus found to give good control of A. biguttula biguttula in brinjal.

2.1.4.3 Bioefficacy of endosulfan against A. biguttula biguttula in cotton

Endosulfan at 0.05 per cent was reported to give 70 per cent control of A. devastans on cotton (Agarwal and Katiyar, 1975). According to Karuppuchamy et al. (1986) population of A. devastans was lowest with the treatment of endosulfan at 0.05 per cent in combination of carbofuran or aldicarb. JaiSingh and Harcharan Singh (1989) reported effective control of A. biguttula biguttula by endosulfan at 0.825 kg ai/ha. Application of endosulfan at

0.05 to 0.09 per cent was stated to be effective against A. biguttula biguttula by Sidhu and Dhawan (1976) and Viswanathan and Abdul Kareem (1983).

2.1.4.4 Bioefficacy of endosulfan against A. biguttula biguttula in cucurbits

Endosulfan sprays at 0.05 per cent were indicated to be effective against A. biguttula biguttula in ridge gourd (Pareek and Noor, 1980).

2.1.4.5 Bioefficacy of endosulfan against A. biguttula biguttula in tomato

Agrawal and Kushwaha (1979) observed that endosulfan at 0.05 per cent was effective against A. devastans in tomato.

2.1.4.6 Bioefficacy of endosulfan against A. biguttula biguttula in sunflower

Use of endosulfan at 0.05 per cent with wettable sulphur at 2 g/l could effectively reduce the jassid infestation on sunflower (Deshmukh, 1977). Three rounds of endosulfan sprays at 0.05 per cent after 25, 35 and 45 days of sowing proved quite effective against A. biguttula biguttula (Balasubramanian and Chelliah, 1985).

2.1.4.7 Bioefficacy of endosulfan against *A. biguttula biguttula* in french bean

Lal (1992) reported the effectiveness of endosulfan against *A. biguttula biguttula* on french bean at 0.05 per cent concentration.

2.1.5 Bioefficacy of deltamethrin

2.1.5.1 Bioefficacy of deltamethrin against *A. biguttula biguttula* in okra

The effective dose of deltamethrin against *A. biguttula biguttula* was found to vary from 0.001 to 0.006 by different workers. At 0.0014, 0.0028 and 0.0042 per cent concentrations, deltamethrin was very effective against the hopper *A. biguttula biguttula* (Waryam Singh *et al.*, 1991). According to Kakar and Dogra (1988) a simple spray of deltamethrin at 0.002 per cent was effective in controlling the insect pests of okra. Singh and Mishra (1988) reported that 0.0025 per cent deltamethrin was very effective against *A. biguttula biguttula*.

The effectiveness of deltamethrin against *A. biguttula biguttula* on okra was also studied by Dhamdhere *et al.* (1981). They found that at 0.0065 per cent deltamethrin was significantly superior to other treatments. At this concentration this chemical controlled leaf hoppers on bhindi but caused an increase in the mite population (Rai, 1985).

2.1.5.2 Bioefficacy of deltamethrin against *A. biguttula biguttula* in brinjal

Deltamethrin was observed to be less effective against *A. biguttula biguttula* in brinjal at 0.002 per cent (Tewari and Moorthy, 1983). At 0.005 per cent deltamethrin was found to be most effective in controlling the pest complex of brinjal. (Thanki and Patel, 1991). LD_5, LD_{10}, LD_{25} and LD_{50} values of deltamethrin were found out for *A. biguttula biguttula* and it was reported that LD_5 value has stimulated the feeding in *A. biguttula biguttula* (Sheila *et al.*, 1991).

2.1.5.3 Bioefficacy of deltamethrin against *A. biguttula biguttula* in cotton

At 0.005 per cent, the use of deltamethrin was observed to be effective in reducing the populations of *A. biguttula biguttula* in cotton (Satpute *et al.*, 1989). The same dose was effective in the case of deltaphos (a mixture of deltamethrin and triazophos) in keeping the population of sucking pests on cotton below the economic threshold level (Dhawan *et al.*, 1991).

2.1.5.4 Bioefficacy of deltamethrin against *A. biguttula biguttula* in groundnut

Deltamethrin at 0.006 per cent was found to be most effective in reducing the mean number of leaf hoppers in groundnut (Kennedy *et al.*, 1992).

2.1.5.5 Bioefficacy of deltamethrin against A. biguttula biguttula in tomato

Deltamethrin at 0.02 kg ai/ha controlled all the pests of tomato including A. biguttula biguttula effectively and gave a high fruit yield of 20,000 kg/ha (Mishra, 1986).

2.1.6 Bioefficacy of ethofenprox

Since ethofenprox is a new insecticide, no work has been reported against A. biguttula biguttula and hence literature on its efficacy against other pests has been included here.

Ethofenprox gave 75 to 100 per cent mortality 48 hours after treatment in contact toxicity studies against green leaf hopper Nephotettix virescens (Dist.) in rice (MaCatula et al., 1987). Clement and David (1988) showed the insecticidal activity of ethofenprox at 0.010 kg ai/ha to Earias vitella (F.) on okra. The effectiveness of ethofenprox against brown plant hopper of rice Nilaparvata lugens (Stal.) was observed by Peter et al. (1989). The toxicity of ethofenprox against the larvae of Heliothis armigera (Hb.) was determined by Peter and Sundararajan (1990).

Bubniewicz and Mrowczynski (1989) showed that ethofenprox was very effective against Oulema spp. on cereals in Poland. Ethofenprox exhibited toxic effects against the bollworm complex (E. vitella, E. insulana and Pectinophora gossypiella Saund) in cotton (Rasul et al., 1990). Ethofenprox at 0.02 per cent concentration killed 62.5 per cent of the eggs of Spodoptera litura (F.) (Peter and David, 1990). Rajasri et al. (1991) also proved the effectiveness of ethofenprox against H. armigera and S. litura. Ethofenprox was proved to be very effective against eggs and adults of sweet potato whitefly, Bemisia tabaci (Gennadius) (Kubuta, 1991).

The toxicity of ethofenprox against the nymphs of sweet potato whitefly was observed by Habu (1991).

Ethofenprox exhibited adulticidal activity against serpentine leaf miner (Liriomyza trifolii Burgess) and reduced the number of feeding and oviposition punctures (Saito et al., 1992). Ramiro et al. (1992) evaluated the effectiveness of insecticides as a function of the types of damage caused by the cotton boll weevil Anthonomos grandis Boheman. They concluded that ethofenprox 10 SC at 0.1 kg ai/ha and 30 EC at 0.075 ai/ha were most effective with regard to damage caused by the feeding of A. grandis.

2.2 Susceptibility/ resistance of sucking pests to quinalphos, monocrotophos, phosphamidon, endosulfan, deltamethrin and ethofenprox

2.2.1 Susceptibility/ resistance of sucking pests to quinalphos

Myzus persicae (Sulz.) was reported to be resistant to quinalphos and the chemical gave only 22.3 per cent control in field situation in South Auckland (Fellowes and Ferguson, 1974). According to Dittrich and Ernst (1983) Sudanese field strain of cotton whitefly Bemisia tabaci was moderately resistant to quinalphos.

2.2.2 Susceptibility/ resistance of sucking pests to monocrotophos

Wavte et al. (1977) reported a six fold resistance to monocrotophos in banded wing whiteflies, Trialeurodes abutilonea (Haldeman) in Louisiana, but the chemical was still effective for the control of this pest in the field. High resistance to monocrotophos in Sudanese field strain of B. tabaci was reported by Dittrich and Ernst (1983) in cotton.

In Japan cross resistance was observed by Ozaki and Kassai (1984) in brown plant hopper in rice. Malathion resistant strains showed 5-26 fold resistance to monocrotophos and fenitrothion resistant strains showed 5-32 fold cross resistance to monocrotophos.

Dittrich *et al.* (1985) concluded that in Sudan the resistance in *B. tabaci* became so high that it could not be controlled by monocrotophos.

Resistance in *Aphis gossypii* (Glov.) against monocrotophos was reported in cotton by Ishaaga and Mendelson (1987).

2.2.3 Susceptibility/ resistance of sucking pests to phosphamidon

Shift in the level of susceptibility of *M. persicae* to phosphamidon in India was studied by Dhingra (1990). She had noticed that the LC_{50} value of phosphamidon had increased 155 times against this insect since 1907.

A high level of resistance to phosphamidon in *A. gossypii* was detected by Kerns and Gaylon (1992) in Alabama and Texas.

2.2.4 Susceptibility/ resistance of sucking pests to endosulfan

Field evidence of resistance to endosulfan in *M. persicae* was observed by Fellowes and Ferguson (1974) in South Auckland. Only 58.3 per cent control could be achieved by endosulfan in *M. persicae*. Non-stable resistance to endosulfan in the same insect was also observed by Bauenfeind and Chapman (1985). Here, the resistant populations become susceptible by maintaining them in insecticide free green house environments. *M. persicae* showed resistance from 10 to as many as 27 generations after collection from the field.

Follet *et al*. (1985) reported 5-12 fold resistance to endosulfan in selected strains of *Psylla pyricola* (Forst) from pear orchards in Oregon.

Increased status of *B. tabaci* from secondary to primary pest on cotton was reported due to the increased resistance to monocrotophos, DDT and organophosphates and stimulation of fertility by DDT (Dittrich *et al*., 1986). Ahmed *et al*. (1987) studied the insecticide resistance in *B. tabaci* in the Sudan Gezira. Resistance to endosulfan was 364 fold in adults and 5 fold in nymphs. For a mixture of dimethoate with endosulfan, these values were 10 and 7 fold while it was 5 and 3 fold for a mixture of amitraz with endosulfan, respectively.

But Dittrich and Ernst (1983) noticed a low level of resistance in *B. tabaci* in Sudanese cotton to endosulfan.

Filbert aphid *Myzocallis coryli* (Goeze) on hazelnut exhibited 1 to 50 fold resistance to endosulfan (Katundu and Aliniazee, 1990) in Willamette Valley, Oregon.

The level of susceptibility of *M. persicae* to endosulfan was observed to be shifted in India. The LC_{50} value for endosulfan was observed to be increased 21 times (Dhingra, 1990).

Reddy *et al*. (1992) found out the relative resistance of chilli thrips *Scirtothrips dorsalis* (Hood.) collected from different localities to endosulfan and indicated the importance of developing insecticide resistance management for chilli in certain areas of Andhra Pradesh.

Endosulfan resistance was noticed in *A. gossypii* by Grafton-Cardwell *et al*. (1992). Endosulfan resistant aphids were found in 15 per cent of cotton fields in California in June - July 1988, 0 per cent in September, 1988, 7 per cent in July 1989 and 0 per cent in September, 1989.

High level of resistance was noticed in *A.* gossypii to endosulfan and deltamethrin by Gubran *et al*. (1992).

2.2.5 Susceptibility/ resistance of sucking pests to deltamethrin

The aphid *M. persicae* has developed resistance to deltamethrin and the mechanism of resistance against deltamethrin was different from that to organophosphates (Büchi, 1981). Brown plant hopper of rice was found to have developed 10-50 fold resistance against deltamethrin (Sun and Dal, 1984; Sun *et al*., 1984 and Park and Choi, 1991). Liu (1987) reported the development of resistance in *A. gossypii* to deltamethrin.

Abdeldaffie *et al*. (1987) reported a 5 fold resistance in *B. tabaci* to a mixture of chlorfenvinphos with endosulfan, 25 fold to deltamethrin and 2.5 fold to a mixture of deltamethrin with endosulfan. For nymphs, the resistance values were 4.28, 4.43 and 21.68, respectively.

Field trials in tea plantations in Malawai confirmed that the thrips *Scirtothrips aurantii* (Faure) developed resistance to all recommended synthetic pyrethroid insecticides including deltamethrin (Rattan, 1992).

2.2.6 Susceptibility/ resistance of sucking pests to ethofenprox

Endo *et al*. (1990) studied the changes in the susceptibility of the small brown plant hopper *Laodelphax striatella* (Fall.) to ethofenprox. The LD_{50} of an ethofenprox - selected strain to ethofenprox was 6-7 times as high as that of the parent (untreated) strain.

Materials and Methods

III. MATERIALS AND METHODS

The present investigation on the relative susceptibility of different leaf hopper (*Amrasca biguttula biguttula* (Ishida) populations in bittergourd from four districts of Kerala towards different insecticides was carried out at the College of Horticulture, Vellanikkara, Thrissur during 1993-94.

3.1 Selection of insecticides for testing against *A. biguttula biguttula*

Five insecticides belonging to different chemical groups viz. organochlorines, organophosphates and synthetic pyrethroids and a CHO compound were selected for testing their toxicity against different populations of *A. biguttula biguttula* in bittergourd collected from eight localities of four districts in Kerala. The details of insecticides used in the study are presented in Table 1.

Quinalphos, monocrotophos, phosphamidon and carbaryl are the most commonly used insecticides against. *A. biguttula biguttula* in bittergourd in Kerala. Hence these three organophosphorus compounds were selected for testing against *A. biguttula biguttula*. Carbaryl was not included since it was earlier reported to be ineffective against these leafhoppers in bittergourd (Sabitha, 1992). Endosulfan, deltamethrin and ethofenprox which are less used

Table 1. Details of the insecticides used in the study

Sl. No.	Common Name	Chemical group	Chemical formula and chemical name	Trade name/ proprietory name	Mode of entry (action)	Acute oral LD_{50} for rat (mg/kg)	Formul-ation used	Source
1.	Quinalphos	Organophos-phorus	$C_{12}H_{15}O_8N_2PS$ O,O-diethyl O-quinoxalin-2-yl Phosphoro-thioate	Ekalux	Contact	62-137	25 EC	Sandoz (India) Ltd.
2.	Monocrotophos	Organophos-phorus	$C_7H_{14}O_5NP$ dimethyl -(E)-1-methyl-2-methyl Carbamoyl-vinyl phosphate	Nuvacron	Contact & Systemic	21	36 SL	Hindustan Ciba-Geigy Ltd.
3.	Phosphamidon	Organophos-phorus	$C_{10}H_{19}O_5NCL$ P O Dimethyl O-(2-chloro-2-diethyl Carbamoyl-1-methyl-vinyl) phosphate	Dimecron	Systemic with stomach action	28.3	85 SL	Hindustan Ciba-Geigy Ltd.
4.	Endosulfan	Chlorinated hydrocarbon	$C_9H_6Cl_6O_3S$. Hexa-Chloro-hexahydro-Methano-benzodioxa thiepin-oxide	Thiodan	Contact	80-100	35 EC	Hoechst India Ltd.
5.	Deltamethrin	Synthetic-pyrethroid	(S)-oc-Cyano-m-phenoxy benzyl (IR, 3R)-3-(2,2-dibromovinyl)-2, 2 dimethyl cyclo propane carboxylate	Rukrin	Contact	135	2.8 EC	Cyanamid (India) Ltd.
6.	Ethofenprox	CHO compound	$C_{25}H_{28}O_3$ 2-(4-ethoxy phenyl)-2-methylpro... 3-Ph...	Trebon	Contact	42,880	10 EC	Coromandel Indag Products India Ltd

against A. biguttula biguttula in bittergourd were also selected for the study in order to assess their biological efficiency against leafhopper populations in bittergourd. Endosulfan is both a chlorinated hydrocarbon and an organic sulphite having contact and stomach action. It is effective against sucking pests, caterpillars and borers but safer to natural enemies and honey bees. Deltamethrin, containing the most active single isomer, is the most potent synthetic pyrethroid against insect pests. Ethofenprox, a new CHO compound composed of carbon, hydrogen and oxygen only is reported to be highly effective against leafhoppers and planthoppers with very low mammalian toxicity. It is also effective against organophosphorus and carbamate-resistant leafhoppers and planthoppers.

3.2 Selection of localities for collecting populations of A. biguttula biguttula

Based on the local reports of cultivators on the heavy incidence of leafhopper populations in bittergourd and the non-effectiveness of commonly used insecticides from Thrissur, Palakkad, Malappuram and Kottayam districts of Kerala state, two localities from each of the district were selected for collecting the leafhopper populations and testing their susceptibility towards different insecticides. The localities selected for the collection of leafhoppers and the designation of populations are given in Table 2.

Table 2. Localities selected for the collection of leaf-hopper populations

District	Locality	Population name
Thrissur	Pattikkadu	TCR I
Thrissur	Nedupuzha	TCR II
Palakkad	Pothappara	PKD I
Palakkad	Odanallur	PKD II
Malappuram	Wandoor	MPM I
Malappuram	Chattipparambu	MPM II
Kottayam	Vempalli	KTM I
Kottayam	Kurichi	KTM II

3.3 Collection and maintenance of leafhopper populations

Nucleus culture of each population of A. biguttula biguttula was collected from the farmers' field in each locality. The different cultures were maintained on 20 day old potted bittergourd plants in the net house separately at the college. Bittergourd (variety Priya) plants were raised in pots of size 26 X 27 cm in the net house for rearing A. biguttula biguttula. Cultures of leafhopper populations from eight locations of four districts were thus maintained separately which served as a steady source of population for conducting the experiments.

From the infested bittergourd fields of different selected localities, leafhoppers were collected by detaching the leaves harbouring them. The end of the detached leaf petiole was covered with moist cotton to prevent drying of the leaf. The leafhoppers thus collected with the leaf from the field were carried in aerated polyethylene bags and transferred to bittergourd plants grown in pots in the net house for maintaining the culture for the experiment. All the populations collected from the eight localities were reared separately.

3.4 Toxicity studies/ susceptibility studies

The experiments were carried out with commercial formulations of the six selected insecticides. For each insecticide, different test concentrations were prepared by diluting the insecticide formulations with tap water and tested against each population of A. biguttula biguttula. The susceptibility of each population was tested towards each of the insecticide. The concentrations of insecticides giving a mortality of A. biguttula biguttula in the range of 20-80 per cent were selected for the experiment. The concentrations of different insecticides tested are given in Table 3.

Table 3. Concentrations of different insecticides tested against A. biguttula biguttula

Quinalphos (per cent)	Monocrotophos (per cent)	Phosphamidon (per cent)	Endosulfan (per cent)	Deltamethrin (per cent)	Ethofenprox (per cent)
0.1	0.005	0.01	0.0001	0.001	0.005
0.3	0.007	0.03	0.0003	0.003	0.007
0.5	0.009	0.05	0.0005	0.005	0.009
0.7	0.01	0.07	0.0007	0.007	0.01
0.9	0.03	0.09	0.0009	0.009	0.03

The leaf dip method (foliar residue method) of bioassay recommended by FAO (1979) was adopted for assessing the susceptibility of the different populations of leafhopper against the insecticides. This technique was reported to produce more toxicity of insecticides in A. biguttula biguttula (Sabitha, 1992). Moreover, the foliar residue method closely resembles the insect - insecticide interaction in the field (Phokela et al., 1989).

Fresh leaves of uniform size were collected from bittergourd plants. These leaves were dipped in 2 ml of different test concentrations of each insecticide separately for 20 seconds in Petridishes (10 cm dia). Then they were taken out and dried under an electric fan for 15 minutes. The petiole ends of the leaves were wrapped with moist cotton to prevent withering. The leaves thus treated with different concentrations of insecticides were kept in separate petridishes (10 cm dia). Each concentration was taken as a treatment and three replications were maintained for each treatment. An untreated control by dipping the leaf in water alone was also maintained along with the treatments.

Ten uniform sized leafhopper nymphs of 3rd instar were then transferred with a camel hair brush to the treated leaves in the petridishes and covered with upper Petridishes. These Petridishes were kept in the laboratory at a temperature of 30 ± 1°C.

Observations on the mortality of the leafhoppers were taken after 24 hours of treatment. Percentage mortality was then calculated. The experiments were thus carried out with six insecticides against eight different populations of A. biguttula biguttula collected from four districts.

3.5 Interpretation of data

The data on percentage mortality was corrected based on Abbot's formula (Abbot 1925) wherever mortality in control was observed. The data on dosage mortality response of different leafhopper populations were subjected to Probit Analysis according to Finney (1971).

Results

IV. RESULTS

Populations of *A. biguttula biguttula* infesting bittergourd were collected from two different locations of the four selected districts viz. Thrissur, Palakkad, Malappuram and Kottayam in Kerala state and were tested for their relative susceptibility towards six insecticides belonging to different chemical groups. The results of the present investigations are presented in this chapter under the following two headings:

4.1 Relative toxicity of different insecticides to field populations of *A. biguttula biguttula* collected from different areas

4.2 Relative susceptibility of different populations of *A. biguttula biguttula* to different insecticides

4.1 Relative toxicity of different insecticides to field populations of *A. biguttula biguttula* collected from different areas

The relative toxicities of six insecticides viz. quinalphos, monocrotophos, phosphamidon, endosulfan, deltamethrin and ethofenprox were evaluated against two different populations of *A. biguttula biguttula* from each of the four districts. The mortality data of the leaf hoppers were subjected to probit analysis and the relative toxicity of insecticides has been calculated by taking LC_{50} value of quinalphos as unity. On local enquiries made among the farmers, quinalphos has been found to be commonly used against A. biguttula biguttula in bittergourd in fields. Hence quinalphos has been taken as the standard for determining the relative toxicity of different insecticides.

4.1.1 Relative toxicity of different insecticides to field populations of A. biguttula biguttula collected from Thrissur district

Populations of A. biguttula biguttula collected from two locations of Thrissur district viz. Pattikkadu and Nedupuzha were designated as TCR I and TCR II.

The results of the mortality data of TCR I population of A. biguttula biguttula are presented in Table 4 and graphically depicted in Fig. 1. It is evident that all the insecticides tested were more toxic than quinalphos to A. biguttula biguttula. Endosulfan was found to have the highest toxicity followed by monocrotophos against TCR I population. Endosulfan and monocrotophos were found to be 2144.47 and 186.00 times as toxic as quinalphos. The descending order of toxicity of different insecticides was endosulfan > monocrotophos > deltamethrin > ethofenprox > phosphamidon > quinalphos. The relative toxicity values of deltamethrin, ethofenprox and phosphamidon were 161.69, 88.92 and 31.65, respectively.

Against TCR II population of A. biguttula biguttula the trend in toxicity of different insecticides was

Table 4. Relative toxicity of different insecticides to TCR I population of *A. biguttula biguttula*

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	1.1528	5.8499 + 6.1954 x	0.72912	0.65596 - 0.81045	1.00
Monocrotophos	3.6738	10.0902 + 2.1153 x	0.00392	0.00280 - 0.00532	186.00
Phosphamidon	3.9076	11.0198 + 3.6765 x	0.02304	0.01890 - 0.02810	31.65
Endosulfan	1.1746	14.8297 + 2.8427 x	0.00034	0.00026 - 0.00045	2144.47
Deltamethrin	2.0229	12.0308 + 2.9981 x	0.00451	0.00377 - 0.00540	161.67
Ethofenprox	5.3060	8.8176 + 1.8303 x	0.00820	0.00626 - 0.01070	88.92

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

Y = Probit kill

x = log (Concentration x 10^4)

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

TCR I = Thrissur I population (Pattikkadu)

Fig. 1. Relative toxicity of different insecticides to TCR I population of *A. biguttula biguttula*

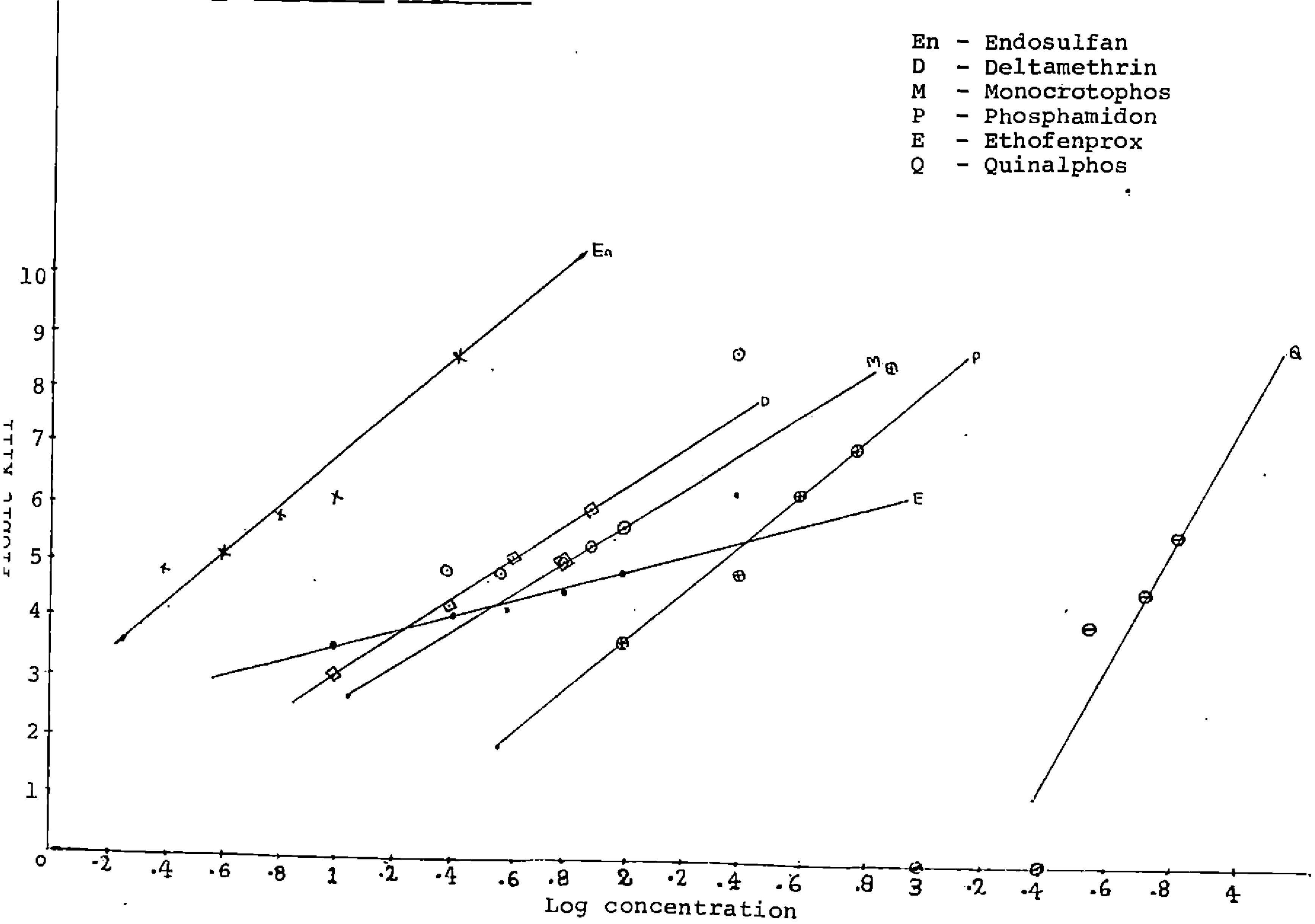


Table 5. Relative toxicity of different insecticides to TCR II population of *A. biguttula biguttula*

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	2.5875	5.1072 + 3.0515 x	0.92227	0.74970 - 1.34560	1.00
Monocrotophos	24.5633	11.6003 + 2.9071 x	0.00536	0.00454 - 0.00630	172.07
Phosphamidon	7.8212	7.1512 + 1.7989 x	0.06370	0.04692 - 0.08649	14.48
Endosulfan	6.8998	12.0162 + 2.0750 x	0.00041	0.00033 - 0.00050	2249.44
Deltamethrin	3.8551	8.4200 + 1.6417 x	0.00825	0.00552 - 0.01233	111.79
Ethofenprox	4.0073	10.6865 + 2.8453 x	0.01003	0.00837 - 0.01201	91.95

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

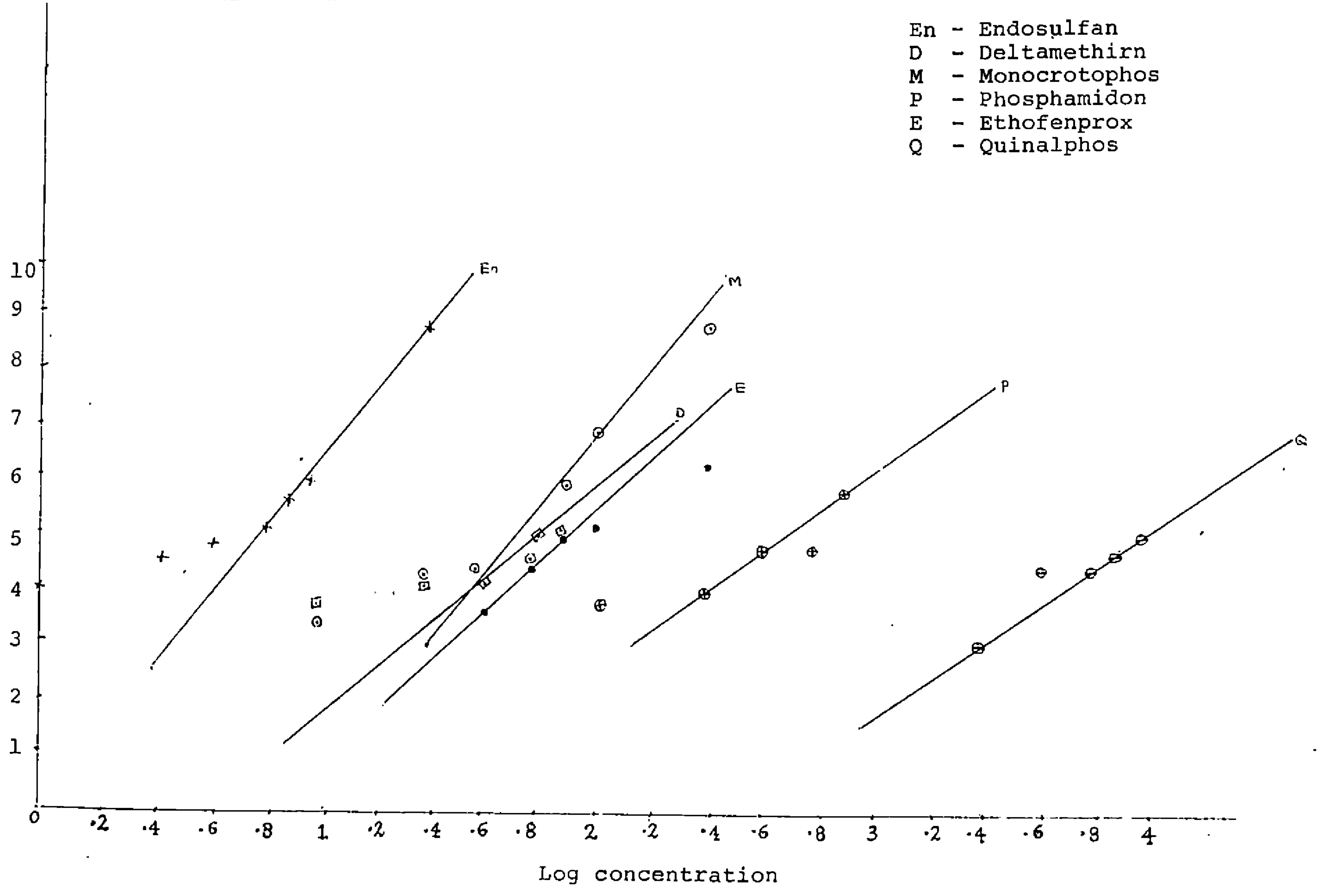
Y = Probit kill

x = log (Concentration x 10^4)

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

TCR II= Thrissur II population (Nedupuzha)

Fig. 2 Relative toxicity of different insecticides to TCR II population of *A. biguttula biguttula*



observed to be the same as that of TCR I population. Data on toxicity of different insecticides are given in Table 5 and presented in Fig. 2. Endosulfan was found to be 2249.4 times as toxic as quinalphos while phosphamidon was 14.48 times more toxic than quinalphos. The toxicity values of monocrotophos, phosphamidon and deltamethrin were less than those against TCR I population. The descending order of toxicity of different insecticides with relative toxicity values was : endosulfan (2249.44) > monocrotophos (172.07) > deltamethrin (111.79) > ethofenprox (91.95) > phosphamidon (14.48) > quinalphos (1.00).

4.1.2 Relative toxicity of different insecticides to field populations of _A_. _biguttula biguttula_ collected from Palakkad district

The two populations of _A_. _biguttula biguttula_ collected from Pothappara and Odanallur of Palakkad district were named as PKD I and PKD II, respectively.

The toxicity data of different insecticides against PKD I population of _A_. _biguttula biguttula_ are given in Table 6 and graphically represented in Fig. 3. From the table it is clear that, endosulfan showed the highest toxicity against PKD I population. It was found to be 3518.68 times more toxic than quinalphos. Endosulfan was followed by deltamethrin in toxicity with 224.38 times as toxic as quinalphos. All the three organophosphorus insecticides, monocrotophos, phosphamidon and quinalphos, were found to be lower in toxicity to PKD I population when compared with the other three insecticides. The descending order of toxicity of different insecticides was endosulfan > deltamethrin > ethofenprox > monocrotophos > phosphamidon > quinalphos. Relative toxicity values of deltamethrin, ethofenprox, monocrotphos, phosphamidon and quinalphos were 224.38, 158.95, 95.22, 44.23 and 1.00, respectively.

In PKD II population of _A_. _biguttula_ _biguttula_ also the same trend of toxicity was observed with the six different insecticides (Table 7 and Fig. 4). Here also endosulfan was proved to be best in toxicity followed by deltamethrin. Quinalphos indicated lowest toxicity. Deltamethrin and ethofenprox were found to be more toxic to PKD II than PKD I population. But endosulfan, monocrotophos and phosphamidon were observed to be less toxic to PKD II than PKD I population. The order of toxicity of different insecticides along with the corresponding relative toxicity values were: endosulfan (2977.35) > deltamethrin (230.39) > ethofenprox (175.14) > monocrotophos (89.70) > phosphamidon (40.85) > quinalphos (1.00).

Table 6. Relative toxicity of different insecticides to PKD I population of *A. biguttula biguttula*

Insecticides	Heterogeneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	1.7427	5.4095 + 3.6829 x	0.77411	0.64473 - 0.92945	1.00
Monocrotophos	1.4609	6.6999 + 0.8136 x	0.00813	0.00457 - 0.01449	95.22
Phosphamidon	1.2138	10.1416 + 2.9267 x	0.01750	0.01359 - 0.02254	44.23
Endosulfan	8.1568	11.6281 + 1.8166 x	0.00022	0.00016 - 0.00031	3518.68
Deltamethrin	0.5471	8.4690 + 1.4089 x	0.00845	0.00243 - 0.00489	224.38
Ethofenprox	1.1034	16.4463 + 4.9505 x	0.00487	0.00430 - 0.00552	158.95

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

Y = Probit kill

x = log (Concentration x 10^4)

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

PKD I = Palakkad I population (Pothappara)

Fig. 3. Relative toxicity of different insecticides to PKD I population of *A. biguttula biguttula*

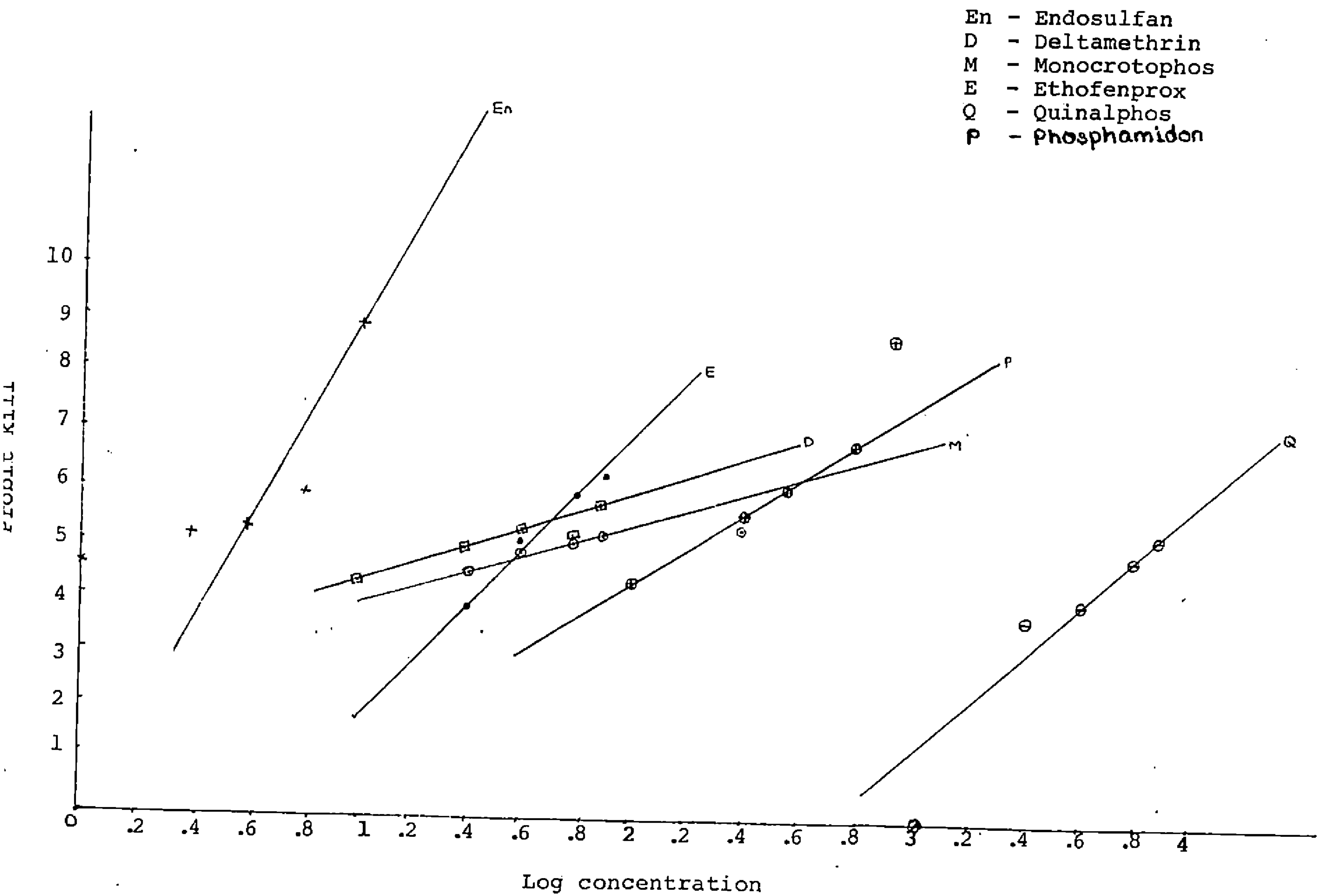


Table 7. Relative toxicity of different insecticides to PKD II population of _A. biguttula biguttula_

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	1.7427	5.4095 + 3.6829 x	0.77411	0.64473 - 0.92945	1.00
Monocrotophos	3.3409	7.3089 + 1.1189 x	0.00863	0.00562 - 0.01326	89.70
Phosphamidon	2.0162	9.9848 + 2.8943 x	0.01895	0.01480 - 0.02426	40.85
Endosulfan	7.0397	13.0309 + 2.2437 x	0.00026	0.00020 - 0.00034	2977.35
Deltamethrin	0.3612	8.5690 + 1.4432 x	0.00336	0.00239 - 0.00475	230.39
Ethofenprox	0.7137	14.6329 + 4.0920 x	0.00442	0.00381 - 0.00512	175.14

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

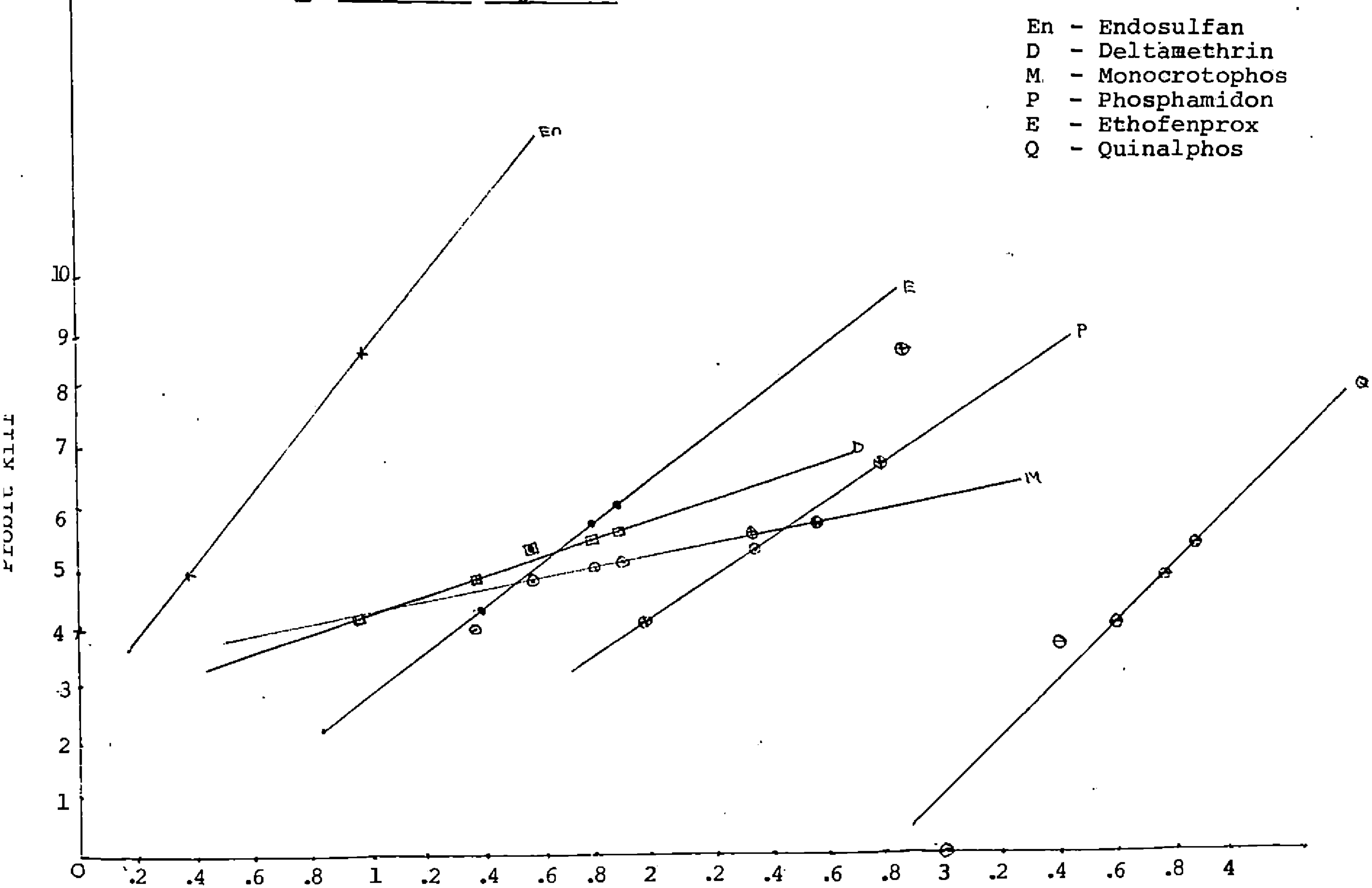
Y = Probit kill

x = log (Concentration x 10^4)

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

PKD II = Palakkad II population (Odanallur)

Fig. 4. Relative toxicity of different insecticides to PKD II population of *A. biguttula biguttula*



4.1.3 Relative toxicity of different insecticides to field populations of A. biguttula biguttula collected from Malappuram district

Leafhopper populations collected from Wandoor and Chattipparambu in Malappuram district were called as MPM I and MPM II, respectively.

Data on the effect of different insecticides against MPM I population are presented in Table 8 and graphically shown in Fig. 5. It is indicated that endosulfan showed the highest toxicity followed by ethofenprox against MPM I population. The order of insecticides according to decreasing toxicity was endosulfan > ethofenprox > deltamethrin > phosphamidon > monocrotophos > quinalphos. The corresponding relative toxicity values were endosulfan (2150.31), ethofenprox (150.31), deltamethrin (118.18) > phosphamidon (42.65), monocrotophos (28.46), quinalphos (1.00). Endosulfan was found to be 2150.31 times more toxic than quinalphos which proved to be least toxic. The three organophosphorus insecticides were found to be lower in toxicity to MPM I population when compared to other three insecticides.

Table 9 presents the toxicity data of different insecticides against MPM II population of A. biguttula biguttula. The results are graphically depicted in Fig. 6. As in the case of MPM I, endosulfan was found to be most

Table 8. Relative toxicity of different insecticides to MPM I population of *A. biguttula biguttula*

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	1.7427	5.4095 + 3.6829 x	0.77411	0.64473 - 0.92945	1.00
Monocrotophos	8.8518	7.7472 + 1.7549 x	0.02720	0.01926 - 0.03841	28.46
Phosphamidon	3.0047	10.6881 + 3.2672 x	0.01815	0.01444 - 0.02281	42.65
Endosulfan	8.2506	13.2571 + 2.4035 x	0.00036	0.00029 - 0.00046	2150.31
Deltamethrin	7.4061	8.5930 + 1.6453 x	0.00655	0.00466 - 0.00919	118.18
Ethofenprox	31.6691	13.1311 + 3.5530 x	0.00515	0.00444 - 0.00597	150.31

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

Y = Probit kill

x = log (Concentration x 10^4)

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

MPM I = Malappuram I population (Wandoor)

Fig. 5. Relative toxicity of different insecticides to MPM I population of *A. biguttula biguttula*

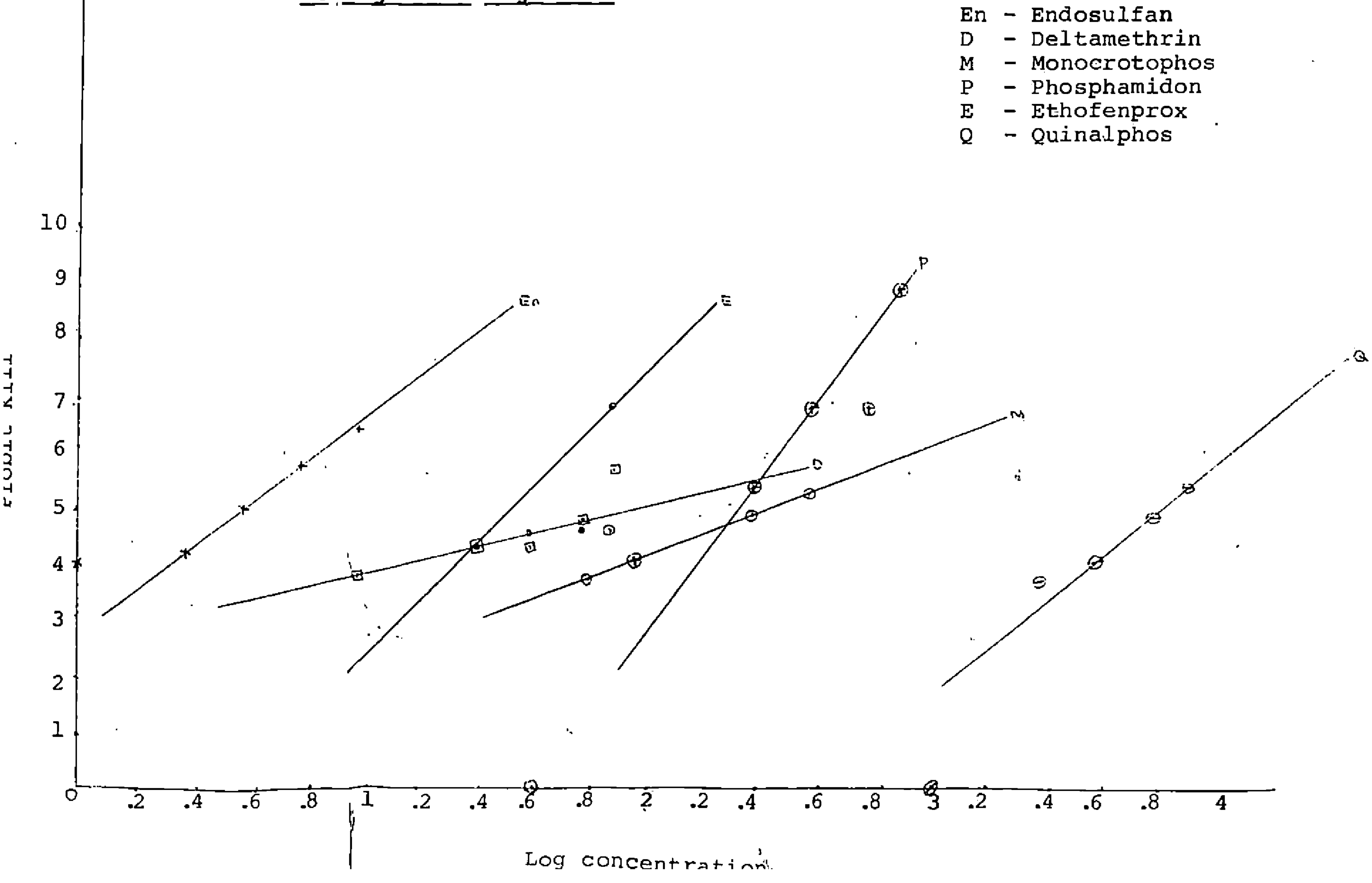


Table 9. Relative toxicity of different insecticides to MPM II population of *A. biguttula biguttula*

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	1.7847	5.4474 + 3.7389 x	0.75917	0.63649 - 0.90549	1.00
Monocrotophos	8.4905	7.9958 + 1.8698 x	0.02499	0.01824 - 0.03422	30.39
Phosphamidon	3.9925	11.1243 + 3.5060 x	0.01791	0.01438 - 0.02231	42.39
Endosulfan	6.2185	13.9411 + 2.6079 x	0.00037	0.00030 - 0.00046	2051.81
Deltamethrin	7.7485	8.3410 + 1.5201 x	0.00634	0.00442 - 0.00908	119.74
Ethofenprox	31.6890	14.0085 + 3.9564 x	0.00528	0.00461 - 0.00605	143.78

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

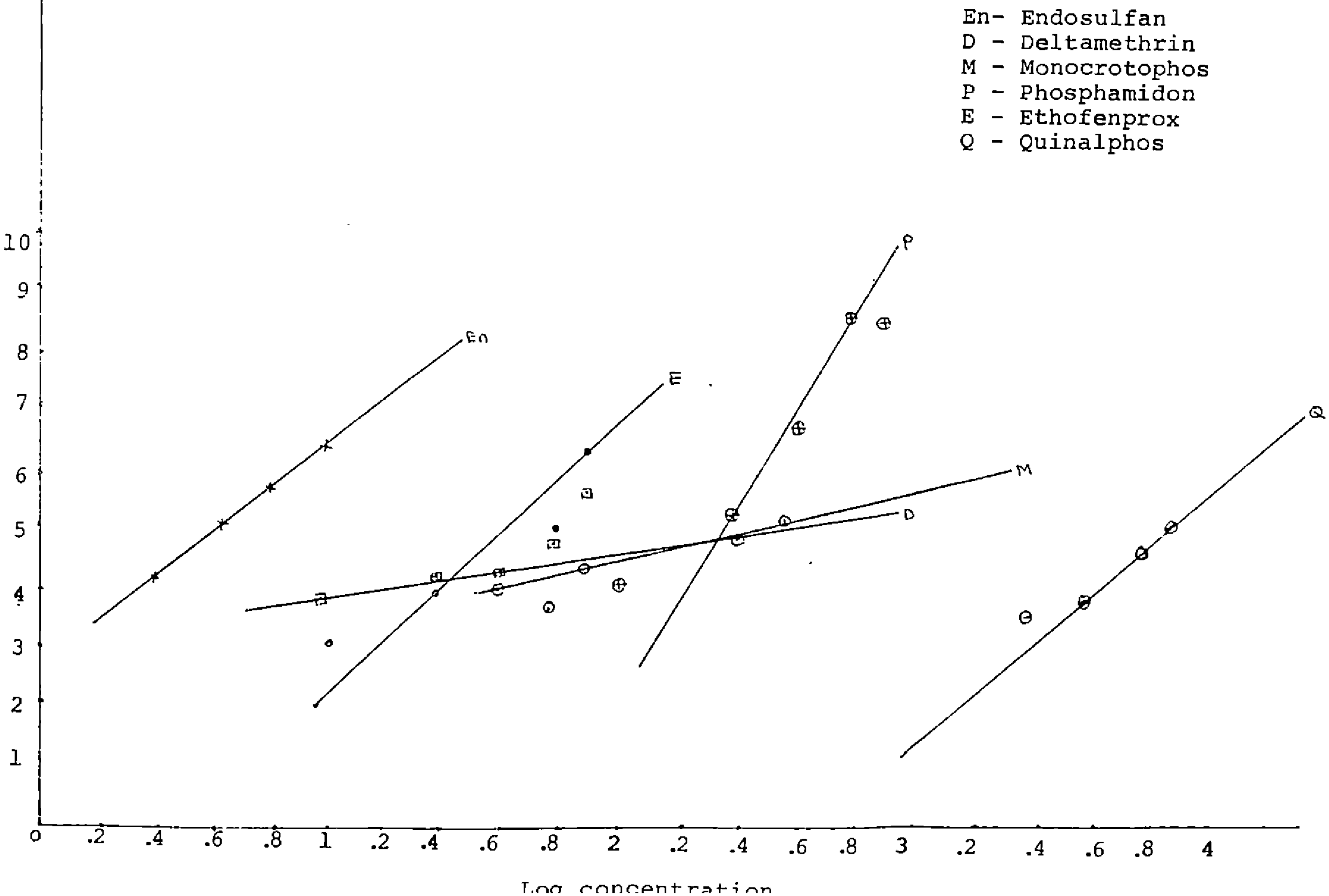
Y = Probit kill

x = log (Concentration x 10^4)

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

MPM II = Malappuram II population (Chattipparambu)

Fig. 6. Relative toxicity of different insecticides to MPM II population of *A. biguttula biguttula*



toxic followed by ethofenprox against MPM II population. Quinalphos was least toxic to MPM II population also. The order of toxicity of all the insecticides was found to be the same as that obtained in MPM II population. No difference was observed between MPM I and MPM II populations in toxicity towards phosphamidon and deltamethrin. Against monocrotophos also, there was not much difference in the toxicity values in MPM I and MPM II populations. The relative toxicity values of different insecticides were endosulfan (2051.81), ethofenprox (143.78), deltamethrin (119.74), phosphamidon (42.39), monocrotophos (30.39) and quinalphos (1.00).

4.1.4 Relative toxicity of different insecticides to field populations of *A. biguttula biguttula* collected from Kottayam district

A. biguttula biguttula collected from Vempalli and Kurichi in Kottayam district were designated as KTM I and KTM II populations.

The results of the mortality data of KTM I population against the six insecticides are presented in Table 10 and graphically shown in Fig. 7. Against KTM I population endosulfan proved to be the highest toxic insecticide followed by deltamethrin. Endosulfan was 1961 times as toxic as quinalphos while deltamethrin was 176.11 times more toxic than quinalphos. Lowest toxicity was observed with

Table 10. Relative toxicity of different insecticides to KTM I population of *A. biguttula biguttula*

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	2.6939	6.3111 + 9.4111 x	0.72557	0.67320 - 0.78190	1.00
Monocrotophos	4.1707	15.2227 + 4.7975 x	0.00789	0.00662 - 0.00826	98.18
Phosphamidon	4.0295	11.0130 + 4.4409 x	0.04426	0.03840 - 0.05090	16.39
Endosulfan	1.3174	15.7099 + 3.1225 x	0.00037	0.00029 - 0.00046	1961.00
Deltamethrin	2.3089	11.4373 + 2.6992 x	0.00412	0.00338 - 0.00502	176.11
Ethofenprox	6.0037	9.7782 + 2.5014 x	0.01229	0.00988 - 0.01529	59.04

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

Y = Probit kill

x = log (Concentration x 10^4)

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

KTM I = Kottayam I population (Vempalli)

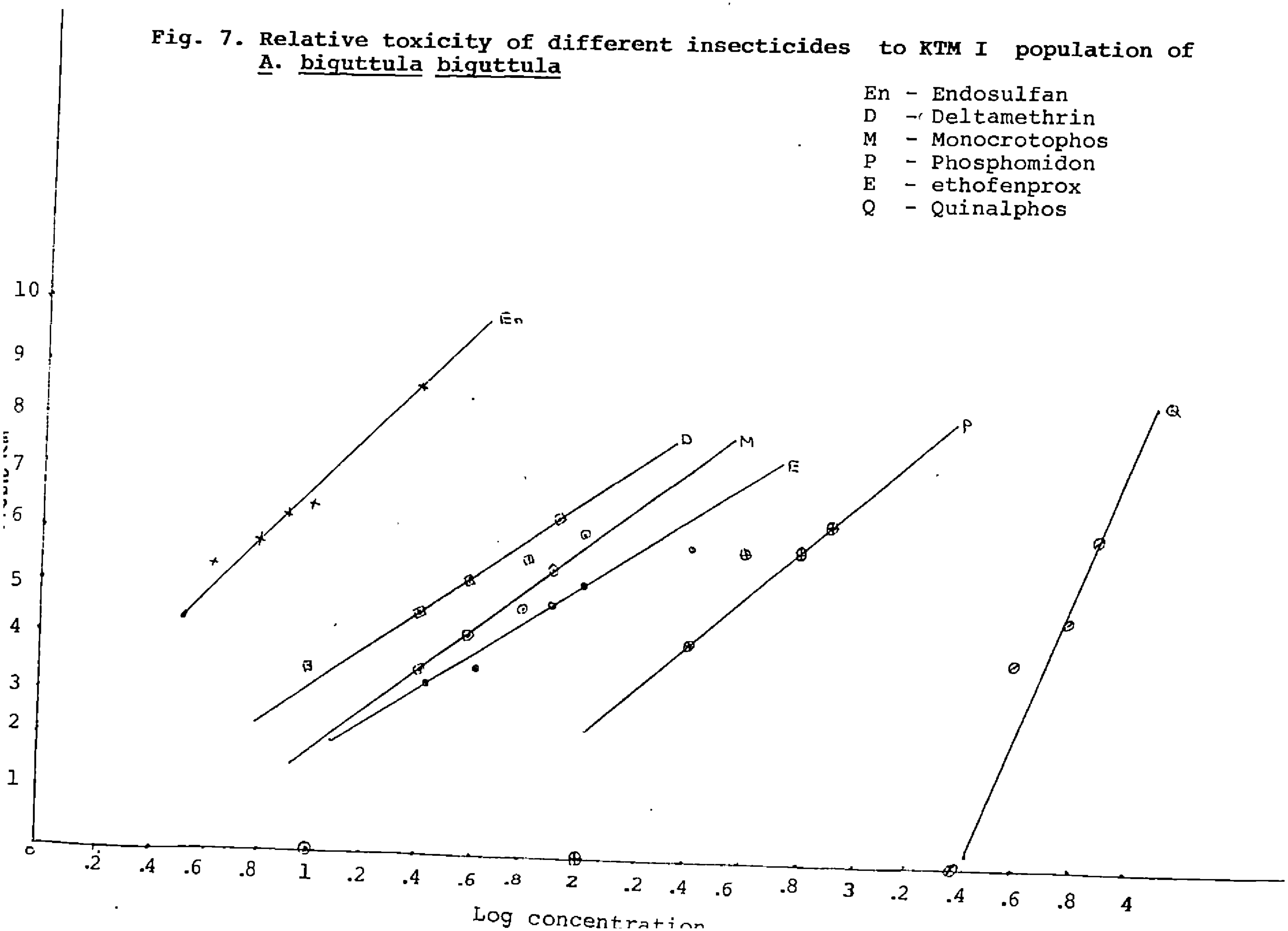


Fig. 7. Relative toxicity of different insecticides to KTM I population of A. biguttula biguttula

Table 11. Relative toxicity of different insecticides to KTM II population of <u>A. biguttula biguttula</u>

Insecticides	Hetero-geneity* X^2	Regression equation Y =	LC_{50}	Fiducial limits	Relative toxicity
Quinalphos	0.3949	6.1547 + 8.4140 x	0.72904	0.67186 - 0.79109	1.00
Monocrotophos	2.5625	14.8913 + 4.6440 x	0.00741	0.00660 - 0.00830	98.39
Phosphamidon	0.9063	9.7299 + 3.4847 x	0.04391	0.03728 - 0.05170	16.60
Endosulfan	2.4079	15.5996 + 3.1026 x	0.00038	0.00030 - 0.00048	1918.53
Deltamethrin	0.7573	11.5035 + 2.7183 x	0.00403	0.00332 - 0000493	180.9(
Ethofenprox	15.7841	10.5653 + 2.7740 x	0.00991	0.00826 - 0.01189	73.57

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

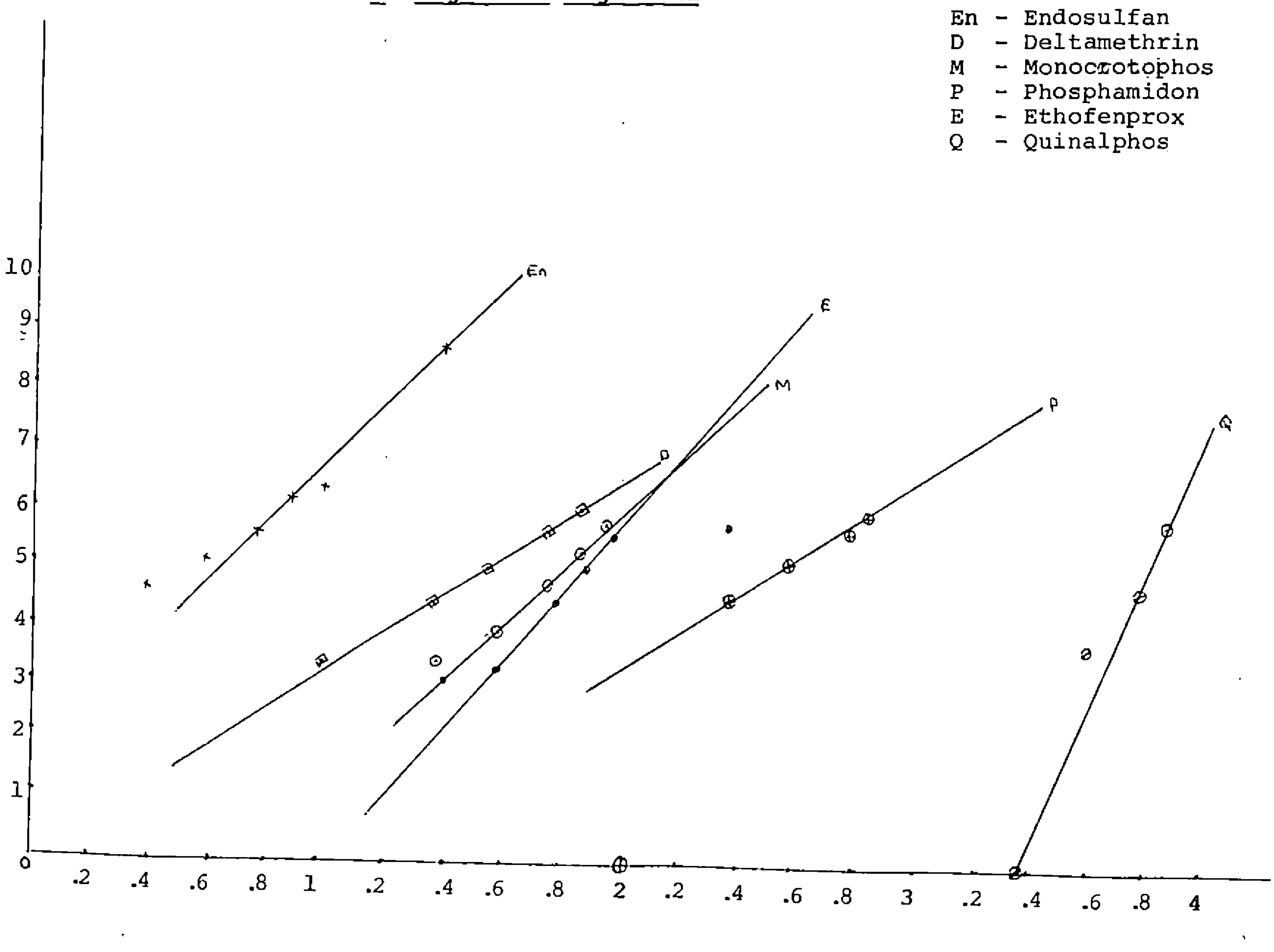
Y = Probit kill

x = log (Concentration x 10^4)

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

KTM II = Kottayam II population (Kurichi)

Fig. 8. Relative toxicity of different insecticides to KTM II populatior
A. biguttula biguttula



quinalphos. Phosphamidon was found to be 16.39 times more toxic than quinalphos. The descending order of toxicity of different insecticides was endosulfan > deltamethrin > monocrotophos > ethofenprox > phosphamidon > quinalphos. The relative toxicity values of these insecticides against KTM I population were endosulfan (1961.00), deltamethrin (176.11), monocrotophos (98.18), ethofenprox (59.04), phosphamidon (16.39) and quinalphos (1.00).

Against KTM II population also the same order of toxicity was observed with different insecticides (Table 11). It is graphically shown in Fig. 8. Here the relative toxicity values were observed as endosulfan (1918.53), deltamethrin (180.90), monocrotophos (98.39), ethofenprox (73.57), phosphamidon (16.60) and quinalphos (1.00). The relative toxicity values of all insecticides except ethofenprox were found to be almost equal against both populations of A. biguttula biguttula collected from Kottayam district. Against Kottayam populations also endosulfan ranked first in toxicity followed by deltamethrin. Quinalphos indicated least toxicity.

4.1.5 Comparison of relative toxicity of different insecticides to field populations of A. biguttula biguttula collected from all the four districts

An overall view of the toxicity of different insecticides against A. biguttula biguttula collected from

Table 12. Order of toxicity of different insecticides against different field populations of *A. biguttula biguttula*

Population	Decreasing order of toxicity of different insecticides					
TCR I	Endosulfan (2144.47)	> Monocrotophos (186.00)	> Deltamethrin (161.69)	> Ethofenprox (88.92)	> Phosphamidon (31.65)	> Quinalphos (1.00)
TCR II	Endosulfan (2249.44)	> Monocrotophos (172.07)	> Deltamethrin (111.79)	> Ethofenprox (91.95)	> Phosphamidon (14.48)	> Quinalphos (1.00)
PKD I	Endosulfan (3518.68)	> Deltamethrin (224.38)	> Ethofenprox (158.95)	> Monocrotophos (95.22)	> Phosphamidon (44.23)	> Quinalphos (1.00)
PKD II	Endosulfan (2977.35)	> Deltamethrin (230.39)	> Ethofenprox (175.14)	> Monocrotophos (89.70)	> Phosphamidon (40.85)	> Quinalphos (1.00)
MPM I	Endosulfan (2150.31)	> Ethofenprox (150.31)	> Deltamethrin (118.18)	> Phosphamidon (42.65)	> Monocrotophos (28.46)	> Quinalphos (1.00)
MPM II	Endosulfan (2051.81)	> Ethofenprox (143.78)	> Deltamethrin (119.74)	> Phosphamidon (42.39)	> Monocrotophos (30.39)	> Quinalphos (1.00)
KTM I	Endosulfan (1961.00)	> Deltamethrin (176.11)	> Monocrotophos (98.18)	> Ethofenprox (59.04)	> Phosphamidon (16.39)	> Quinalphos (1.00)
KTM II	Endosulfan (1918.53)	> Deltamethrin (180.90)	> Monocrotophos (98.39)	> Ethofenprox (73.57)	> Phosphamidon (16.60)	> Quinalphos (1.00)

Figures in parentheses indicate relative toxicity values.

all the four districts (Table 12) showed that the order of toxicity of different insecticides was same between the two populations from each district. Endosulfan was proved to be the most toxic insecticide against A. biguttula biguttula in all the eight populations from four districts, with LC_{50} values ranging from 0.00022 to 0.00041. Quinalphos was found to be the least effective insecticide against all the populations of four districts. Endosulfan was found to be 2249.44 to 3518.68 times as toxic as quinalphos against different populations. Monocrotophos was found to be second best in toxicity in Thrissur district only, ethofenprox only in Malappuram district while deltamethrin ranked second in toxicity against A. biguttula biguttula both in Kottayam and Palakkad districts. Phosphamidon was found to possess low level of toxicity against leaf hopper populations in all districts except Malappuram. The three organophosphorus insecticides were found to be lower in toxicity than endosulfan, deltamethrin and ethofenprox in Palakkad, Malappuram and Kottayam districts.

4.2 Relative susceptibility of different populations of A. biguttula biguttula from four districts to different insecticides

Two populations of A. biguttula biguttula collected from each district of Thrissur, Palakkad, Malappuram and Kottayam were tested for susceptibility against six insecticides. The relative susceptibility of different populations were calculated by taking the LC_{50} values of different insecticides against TCR I population as the standard.

4.2.1 Susceptibility of different populations of *A. biguttula biguttula* to quinalphos

The relative susceptibility of different populations of *A. biguttula biguttula* to quinalphos is presented in Table 13.

It is quite evident that the LC_{50} values of quinalphos were very high in all the populations indicating very low susceptibility of all populations of *A. biguttula biguttula* towards quinalphos. The LC_{50} value was found to range from 0.72557 in KTM I population to 0.92227 in TCR II population. All the eight populations from the four districts exhibited the same trend of low susceptibility towards quinalphos. No difference in LC_{50} values of quinalphos was observed between the two populations collected from a district except in Thrissur populations.

4.2.2 Susceptibility of different populations of *A. biguttula biguttula* to monocrotophos

Data on the dosage mortality response of the eight different populations of *A. biguttula biguttula* against monocrotophos are presented in table 14. From the LC_{50}

values of monocrotophos obtained for different populations, it is clear that highest susceptibility was exhibited by Thrissur populations. The LC_{50} value of monocrotophos for TCR I population was 0.00392 and that for TCR II population was 0.00536. Leaf hopper populations from Malappuram district manifested lowest susceptibility to monocrotophos. MPM I and MPM II populations were found to be 6.9 and 6.4 times less susceptible than TCR I population to monocrotophos. The descending order of susceptibility of different populations was TCR I > TCR II > KTM I = KTM II > PKD I > PKD II > MPM II > MPM I. No difference in susceptibility was observed between the two populations from Kottayam district. Both populations were found to be 1.9 times less susceptible than TCR I population. It is seen that PKD I and PKD II populations were 2.1 and 2.2 times less susceptible than TCR I population to monocrotophos. No variation in susceptibility was observed between the two populations from the same district. The LC_{50} value of monocrotophos was found to range from 0.00392 in TCR I population to 0.0272 in MPM I population.

4.2.3 Susceptibility of different populations of *A. biguttula biguttula* to phosphamidon

The dosage mortality response of populations of *A. biguttula biguttula* collected from four districts to phosphamidon is given in Table 15. It is indicated that all

Table 13. Dosage mortality response of different populations of *A. biguttula biguttula* to quinalphos

District/population	Place of collection	Regression equation Y=	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	5.8499 + 6.1954 x	0.72912	1.0
Thrissur/TCR II	Nedupuzha	5.1072 + 3.0515 x	0.92227	1.3
Palakkad/PKD I	Pothappara	5.4095 + 3.6829 x	0.77411	1.0
Palakkad/PKD II	Odanallur	5.4095 + 3.6829 x	0.77411	1.0
Malappuram/MPM I	Wandoor	5.4095 + 3.6829 x	0.77411	1.0
Malappuram/MPM II	Chattipparambu	5.4474 + 3.7389 x	0.75917	1.0
Kottayam/KTM I	Vempalli	6.3111 + 9.4111 x	0.72557	1.0
Kottayam/KTM II	Kurichi	6.1547 + 8.4140 x	0.72904	1.0

Y = Probit Kill

x = Log (Concentration x 10^4)

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

Table 14. Dosage mortality response of different populations of *A. biguttula biguttula* to monocrotophos

District/population	Place of collection	Regression equation Y =	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	10.0902 + 2.1153 x	0.00392	1.0
Thrissur/TCR II	Nedupuzha	11.6003 + 2.9071 x	0.00536	1.4
Palakkad/PKD I	Pothappara	6.6999 + 0.8136 x	0.00813	2.1
Palakkad/PKD II	Odanallur	7.3089 + 1.1189 x	0.00863	2.2
Malappuram/MPM I	Wandoor	7.7472 + 1.7549 x	0.02720	6.9
Malappuram/MPM II	Chattipparambu	7.9958 + 1.8698 x	0.02499	6.4
Kottayam/KTM I	Vempalli	15.2227 + 4.7975 x	0.00739	1.9
Kottayam/KTM II	Kurichi	14.8913 + 4.6440 x	0.0074	1.9

Y = Probit Kill

x = Log (Concentration x 10^4)

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

Table 15. Dosage mortality response of different populations of *A. biguttula biguttula* to phosphamidon

District/population	Place of collection	Regression equation Y =	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	11.0198 + 3.6765 x	0.02304	1.0
Thrissur/TCR II	Nedupuzha	7.1512 + 1.7989 x	0.06370	2.8
Palakkad/PKD I	Pothappara	10.1416 + 2.9267 x	0.01750	0.8
Palakkad/PKD II	Odanallur	9.9848 + 2.8943 x	0.01895	0.8
Malappuram/MPM I	Wandoor	10.6881 + 3.2672 x	0.01815	0.8
Malappuram/MPM II	Chattipparambu	11.1243 + 3.5060 x	0.01791	0.8
Kottayam/KTM I	Vempalli	11.0130 + 4.4409 x	0.04426	1.9
Kottayam/KTM II	Kurichi	9.7299 + 3.4847 x	0.04391	1.9

Y = Probit Kill

x = Log (Concentration x 10^4)

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

the four populations of _A. biguttula biguttula_ collected from Palakkad and Malappuram districts manifested highest susceptibility to phosphamidon. The LC_{50} values of phosphamidon were found to be same in all these populations. These populations were found to be more susceptible than the TCR I population which was taken as standard. TCR II population was found to be 2.8 times less susceptible than TCR I population indicating susceptibility variation between the two populations from Thrissur district. But in all other districts, both populations exhibited same susceptibility to phosphamidon. Both populations from Kottayam district were found to be 1.9 times less susceptible than TCR I population. Lowest susceptibility was thus mainfested by Kottayam populations. The decreasing order of susceptibility of different populations to phosphamidon was PKD I = PKD II = MPM I = MPM II > TCR I > KTM I = KTM II > TCR II. The LC_{50} value of phosphamidon was found to vary from 0.01750 in PKD II population to 0.06370 in TCR II population.

4.2.4 Relative susceptibility of populations of _A. biguttula biguttula_ against the three commonly used organophosphorus insecticides - quinalphos, monocrotophos and phosphamidon

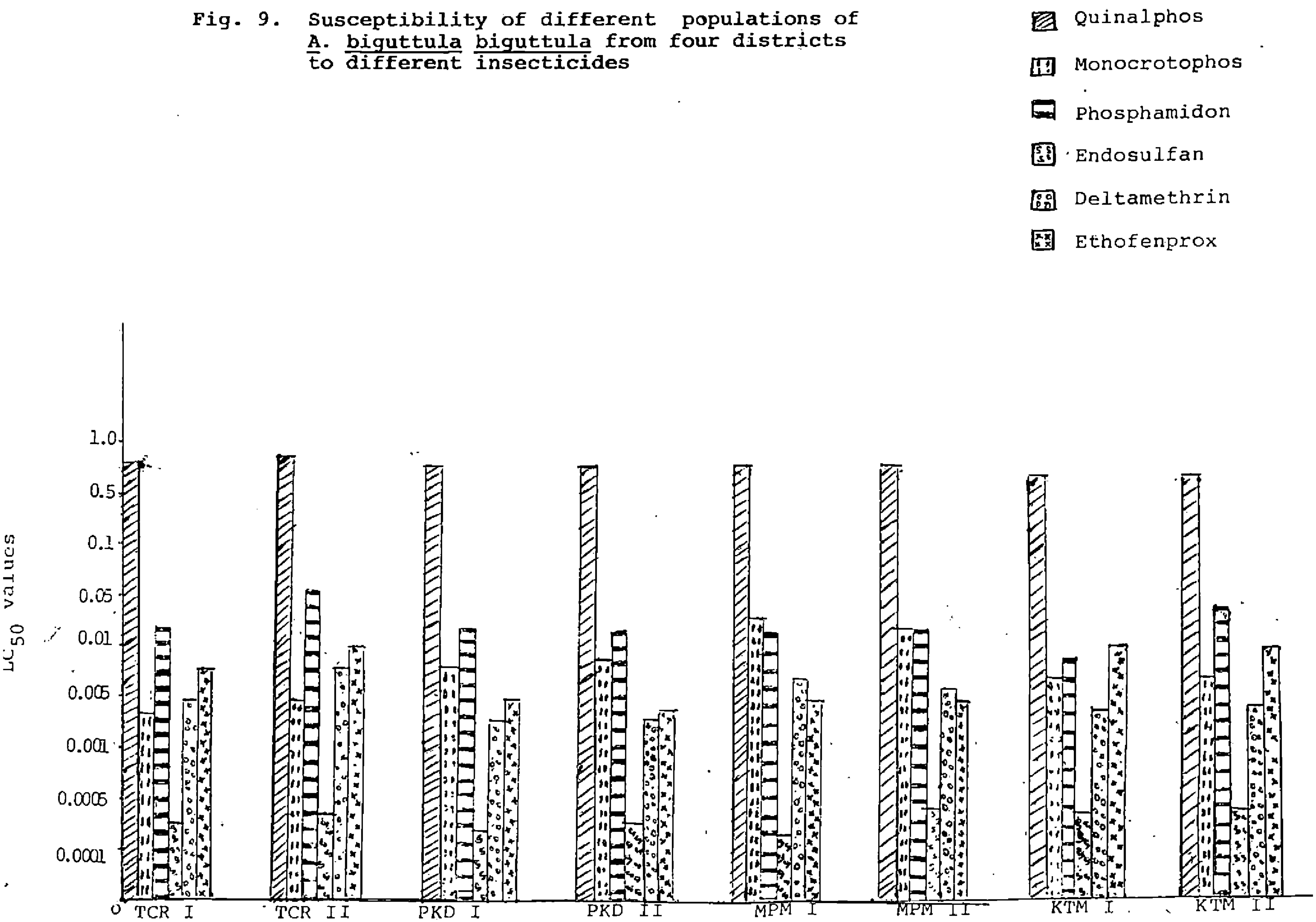
An overall view of the relative susceptibility of different populations of _A. biguttula biguttula_ to the three organophosphorus insecticides - quinalphos, monocrotophos

Table 16. Decreasing order of susceptibility of different populations of A. biguttula biguttula to the three organophosphorus insecticides

Insecticides	Order of susceptibility of different populations														
Quinalphos	TCR I (1.0)	=	MPM I (1.0)	=	MPM II (1.0)	=	KTM I (1.0)	=	KTM II (1.0)	>	PKD I (1.1)	=	PKD II (1.1)	>	TCR II (1.3)
Monocrotophos	TCR I (1.0)	>	TCR II (1.4)	>	KTM I (1.9)	=	KTM II (1.9)	>	PKD I (2.1)	>	PKD II (2.2)	>	MPM II (6.4)	>	MPM I (6.9)
Phosphamidon	PKD I (0.8)	=	PKD II (0.8)	=	MPM I (0.8)	=	MPM II (0.8)	>	TCR I (1.0)	>	KTM I (1.9)	=	KTM II (1.9)	>	TCR II (2.8)

Figures in parentheses indicate relative susceptibility values.

Fig. 9. Susceptibility of different populations of *A. biguttula biguttula* from four districts to different insecticides



and phosphamidon is given in Table 16 and graphically depicted in Fig.9. It is clear that TCR I population exhibited highest susceptibility to quinalphos and monocrotophos, while Palakkad and Malappuram populations manifested highest susceptibility to phosphamidon. Malappuram and Kottayam populations indicated equal susceptibility to quinalphos along with TCR I population. The least susceptible population to quinalphos and phosphamidon was found to be TCR II. Malappuram populations were found to be least susceptible to monocrotophos but exhibited high susceptibility to quinalphos and phosphamidon.

4.2.5 Susceptibility of different populations of *A. biguttula biguttula* to endosulfan

Data on the susceptibility of different populations of *A. biguttula biguttula* to endosulfan are given in Table 17. All the eight populations from the four districts exhibited high susceptibility to endosulfan. The LC_{50} value of endosulfan against different populations was found to vary from 0.00022 for PKD I population to 0.00041 for TCR II population. All the populations were found to be equally susceptible towards endosulfan. However, both populations from Palakkad district were more susceptible than populations from Thrissur district. The four populations collected from Malappuram and Kottayam districts were observed to have equal susceptibility to endosulfan with the same LC_{50} value of 0.0004. The order of susceptibility of different populations to endosulfan was PKD I > PKD II > TCR I > MPM I = MPM II = KTM I = KTM II > TCR II.

4.2.6 Susceptibility of different populations of *A. biguttula biguttula* to deltamethrin

Table 18 presents the susceptibility pattern of different populations of *A. biguttula biguttula* to deltamethrin. LC_{50} value of deltamethrin was found to range from 0.00336 to 0.00845 for different populations. All the four populations collected from Palakkad and Kottayam districts were found to be more susceptible to deltamethrin than the standard TCR I population. MPM I and MPM II populations were found to be less susceptible than TCR I population to deltamethrin. The LC_{50} value of deltamethrin against TCR II population was 0.00825 indicating its lowest susceptibility as compared with other populations. The order of decreasing susceptibility of different populations to deltamethrin was PKD II > PKD I > KTM I = KTM II > MPM II > MPM I > TCR II.

4.2.7 Susceptibility of different populations of *A. biguttula biguttula* to ethofenprox

Data on the relative susceptibility of different populations of *A. biguttula biguttula* to ethofenprox are

Table 17. Dosage mortality response of different populations of *A. biguttula biguttula* to endosulfan

District/population	Place of collection	Regression equation Y =	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	14.8297 + 2.8427 x	0.00034	1.0
Thrissur/TCR II	Nedupuzha	12.0162 + 2.0750 x	0.00041	1.2
Palakkad/PKD I	Pothappara	11.6281 + 1.8166 x	0.00022	0.6
Palakkad/PKD II	Odanallur	13.0309 + 2.2437 x	0.00026	0.8
Malappuram/MPM I	Wandoor	13.2571 + 2.4035 x	0.00036	1.1
Malappuram/MPM II	Chattipparambu	13.9411 + 2.6079 x	0.00037	1.1
Kottayam/KTM I	Vempalli	15.7099 + 3.1225 x	0.00037	1.1
Kottayam/KTM II	Kurichi	15.5996 + 3.1026 x	0.00038	1.1

Y = Probit Kill

x = Log (Concentration x 10^4)

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

Table 18. Dosage mortality response of different populations of *A. biguttula biguttula* to deltamethrin

District/population	Place of collection	Regression equation Y =	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	12.0308 + 2.9981 x	0.00451	1.0
Thrissur/TCR II	Nedupuzha	8.4200 + 1.6417 x	0.00845	1.8
Palakkad/PKD I	Pothappara	8.4690 + 1.4089 x	0.00345	0.8
Palakkad/PKD II	Odanallur	8.5690 + 1.4432 x	0.00336	0.7
Malappuram/MPM I	Wandoor	8.5930 + 1.6453 x	0.00655	1.5
Malappuram/MPM II	Chattipparambu	8.3410 + 1.5201 x	0.00634	1.4
Kottayam/KTM I	Vempalli	11.4373 + 2.6992 x	0.00412	0.9
Kottayam/KTM II	Kurichi	11.5035 + 2.7183 x	0.00405	0.9

Y = Probit Kill

x = Log (Concentration x 10^4)

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

Table 19. Dosage mortality response of different populations of *A. biguttula biguttula* to ethofenprox

District/population	Place of collection	Regression equation Y =	LC_{50}	Relative susceptibility
Thrissur/TCR I	Pattikkadu	8.8176 + 1.8303 x	0.00820	1.0
Thrissur/TCR II	Nedupuzha	10.6865 + 2.8453 x	0.01003	1.2
Palakkad/PKD I	Pothappara	16.4463 + 4.9505 x	0.00487	0.6
Palakkad/PKD II	Odanallur	14.6329 + 4.0920 x	0.00442	0.5
Malappuram/MPM I	Wandoor	13.1311 + 3.5530 x	0.00515	0.6
Malappuram/MPM II	Chattipparambu	14.0085 + 3.9564 x	0.00528	0.6
Kottayam/KTM I	Vempalli	9.7782 + 2.5014 x	0.01229	1.5
Kottayam/KTM II	Kurichi	10.5653 + 2.7740 x	0.00991	1.2

Y = Probit Kill

x = Log (Concentration x 10^4)

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

presented in Table 19. The LC_{50} value of ethofenprox to different populations was found to vary from 0.00442 in PKD I population to 0.01229 in KTM I population. Among the eight populations tested for susceptibility, populations from Palakkad and Malappuram were found to be more susceptible to ethofenprox than TCR I population which was taken as the standard. Both populations of A. biguttula biguttula from Kottayam (KTM I and KTM II) and TCR II population were found to be less susceptible than TCR I population. The descending order of susceptibility with relative susceptibility values of different populations to ethofenprox were : PKD II (0.5) > PKD I (0.6) = MPM I (0.6) = MPM II (0.6) > TCR I (1.0) > KTM II (1.2) = TCR II (1.2) > KTM I (1.5).

4.2.8 Relative susceptibility of different populations of A. biguttula biguttula against less commonly used insecticides-endosulfan, deltamethrin and ethofenprox

An overall view of the relative susceptibility of eight different populations of A. biguttula biguttula towards three less commonly used insecticides - endosulfan, deltamethrin and ethofenprox is given in Table 20 and graphically depicted in Fig. 9. It is quite evident that populations of A. biguttula biguttula collected from Palakkad district were most susceptible to endosulfan, deltamethrin and ethofenprox. Populations from Kottayam and Malappuram districts ranked second in susceptibility to

Table 20. Decreasing order of susceptibility of different populations of _A. biguttula biguttula_ to endosulfan, deltamethrin and ethofenprox

Insecticides	Order of susceptibility of different populations														
Endosulfan	PKD I (0.6)	>	PKD II (0.8)	>	TCR I (1.0)	>	MPM I (1.1)	=	MPM II (1.1)	=	KTM I (1.1)	=	KTM II (1.1)	>	TCR II (1.2)
Deltamethrin	PKD II (0.7)	>	PKD I (0.8)	>	KTM I (0.9)	=	KTM II (0.9)	>	TCR I (1.0)	>	MPM II (1.4)	>	MPM I (1.5)	>	TCR II (1.8)
Ethofenprox	PKD II (0.5)	>	PKD I (0.6)	=	MPM I (0.6)	=	MPM II (0.6)	>	TCR I (1.0)	>	TCR II (1.2)	=	KTM II (1.2)	>	KTM I (1.5)

Figures in parentheses indicate relative susceptibillty values.

deltamethrin and ethofenprox. The highest susceptibility of Palakkad populations to endosulfan was followed by TCR I population. However, the lowest susceptibility to endosulfan and deltamethrin was observed with TCR II population while KTM I population showed the least susceptibility to ethofenprox. The susceptibility pattern of eight populations collected from four districts against all the six insecticides indicated that Palakkad populations were most susceptible to phosphamidon, endosulfan, deltamethrin and ethofenprox. TCR I population was most susceptible to quinalphos and monocrotophos, while TCR II population exhibited lowest susceptibility to quinalphos, phosphamidon, endosulfan and deltamethrin. Lowest susceptibility was manifested by Malappuram populations towards monocrotophos. Kottayam populations exhibited lowest susceptibility to ethofenprox.

Discussion

V. DISCUSSION

The results obtained from the studies conducted on the relative susceptibility of eight populations of *A. biguttula biguttula* collected from different localities of four districts towards six insecticides belonging to different chemical groups are discussed in this chapter.

5.1 Relative toxicity of different insecticides to field populations of *A.biguttula biguttula* collected from different areas

5.1.1 Relative toxicity of six insecticides to field populations of *A. biguttula biguttula* collected from two localities in Thrissur district

Endosulfan was proved to have highest toxicity against both populations of *A. biguttula biguttula* collected from two different localities in Thrissur district. The descending order of toxicity of different insecticides to the two populations from this district was found to be same as endosulfan > monocrotophos > deltamethrin > ethofenprox > phosphamidon > quinalphos. All the five insecticides were more toxic than quinalphos to *A. biguttula biguttula*. Wide variations in the relative toxicity values were observed between the insecticides indicating their differences in toxicity against *A.*

biguttula biguttula. Endosulfan was 2144.47 and 2249.44 times as toxic as quinalphos against TCR I and TCR II populations suggesting its very high effectiveness to A. biguttula biguttula as compared to quinalphos.

The high effectiveness of endosulfan against A. biguttula biguttula in okra was documented by many workers (Sidhu and Simwat, 1973; Srinivasan et al., 1973; Dhamdhere et al., 1980; Krishnakumar and Srinivasan, 1987; Yadav et al., 1989 and Rao et al., 1991). It was also found highly effective against A. biguttula biguttula in some other crops like brinjal (Veeravel and Baskaran, 1976; Tewari and Moorthy, 1983; Singh and Kavadia, 1989 and Thanki and Patel, 1991), cotton (Sidhu and Dhawan, 1976; Viswanathan and Abdul kareem, 1983 and Jai Singh and Harcharan Singh, 1989), cucurbits (Pareek and Noor, 1980), sunflower (Balasubramanian and Chelliah, 1985) and french bean (Lal, 1992).

Monocrotophos ranked second in toxicity against both populations of A. biguttula biguttula in Thrissur district. It was found to be 186 and 172 times as toxic as quinalphos against TCR I and TCR II populations of A. biguttula biguttula. This finding is in consonance with the report of Sabitha (1992) wherein monocrotophos was found to be the second best in toxicity against population of A. biguttula biguttula from Vellanikkara of Thrissur district. The bioefficacy of monocrotophos against A. biguttula biguttula has been reported on many crops. In okra effective control of A. biguttula biguttula was reported by Easwaramoorthy et al. (1976); Patel et al. (1980); Pareek et al. (1987); Narke and Suryawanshi (1987) and Singh and Mishra (1988). The effective use of monocrotophos against A. biguttula biguttula was also observed in brinjal (Mote, 1981), cotton (Sidhu and Dhawan, 1976; Sidhu et al., 1979; Dhawan et al., 1988; Raju and Reddy, 1988; Senapathi and Behera, 1989; Surulivelu and Kumaraswami, 1989 and Shah et al., 1990), potato (Mavi and Singh, 1975), greengram (Gartoria and Singh, 1984), french bean (Lal, 1992), groundnut (Kennedy et al., 1992), cowpea (Verma and Dikshit, 1990) and pigeon pea (Mishra and Saxena, 1982).

Deltamethrin ranked third in toxicity to populations of A. biguttula biguttula from both localities in Thrissur district. It was found to be 161.69 and 111.79 times as toxic as quinalphos against TCR I and TCR II populations indicating a fairly high effectiveness against A. biguttula biguttula. The effectiveness of deltamethrin against A. biguttula biguttula is in agreement with the findings in brinjal (Tewari and Moorthy, 1983), okra (Dhamdhere et al., 1981; Kakar and Dogra, 1988; Singh and Mishra, 1988 and Waryam Singh et al., 1991), cotton (Satpute et al., 1989), groundnut (Kennedy et al., 1992) and tomato (Mishra, 1986).

Ethofenprox was observed to be 88.92 and 9.20 times as toxic as quinalphos while phosphamidon was only 31.65 and 14.48 times as toxic as quinalphos against TCR I and TCR II populations of A. biguttula biguttula. This indicates low efficiency of phosphamidon against field populations of A. biguttula biguttula in this district.

Ethofenprox, a new "CHO Compound", is similar to the synthetic pyrethroids but is an ether derivative. Since it is a new insecticide, no work has been reported against A. biguttula biguttula. But it was reported to cause a rapid knock down and a high degree of effectiveness against some other sucking pests like brown plant hopper and white backed plant hopper in rice (Krishnaiah and Kalode, 1993). A high degree of efficacy of ethofenprox against green leaf hopper Nephotettix virescens (MaCatula et al., 1987) and brown plant hopper Nilaparvata lugens (Patel et al., 1980) on rice and Bemisia tabaci on potato (Kubuta, 1991) was also observed. Ethofenprox, the non-ester pyrethroid is known to be extremely safe to mammals with a high LD_{50} value (42,880 mg/kg) and would be used for the control of leaf hoppers and plant hoppers in rice (Krishnaiah and Kalode, 1993).

Eventhough phosphamidon was found to be comparatively low toxic against A. biguttula biguttula in bittergourd, its effectiveness has been reported in other crops like okra (Dhamdhere et al., 1980), cotton (Bhamburkar, 1986; Raju and

Reddy, 1988 and Singh and Lakra, 1989), sunflower (Deshmukh, 1977) and french bean (Lal, 1992). Quinalphos was found to be least toxic against both populations of A. biguttula biguttula in Thrissur district. However, this is in disagreement with the findings of Sabitha (1992) who reported highest toxicity of quinalphos against Vellanikkara populations of A. biguttula biguttula from Thrissur district. The low effectiveness of quinalphos might have resulted in the continuous and excessive use of this insecticide against A. biguttula biguttula in bittergourd. This probably might have led to the low toxicity of quinalphos against A. biguttula biguttula in this district. This may be due to the reduced susceptibility of this insect towards quinalphos.

5.1.2 Relative toxicity of six insecticides to field populations of A. biguttula biguttula collected from two localities in Palakkad district

In Palakkad district also, the highest toxic insecticide was found to be endosulfan with very high relative toxicity values (3518.68 and 2977.35) followed by deltamethrin and ethofenprox. Deltamethrin was 224.38 and 230.9 times as toxic as quinalphos while ethofenprox was 158.95 and 175.14 times toxic in PKD I and PKD II populations. The highest toxicity of endosulfan to leafhopper populations in bittergourd collected from both farmers' fields and homestead gardens in Palakkad district was reported earlier by Sabitha (1992).

The three organophosphorus insecticides - monocrotophos, phosphamidon and quinalphos were less toxic than the other insecticides against _A. biguttula biguttula_ in Palakkad district. However, monocrotophos was more toxic than phosphamidon and quinalphos. Quinalphos was least toxic towards _A. biguttula biguttula_.

5.1.3 Relative toxicity of six insecticides to field populations of _A. biguttula biguttula_ collected from two localities in Malappuram district

The non-organophosphorus insecticides were found to be more toxic to populations of _A. biguttula biguttula_ in Malappuram district as in Palakkad district. Endosulfan was proved to be very highly toxic to MPM I and MPM II populations with 2150.31 and 2051.81 as relative toxicity values. This finding is in consonance with Sabitha (1992) who reported the high effectiveness of endosulfan in Malappuram district. Endosulfan, ethofenprox and deltamethrin were more toxic than the three organophosphorus insecticides - phosphamidon, monocrotophos and quinalphos. Ethofenprox is 150.31 and 143.78 times as toxic as quinalphos against MPM I and MPM II populations.

5.1.4 Relative toxicity of six insecticides to field populations of *A. biguttula biguttula* collected from two localities in Kottayam district

In Kottayam district also, the highest toxic insecticide was endosulfan. Quinalphos was proved to be least toxic to *A. biguttula biguttula*. The order of toxicity of different insecticides was similar towards the two populations of *A. biguttula biguttula* collected from Kottayam district. Among the organophosphorus insecticides, phosphamidon and quinalphos were found to have low efficacy in controlling the hoppers while monocrotophos possessed high toxicity. Sabitha (1992) indicated high toxicity of endosulfan and monocrotophos against *A. biguttula biguttula* population in bittergourd collected from Kottayam district. The relative toxicity values of all the insecticides except ethofenprox was found to be more or less equal in both the populations indicating their similar toxicity against both the populations. Endosulfan was 1961 and 1918.53 times as toxic as quinalphos against KTM I and KTM II populations.

5.1.5 Overall comparison of toxicity of different insecticides to the eight populations of *A. biguttula biguttula* collected from farmers' fields of four different districts.

An overall comparison of the toxicity of different insecticides against the eight populations of *A. biguttula biguttula* has revealed that endosulfan was the most effective insecticide against A. biguttula biguttula in all the districts of Thrissur, Palakkad, Malappuram and Kottayam. Quinalphos, the most commonly used organophosphorus insecticide was found to have least effectiveness against this hopper in these four districts. The LC_{50} value of quinalphos ranged from 0.7 to 0.9 indicating its low level of effectiveness against A. biguttula biguttula on bittergourd.

Among the three organophosphorus insecticides tested, monocrotophos was proved to have highest toxicity with LC_{50} values ranging from 0.00392 to 0.02720 against A. biguttula biguttula populations in Thrissur district.

The synthetic pyrethroid, deltamethrin was proved very effective against A. biguttula biguttula especially in Palakkad and Kottayam districts. The LC_{50} value ranged from 0.00336 to 0.00825 for different populations of A. biguttula biguttula.

Ethofenprox, the non-ester pyrethrod, was quite effective against A. biguttula biguttula in Malappuram district which was second in toxicity. But in other districts - Thrissur, Palakkad and Kottayam it ranked below deltamethrin in toxicity.

The order of toxicity of different insecticides against the two different populations collected from each district was found to be same. But the toxicity of insecticides against populations varied between different districts.

In Palakkad and Malappuram populations of *A. biguttula biguttula*, organophosphorus insecticides were less toxic than endosulfan, deltamethrin and ethofenprox. As proved by Sabitha (1992) endosulfan showed highest toxicity to leaf hopper populations from these two districts.

In Thrissur and Kottayam populations also endosulfan was the best in toxicity. Monocrotophos and deltamethrin proved more toxic than ethofenprox against these two populations. But the other two organophosphorus insecticides - phosphamidon and quinalphos were less toxic.

Sabitha (1992) evaluated the toxicity of different insecticides against *A. biguttula biguttula* collected from the same four districts. The range of LC_{50} values of three insecticides which were common in both these studies (Table 21) indicated that quinalphos proved much less toxic with a higher LC_{50} value (0.73 to 0.92) in the present study as compared with the lower LC_{50} value (0.02 - 0.06) obtained earlier by Sabitha (1992).

But monocrotophos and endosulfan were proved to be more toxic in the present investigation than in the earlier.

Table 21. Comparison of LC_{50} values of some insecticides against A. biguttula biguttula

Insecticides	Range of LC_{50} Values(per cent)	
	A	B
Quinalphos	0.73 - 0.92	0.02-0.06
Monocrotophos	0.004 - 0.03	0.02-0.05
Endosulfan	0.0002 - 0.0004	0.02-0.04

A = Values of LC_{50} obtained in the present investigation

B = Values of LC_{50} worked out earlier by Sabitha (1992)

The high LC_{50} value indicates very low toxicity of quinalphos against A. biguttula biguttula which, probably, might have been due to the development of reduced susceptibility in the leaf hopper populations. In the case of the other two insecticides the LC_{50} values were found to be lower. The LC_{50} values of endosulfan and monocrotophos were found to be lower in the present studies indicating their higher toxicity. Moreover the difference in the bioassay techniques might also have been contributed to difference in the LC_{50} values of these insecticides. The toxicity of insecticides against A. biguttula biguttula was more by the leaf dip method than the spray residue technique. To cause the same level of mortality in A. biguttula biguttula a lower dose of insecticides was required by leaf dip method (Sabitha, 1992).

5.2 Relative susceptibility of different populations of A. biguttula biguttula from four districts towards six insecticides

Extensive and continuous use of insecticides in bittergourd against A. biguttula biguttula in the field has made exceedingly difficult to find a purely susceptible population of A. biguttula biguttula. No base line toxicity data of different insecticides against A. biguttula biguttula is available. Sabitha (1992) reported the relative susceptibility of different populations of A. biguttula biguttula by taking Thrissur population as standard for comparison. Hence in the present studies also, owing to the lack of basic information on toxicology of truly susceptible field populations, Thrissur population has been taken for comparing susceptibility of different populations of A. biguttula biguttula.

5.2.1 Comparative susceptibility of different populations of A. biguttula biguttula to quinalphos

All the eight populations of A. biguttula biguttula collected from the four districts indicated very low susceptibility to quinalphos with high LC_{50} values. The LC_{50} values of quinalphos ranged between 0.72904 to 0.92227 for different populations, which are very much higher than field recommendation rates (0.05 per cent), (KAU, 1993). The two different populations from each district showed equal susceptibility to quinalphos except in Thrissur district. Sabitha (1992) observed highest susceptibility to quinalphos in Vellanikkara population of Thrissur district. According to her findings the LC_{50} values of quinalphos ranged from 0.03 to 0.06 for different populations collected from Thrissur, Palakkad, Malappuram and Kottayam districts. But in the present studies, the LC_{50} values of quinalphos were found to be much higher ranging from 0.73 to 0.92. These high LC_{50} values very clearly reveal the low susceptibility of leaf hopper populations from Thrissur, Palakkad, Malappuram and Kottayam districts to quinalphos. It can thus be inferred that A. biguttula biguttula from these four districts have developed reduced susceptibility towards quinalphos.

Fellowes and Ferguson (1974) observed the development of resistance in Myzus persicae to quinalphos. Sudanese field strains of Bemisia tabaci were reported to be moderately resistant to quinalphos in cotton (Dittrich and Ernst, 1983).

5.2.2 Comparative susceptibility of different populations of *A. biguttula biguttula* to monocrotophos

Susceptibility of different populations of *A. biguttula biguttula* from different districts showed considerable variation towards monocrotophos. Monocrotophos was proved to be highly effective in controlling this leaf hopper with LC_{50} values ranging from 0.004 to 0.03 for different populations. The least susceptible populations were from Malappuram district while highest susceptibility was observed in Thrissur populations. Palakkad populations were more susceptible to monocrotophos than Malappuram populations of *A. biguttula biguttula*. These findings are in agreement with Sabitha (1992) who observed the same trend in susceptibility of leaf hopper populations from these four districts towards monocrotophos. However, the LC_{50} values of monocrotophos obtained in the present studies were lower than those reported by Sabitha for different populations indicating the increased susceptibility of leaf hopper population to monocrotophos. The reduced exposure of *A. biguttula biguttula* owing to the less frequent application of monocrotophos by the farmers of these districts might have contributed for this higher susceptibility. No susceptibility variation was found between the populations within the district but variation is evident among populations from different districts.

5.2.3 Comparative susceptibility of different populations of *A. biguttula biguttula* to phosphamidon

All the populations showed comparatively lower susceptibility to phosphamidon. The LC_{50} values of phosphamidon ranged from0.02 to 0.06 for different populations. Palakkad and Malappuram populations indicated equal susceptibility to phosphamidon wherein the susceptibility was higher as compared to Thrissur populations. Kottayam populations exhibited lowest susceptibility to phosphamidon when compared with other populations. The different populations from the same district showed equal susceptibility to phosphamidon except with Thrissur populations. A shift in the level of susceptibility towards phosphamidon was reported in *M. persicae* (Dhingra, 1990).

5.2.4 Comparative susceptibility of different populations of *A. biguttula biguttula* to endosulfan

Endosulfan was proved to be the best insecticide in toxicity against *A. biguttula biguttula* from all the districts. All the populations were highly susceptible to this insecticide. Among the different populations, Palakkad populations were most susceptible. Malappuram and Kottayam populations showed equal susceptibility towards endosulfan. The highest susceptibility of endosulfan to *A.*

biguttula biguttula from Thrissur, Palakkad, Malappuram and Kottayam districts was earlier reported by Sabitha (1992). It was indicated that leaf hopper populations from Palakkad district manifested highest susceptibility to endosulfan. This observation on the highest susceptibility to endosulfan is again confirmed by the present findings. Endosulfan is both a chlorinated hydrocarbon and an organic sulphite. It is effective against sucking insects, caterpillars and borers. On local enquiries with farmers, it was understood that organophosphorus insecticides were being used continuously against A. biguttula biguttula. The highest susceptibility to endosulfan might have been due to the less exposure of A. biguttula biguttula to endosulfan in these areas.

5.2.5 Comparative susceptibility of different populations of A. biguttula biguttula to deltamethrin

Palakkad populations were most susceptible to deltamethrin followed by Kottayam populations. The LC_{50} value of deltamethrin ranged from 0.003 to 0.008 for different populations whereas the recommended concentration is 0.0015 to 0.0030 per cent. No variation in susceptibility was noticed between the two populations of A. biguttula biguttula from each district. Malappuram populations showed lowest susceptibility to deltamethrin. Susceptibility variations were observed between populations from different districts.

Generally the insecticidal potency of synthetic pyrethroids is greater than that of the conventional insecticides. Deltamethrin, in contrast to other synthetic pyrethroids is not a mixture of isomers. It is strictly a pure isomer-the d-cis isomer-which owes its insecticidal potency. Many workers have proved the toxicity of deltamethrin against A. biguttula biguttula populations. Most important works were by Dhamdhere et al. (1981); Kakar and Dogra (1988), Singh and Mishra (1988) and Waryam Singh et al. (1991).

5.2.6 Comparative susceptibility of different populations of A. biguttula biguttula to ethofenprox

Ethofenprox, is a new insecticide similar to the synthetic pyrethroids, has not been tested against A. biguttula biguttula. It has been reported to be effective against green leaf hopper, brown plant hopper and white backed plant hopper in rice . Perusal of the data on the response of different populations of A. biguttula biguttula to ethofenprox indicated equal susceptibility of Palakkad and Malappuram populations to it. The LC_{50} values of ethofenprox ranged from 0.004 to 0.01. Ethofenprox at 0.01 per cent concentration showed a high degree of effectiveness against brown plant hopper, white backed plant hopper and green leaf hopper in rice (Krishnaiah and Kalode, 1993).

5.2.7 Overall comparison of the susceptibility of different populations of *A. biguttula biguttula* to different insecticides

In an overall view it could be noted that susceptibility of different populations within a district towards different insecticides was almost same except with populations from Thrissur district. At the same time, variation was noticed in the susceptibility pattern of populations from different districts to different insecticides.

Susceptibility variations in other insect populations collected from different states of India were noticed by many workers. Difference in susceptibility of *Heliothis armigera* to cypermethrin, decamethrin and fenvalerate was observed in different districts of Andhra Pradesh (Reddy *et al.*, 1992). Susceptibility variations were indicated by Deshmukh and Saramma (1973) in *Plutella maculipennis* collected from Ludhiana and Jullunder districts in Punjab to insecticides. Development of resistance was detected in *P. xylostella* to commonly used synthetic pyrethroids collected from different states of India (Chawla and Kalra, 1976; Dhingra *et al.*, 1988 and Saxena *et al.*, 1989).

From the present study it was quite clear that all the populations were most susceptible to endosulfan and least susceptible to quinalphos. Sabitha (1992) has also reported the high susceptibility of leaf hoppers collected from Palakkad district to endosulfan. According to her findings, Thrissur population of A. biguttula biguttula was most susceptible to monocrotophos. But in this study, monocrotophos was proved to be the second best in toxicity to Thrissur populations. Next to endosulfan, Palakkad and Kottayam populations were most susceptible to deltamethrin and Malappuram populations to ethofenprox. The leaf hopper populations from all the four districts were more susceptible to non-organophosphorus insecticides - endosulfan, deltamethrin and ethofenprox than the conventionally used organophosphorus insecticides. Among the organophosphorus insecticides, monocrotophos was most effective. The low susceptibility of different populations of A. biguttula biguttula to different organophosphorus insecticides might be due to the frequent and over use of organophosphorus insecticides in the field.

The results of the present studies and those of Sabitha (1992) lead to the following conclusions:

Considerable variations exist in the susceptibility of populations of A. biguttula biguttula in bittergourd in the field.

A. biguttula biguttula populations from Thrissur, Palakkad, Malappuram and Kottayam show low susceptibility to the conventional organophosphorus insecticides - quinalphos, monocrotophos and phosphamidon. Quinalphos proved to be least susceptible to *A. biguttula biguttula* and due to the low effectiveness its use against leaf hoppers in bittergourd has to be discouraged. Carbaryl, the carbamate insecticide, also proved to be ineffective against *A. biguttula biguttula* in similar studies of Sabitha (1992). Out of the three organophosphorus insecticides, monocrotophos proved better in toxicity against *A. biguttula biguttula* in bittergourd.

Susceptibility of different populations was higher towards non-organophosphorus insecticides - endosulfan, deltamethrin and ethofenprox. Endosulfan proved to have the highest susceptibility followed by deltamethrin and ethofenprox towards all the populations from the four districts. Hence it would be better to advocate the use of endosulfan against *A. biguttula biguttula* infestation in bittergourd instead of the conventional organophosphorus insecticides. Endosulfan was also reported to have low persistence against *A. biguttula biguttula* in bittergourd (Sabitha, 1992).

As one of the main objectives of the present study was to confirm the variations in susceptibility pattern of

A. biguttula biguttula populations infesting bittergourd in the field to commonly used insecticides as reported by Sabitha (1992), the investigation on susceptibility was restricted to different leafhopper populations from the same four districts selected earlier by her. Therefore, extensive studies have to be carried out on the susceptibility pattern of field populations of *A. biguttula biguttula* in the other districts also. Then only it would e possible to draw definite conclusions on the usceptibility spectrum of *A. biguttula biguttula* in Kerala tate. Moreover it would help to suggest the changes equired in the management practices of *A. biguttula iguttula* in bittergourd.

Summary

SUMMARY

The leafhopper, Amrasca biguttula biguttula (Ishida) (Homoptera: Cicadellidae) is one of the destructive pests of bittergourd (Momordica charantia L.). The nymphs and adults suck cell sap from the tissues of leaves by congregating mostly on the ventral surface of the leaves and cause severe damage. The feeding symptom commonly termed as 'hopper burn' is due to the toxaemia of the hoppers' saliva which is injected into the leaf during sucking of the sap.

Recently the incidence of this pest on bittergourd has been found to be quite serious and caused enormous damage to the crop in different parts of Kerala especially during summer season.

Eventhough many foliar insecticides were observed to be effective against this pest previously, many reports on the non-effectiveness of the commonly used insecticides against this pest were being received now-a-days from farmers of various places in the state. The reduced susceptibility of A. biguttula biguttula against different commonly used insecticides cause serious problem in the field cultivation of bittergourd. In view of this serious problem, Sabitha (1992) carried out studies and observed great variations

in the susceptibility of populations of _A. biguttula biguttula_ from four districts of Kerala state viz. Thrissur, Palakkad, Malappuram and Kottayam to different insecticides. In order to confirm her findings on the susceptibility variations, a study was undertaken on the relative susceptibility of eight populations of _A. biguttula biguttula_ from Thrissur, Palakkad, Malppuram and Kottayam districts of Kerala towards six insecticides belonging to different chemical groups.

This study was conducted at the College of Horticulture, Vellanikkara, Thrissur during the year 1993-'94. Two different localities from each of the four districts (same as those selected by Sabitha, 1992) viz., Thrissur, Palakkad, Malappuram and Kottayam were selected to collect _A.biguttula biguttula_. Leaf hopper populations were collected from Pattikadu and Nedupuzha (Thrissur district), Pothappara and Odanallur (Palakkad district), Wandoor and Chattipparambu (Malappuram district) and Vempalli and Kurichi (Kottayam district) and tested against quinalphos, monocrotophos, phosphamidon (organophosphorus insecticides) endosulfan (organochlorine insecticides), deltamethrin (synthetic pyrethroid) and ethofenprox (CHO compound).

Foliar residue (leaf-dip) method of bioassay was adopted in the study. Sabitha (1992) indicated that 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. Therefore leaf-dip method was adopted to carry out the study.

The relative toxicity studies revealed that endosulfan was highly toxic to A. biguttula biguttula in all the four districts, while quinalphos which is commonly used by the farmers, was least toxic to these leaf hoppers. The LC_{50} value of endosulfan was found to range from 0.00022 to 0.00041 per cent indicating its high level of toxicity.

The low effectiveness of quinalphos might be due to the continuous and excessive use of this insecticide by the farmers against this pest.

The second best insecticide, in toxicity, was found to be monocrotophos in Thrissur district, deltamethrin in Palakkad and Kottayam and ethofenprox in Malappuram district.

Among the three organophosphorus insecticides tested, monocrotophos was good in controlling A. biguttula biguttula while phosphamidon was having low level of toxicity against this pest in all the four districts. Quinalphos was found to be not effective in controlling A. biguttula biguttula in bittergourd at the recommended concentration. The LC_{50} value of quinalphos ranged from 0.7 to 0.9 in different populations.

Compared to organophosphorus insecticides, the insecticides from other groups viz. endosulfan, deltamethrin and ethofenprox were found to be more toxic to A. biguttula biguttula. The order of toxicity of different insecticides was found to be the same against both the populations collected from each district. But this order of toxicity of different insecticides varied among different districts.

Relative susceptibility studies proved considerable variations in susceptibility of different populations of A. biguttula biguttula collected from different districts towards different insecticides. All the populations were highly susceptible to endosulfan at very low concentration levels. Next to endosulfan, Thrissur populations were more susceptible to monocrotophos followed by deltamethrin and ethofenprox. Palakkad populations were susceptible to deltamethrin followed by ethofenprox and monocrotophos. Malappuram populations were more susceptible to ethofenprox followed by deltamethrin and phosphamidon. Kottayam populations were more susceptible to deltamethrin followed by monocrotophos and ethofenprox. All the eight populations from four districts were least susceptible to quinalphos indicating very high LC_{50} values. It is quite evident from the studies that the susceptibility of different populations of A. biguttula biguttula towards organophosphorus insecticides has been reduced, particularly to quinalphos which was proved totally ineffective against A. biguttula biguttula. The variation in the susceptibility of populations of A. biguttula biguttula from the different districts to the different insecticides was thus confirmed.

Purely susceptible population of A. biguttula biguttula without any exposure to insecticides was not known to be available. Owing to the lack of base line toxicity studies, it was not possible to measure the magnitude of susceptibility in the field populations in this study. Therefore, detailed studies are required in this line and also it is necessary to assess the susceptibility variations in the field populations of other districts of the state.

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* Original not seen

RELATIVE SUSCEPTIBILITY OF POPULATIONS OF *Amrasca biguttula biguttula* (ISHIDA) INFESTING BITTER-GOURD (*Momordica charantia* L.) COLLECTED FROM DIFFERENT LOCATIONS TO INSECTICIDES PART II

By

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ABSTRACT OF A THESIS

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ABSTRACT

A study was undertaken at the College of Horticulture, Vellanikkara during 1993-94 to evaluate the relative susceptibility of eight different populations of *Amrasca biguttula biguttula* (Ishida) on bittergourd collected from four districts of Kerala state to six insecticides belonging to different chemical groups. Two different localities were selected for the collection of the leaf hopper, from each district. The selected localities were, Pattikkadu and Nedupuzha (Thrissur district), Pothappara and Odanallur (Palakkad district), Wandoor and Chattipparambu (Malappuram district) and Vempalli and Kurichi (Kottayam district). All the populations were collected from farmers' fields which were subjected to regular insecticidal spraying.

The insecticides selected for the study belong to different chemical groups viz. organophosphorus compounds (quinalphos, monocrotophos and phosphamidon), organo chlorine compounds (endosulfan), synthetic pyrethroid (deltamethrin) and CHO compound (ethofenprox). Among these insecticides, the organophosphorus compounds were widely used by the farmers for controlling this pest in the field.

Relative toxicity of different insecticides to different populations were found by leaf dipping technique

of bioassay and the results were subjected to probit analysis (Finney, 1971). Based on the relative toxicity studies it was clear that endosulfan was the most toxic insecticide against A. biguttula biguttula collected from all the eight localities. Monocrotophos ranked second in toxicity against populations from Thrissur district while deltamethrin was proved to be the second highly toxic insecticide to Palakkad and Kottayam hopper populations. Against Malappuram populations of A. biguttula biguttula highest toxicity of endosulfan was followed by ethofenprox. Phosphamidon was found to be relatively less toxic to this pest. Quinalphos, the commonly used organophosphorus insecticide was found to have least toxicity and thereby it was observed to be ineffective in controlling this pest in bittergourd in all the four districts.

Great variation was observed in the relative toxicity values of different insecticides indicating their difference in toxicity level to A. biguttula biguttula . The order of toxicity of different insecticides was found to be the same between the two populations from each district but varied with populations from different districts.

Organophosphorus compounds were found to be relatively less toxic than endosulfan, deltamethrin and ethofenprox belonging to other groups. Therefore, the use of quinalphos against A. biguttula biguttula among the farmers has to be discouraged and endosulfan can be advocated against *A. biguttula biguttula* in bittergourd as an alternative. Carbaryl was proved to be ineffective against leaf hopper populations in bittergourd earlier (Sabitha, 1992).

The relative susceptibility studies with populations of *A. biguttula biguttula* from the four districts revealed that all the eight populations were highly susceptible to endosulfan. The LC_{50} value of endosulfan was found to be very low, ranging from 0.00022 to 0.00041 per cent. At the same time all the populations were least susceptible to the most commonly used organophosphorus insecticide quinalphos. All the populations showed higher susceptibility to endosulfan, deltamethrin and ethofenprox than the organophosphorus insecticides. Thrissur population was more susceptible to monocrotophos next to endosulfan. Palakkad and Kottayam populations were more susceptible to deltamethrin while Malappuram populations indicated more susceptibility to ethofenprox, next to endosulfan. The LC_{50} value of phosphamidon ranged from 0.02 to 0.06 and all the eight populations of *A. biguttula biguttula* manifested lower susceptibility to this insecticide in comparison with the other chemicals.