CONTROL OF VEGETABLE PESTS USING CHITIN SYNTHESIS INHIBITORS

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Control of vegetable pests using chitin synthesis inhibitors" is a bonafide record of research work done by me during the course of research and that this 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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CERTIFICATE

Certified that this thesis entitled "Control of vegetable pests using chitin synthesis inhibitors" is a record of research work done independently by Mr. RAJAPADMANABHAN VIVEK. A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

1. INTRODUCTION

The broad spectrum insecticides of the chlorinated, phosphatic and carbamate groups which were being extensively used in the past three decades were undoubtedly the major tools available with the plant protection technologists for solving pest problems in field. However, the increasing awareness of the adverse side-effects of these insecticides prompted researchers to look for chemicals selective to the pests involved and safer to non-target organisms and in the human environment. These efforts led to the discovery of a new set of chemicals called 'third generation pesticides' for use in the field of Agriculture. Among these, the chitin synthesis inhibitors form one of the more recent additions.

The chitin synthesis inhibitors are relatively selective and less toxic to fish, birds and mammals. They inhibit chitin synthetase, the final enzyme in the metabolic pathway by which chitin is synthesised from glucose. Consequently, the formation of the new cuticle and the casting off of the old one are interrupted. Thus, the normal development and metamorphosis of the insects get affected and this ultimately causes their death.

Diflubenzuron (Dimilin) and triflumuron (Bay Sir 8514), belonging to the benzoyl-phenyl urea group, are two important chemicals now available as effective pesticides among the chitin synthesis inhibitors. The utility of these chemicals for pest suppression has been investigated in the laboratory and field in many of the developed countries and they have been reported promising against various insects belonging to orthoptera, lepidoptera, coleoptera, diptera and hemiptera (Grosscurt, 1978 b). The chitin synthesis inhibitors had effectively controlled several pests of agricultural and horticultural crops (Bower and Kaldor, 1980; Schmidt and Dorntlein, 1980; Sundaramurthy, 1980; Ascher and Eliyahu, 1981), pests of stored products (McGregor and Kramer, 1976; Brown *et al.*, 1978; Bene and Porcinai, 1980) and of public health importance(Martins *et al.*, 1979; Siti Aminah and ten Houten, 1980).

The work done on the utility of these chitin synthesis inhibitors for pest control in India is very limited. These include some work on *Epilachna* sp., *Nephantis serinopa*, *Spodoptera litura* and *Spodoptera mauritia* (Sundaramurthy, 1979 and 1980; Sundaramurthy and Balasubramanian, 1978; Beevi and Dale, 1980). Being safer than conventional pesticides, the chitin synthesis inhibitors have high potentiality in the control of vegetable pests. Detailed studies in this area are highly lacking. With a view to minimising this lacuna the present investigations were taken up. The dose-effect relationship of the two toxicants to various vegetable pests and their sterilant action and ovicidal effect on Epilachna were studied in the laboratory. The relative efficacy of the chemicals in controlling the major pests of bhindi, brinjal and amaranthus under field conditions, in comparison with malathion, was investigated. The persistent toxicity of the insecticides to various vegetable pests under field conditions was also studied.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Discovery of chitin synthesis inhibitors

The insecticidal property of substituted benzoyl -phenyl-ureas, with a unique mode of action, was discovered by Van Daalen *et al.* (1972) during its evaluation as a herbicide. A number of phenyl-ureas were subsequently evaluated against larvae of *Aedes aegypti*, *Pieris brassicae* and *Leptinotarsa decemlineata* (Wellinga *et al.*, 1973 a). Only mono and diortho substituted benzoyl derivatives exhibited larvicidal activity and the outstanding ones among them were PH 6038 and PH 6040 (Dimilin). Wellinga *et al.* (1973 b) confirmed the efficacy of many benzoyl ureas as excellent insecticides bringing about disturbances in the process of chitin deposition, resulting in abortive moult. Bay Sir 8514 was synthesised in 1975, and Hammann and Sirrenberg (1980) reported it as a highly effective insecticide notable for its favourable toxicological properties.

2.2 Control of pests using chitin synthesis inhibitors

2.2.1 Cotton pests.

Extensive work was done on the control of boll weevil, *Anthonomus grandis*. Laboratory experiments showed that Dimilin 0.1% (Moore and Taft, 1975), 431 and 2797 ppm (McLaughlin, 1976) and 0.11 μg/female (Earle et al., 1979) were effective in significantly decreasing fertility of the pest.

Field application of the compound was reported to cause larval-adult mortality and reduced adult emergence of the boll weevil with doses of 141,282 and 564 g/ha (Ganyard et al., 1977), 0.25 kg a.i/acre (Lloyd et al., 1977), 0.14 kg a.i/ha (Ganyard et al., 1978), 35, 70 and 140 g a.i/ha (House et al., 1978; Rummel et al., 1979; and Ables et al., 1980 a), 141.8 g a.i/ha (Johnson et al., 1978), 52.5 g a.i/ha (Rummel, 1980), and 0.1% (Villavaso et al., 1980).

Abid et al. (1978) reported that the moulting process was abnormal and incomplete in shoot borer, Earias insulana, when Dimilin was applied to the third instar larvae. Doses ranging from 0.005 to 0.1% caused 76 to 100% mortality in different instars of the insect (Ascher et al., 1978 a).

Extensive work has also been done on the cotton leaf worm, Spodoptera littoralis, an important pest of cotton in Egypt. Doses of diflubenzuron tried were 0.69 and 1.2 g/l (El-Tantawi et al., 1976), 0.04 and

0.066 g/larva (Ascher and Nemny, 1976), 100 to 5 x 10^{-8} g/pupa (Abo-Elghar et al., 1978 a) and 0.01 and 0.1 μg/larva (Radwan et al., 1978). Almost all doses tried have proved successful by causing morphological changes which interferred with normal life-functions, if not by completely killing the stage treated. Salama and El-Din (1977) reported that 5 ppm concentration of diflubenzuron caused 100% mortality of the eggs of S. littoralis. A dose of 0.05 μg/pupa resulted in all the emerged adults being either deformed or dead (Abo-Elghar et al., 1978 a).

Radwan et al. (1978) reported that diflubenzuron reduced adult life-span and caused a pronounced sterilising effect on the cotton leaf worm. Further, S. littoralis did not develop resistance to diflubenzuron (Abo-Elghar et al., 1978 b, and El-Guindy et al., 1980).

Diflubenzuron and Bay Sir 8514 were equally toxic to S. littoralis eggs (Ascher et al., 1979), but Bay Sir 8514 had higher contact toxicity to the larvae (Ascher and Eliyahu, 1981). In field, 250 g/ha of Bay Sir 8514 caused 83 to 100% mortality of leaf worm in Egypt (Schmidt and Dorntlein, 1980).

Flint and Smith (1977) found that Dimilin caused reduced emergence of Pectinophora gossypiella, while

Flint *et al.* (1977 and 1978) did not find the pesticide effective against the pest. *Buculatrix thurberiella* and *Trichoplusia ni* were also reported to be effectively controlled with diflubenzuron (Flint *et al.*, 1978). *B. thurberiella* was controlled by Bay Sir 8514 at 31 g a.i/ha (Schmidt and Dorntlein, 1980). *Pseudoplusia includens* and *Alabama argillacea* were also effectively controlled by this compound (Schmidt and Dorntlein, 1980).

2.2.2 Tobacco pests.

Sundaramurthy (1977), and Sundaramurthy and Balasubramanian (1978) reported that diflubenzuron 0.1% caused 46 to 96% inhibition of larval transformation to pupae of *Spodoptera litura*. Further, Balasubramanian and Natesan (1979) found that treatment of eggs, different larval instars, pupae, and adults of *S. litura* caused characteristic malformations in the pest. Dipping of pupae in diflubenzuron caused pupal mortality, partial emergence and malformed adults; susceptibility decreased with increase in age (Natesan and Balasubramanian, 1980).

In field, diflubenzuron gave effective control of *S. litura* (Santharam and Balasubramanian, 1980; Ramzan and Singh, 1980). The tobacco bud worm, *Heliothis* *virescens* was controlled by diflubenzuron (Wolfenbarger *et al*., 1977), the LC_{50} for neonate larvae being 1.3×10^{-3} per cent w/v, and for pupae, 1.3×10^{-4} per cent w/v. Condriet and Sean (1979) found that the first three instars of the pest were more susceptible to the pesticide.

2.2.3 *Coconut pests.*

Diflubenzuron 0.2 to 0.4 g/l inhibited moulting of *Nephantis serinopa* ranging from 27.5 to 75% (Sundaramurthy and Santhakrishnan, 1979). Sundaramurthy (1980) reported that 77.4 to 100% control of this pest was achieved with diflubenzuron applied in field in doses ranging from 2.5 to 20 g a.i in 10 l water.

2.2.4 *Tea and coffee pests.*

Bay Sir 8514 was found effective for the control of *Homona magnanima* and *Gracilaria theivora* on tea and *Leucoptera coffedla* on coffee (Schmidt and Dorntlein, 1980).

2.2.5 *Rice pests.*

Beevi (1979), and Beevi and Dale (1980) found that diflubenzuron killed eggs, larvae, pupae and adults of *Spodoptera mauritia* in laboratory doses of 1 ppm to 1000 ppm. Natesan *et al*. (1980) reported that at

200 ppm, diflubenzuron caused 80% of the test larvae of *Cnaphalocrosis medinalis* to develop deformed.

2.2.6 Pests of corn.

Laboratory studies on the European corn borer, *Ostrina nubilalis*, revealed that only 28.1% of the eggs dipped in a 1.95 ppm solution of diflubenzuron hatched (Faragalla *et al*., 1980). Field application of 0.28, 0.56 and 1.12 kg a.i/ha resulted in fewer normal larvae and less stalk damage when compared to control plots (Berry *et al*., 1980).

Schmidt and Dorntlein (1980) reported that Bay Sir 8514 was effective in controlling *Ostrina nubilalis*, *Busseola fusca*, *Sesmia cretica*, *Chilo agamemnon* and *Spodoptera frugiperda* at doses 50 to 125 g a.i/ha.

2.2.7 Pests of fruit trees.

Hoying and Riedl (1980) reported that Dimilin effectively killed codling moth eggs, first instar larvae, and adults. In field, treatments of 30 g/ha (Audemard *et al*., 1975), 0.05% (Westigard, 1979), and 150 g/ha (Bower and Kaldor, 1980) were found successful against *Cydia pomonella*.

Against the gypsy moth, *Lymantria dispar*, 0.013 ppm (Granett and Dunbar, 1975), 0.025 and 0.05% a.i (Lyanchenko and Andreeva, 1979), 0.56 and 0.067 kg/ha (Forgash *et al*., 1979), and 0.01 to 0.8 ppm (Abdelmonem and Mumma, 1981) of diflubenzuron gave good results in the laboratory.

Field doses reported effective against the pest were 0.125 to 0.0039 lb a.i/10 gal water (Granett and Dunbar, 1975), and 70 g/ha (Cameron and Waldvogel, 1980).

Treatments of 0.1 and 0.06% diflubenzuron on eggs of the apple leaf miners Leucoptera scitella and Lithocolletis blancardella caused 100 to 94.4% mortality (Injac, 1981). Mori and Vianello (1980) reported that protection of apple trees with diflubenzuron was as good as that with organophosphorus insecticides.

Dipping final instar larvae of Dacus oleae in TH 6040 at doses ranging from 500 to 2500 ppm resulted in larval-pupal mosaics and, subsequently, high pupal mortality (Fytizas, 1976).

In laboratory and field studies it was found that feeding adult Conotrachelus nenuphar with diflubenzuron affected egg and larval development in the next generation (Calkins et al., 1977).

Ascher et al. (1978 b) reported from field and laboratory studies that diflubenzuron controlled Boarmia selenaria on avacado. A treatment of 0.05% of the compound on B. rhamboidaria on grapevine allowed only a few of the treated larvae to survive upto adult stage (Dieter-Steigra, 1978). Psylla piri in apple and pear orchards were effectively controlled with Dimilin (Picco, 1981).

Schroeder et al. (1976) found that a diflubenzuron application at the rate of 283 g a.i/acre reduced egg hatch of Diapreps abbreviatus on citrus from 71 to 15%. Phyllocoptruta oleivora, the citrus rust mite, could not moult when treated with 0.04 to 0.3 g/l of the compound (McCoy, 1978), while dosages of 0.15 and 0.3 g/l effectively reduced the reproductive potential of Pachnaeus litus, P. opalus, Artipus floridanus and Diaprepes abbreviatus, four species of citrus weevils (Lovestrand and Beavers, 1980). Beavers and Schroeder (1981) reported that 0.15 to 0.30 g/l of Bay Sir 8514 reduced the egg hatch to 1 to 2% when adult D. abbreviatus were fed with the compound.

Other pests of fruit trees controlled with Bay Sir 8514 include Leucoptera scitella, Lyonetia clarkella, Carpocapsa pomonella, Laspeyresia molesta, Dichocrocis punctiferalis, Psylla piri, P. mali, Prays citri and Phyllocristis citrella (Schmidt and Dorntlein, 1980).

2.2.8 Pests of vegetables, oilseeds and soybean.

Turnipseed et al. (1974), and Lara et al. (1977) found that diflubenzuron at doses upto 75 g a.i/ha controlled Anticarsia gemmatalis, the velvet bean caterpillar.

Both Agrotis segetum and Mamestra brassicae were found susceptible to Dimilin at doses ranging from

0.00025 ppm to 25 ppm (Lipa, 1976), while a 0.1% treatment of the compound at 1 μl/insect on the thorax of Hylemya brassicae, the cabbage root fly, reduced hatching rate of eggs to 35.1% (Vande and Delcour, 1976).

Seed treatment with diflubenzuron at 0.25 and 0.5 g/kg beans gave adequate protection against Delia platura and Hylemya cilicrura (Vande et al., 1975).

Arambourg et al. (1977), and Albajes and Santiago-Alvarez (1979) found diflubenzuron effective against Ceratitis capitata (2.5 ppm, 25 ppm, 250 ppm and 1000 ppm gave mortality of 3.77%, 3.88%, 38.84% and 80.17%, respectively). Mohamad et al. (1979) found 0.007% of the compound to be effective against Plutella xylostella. Reed and Bass (1979) reported that the amount of diflubenzuron treated medium consumed by Pseudoplusia includens decreased as dosage increased.

Feeding 1.25 to 100 ppm of Dimilin to Epilachna vigintioctopunctata final instar larvae prevented them from turning into pupae. The percentage inhibition of moulting ranged from 60 to 85, with 20 to 50% inhibition of adult emergence. Adults were with partly developed wings and remained partly in pupal skin (Sundaramurthy, 1979).

Wellinga et al. (1973 a), Grosscurt (1977, 1978 a and 1978 b), and Grosscurt and Anderson (1980) reported the effectiveness of diflubenzuron against the Colarado potato beetle, *Leptinotarsa decemlineata*.

Diflubenzuron caused sterility in *Psila rosae* (Overbeck, 1979), *Graphognathous peregrinus* and *G.leucoloma* (Ottens and Todd, 1979), larval mortality and morphologically defective adults in *Athalia rosae* (Lung, 1980), *Achoea janata* (Subramanyam *et al.*, 1980) and *Pseudoplusia includens* (Reed and Bass, 1980).

According to Rabindra and Balasubramanian (1981) diflubenzuron at 0.05 g/l and 1.0 g/l caused 96% and 100% mortality respectively in the castor semilooper.

Bay Sir 8514 effectively controlled vegetable pests, including *Pieris brassicae*, *Mamestra brassicae*, *Plutella maculipennis*, *Pthorimaea operculella*, *Leptinotarsa decemlineata* and *Anticarsia gemmatalis* (Schmidt and Dorntlein, 1980).

2.2.9 Pests of forage crops and forest trees.

Neal (1974) reported that TH 6040 caused larval mortality in *Hypera postica* and Henzell *et al.* (1979) reported 65 to 96% reduced egg hatch in *Graphognathous leucoloma* on lucerne following treatments of 20 to 100 g/ha. An ovicidal effect of 100% was found in *Melolontha melolontha* and *Gastroidea viridula* by Buchi and Jossi (1979) after 0.1% Dimilin treatment. Zepp *et al.* (1979) reported a reduction in fecundity by 81, 76 and 15% in *Othiorhynchus sulcatus* with diflubenzuron doses of 0.05, 0.025 and 0.0135 g/l, respectively.

Total mortality was caused in *Thaumetopoea pityocampa* with 20 g/l diflubenzuron (Ferrari and Tiberi, 1979), *T. wilkinsoni* with 75 g a.i Dimilin (Halperin, 1980) and *Dendroctonus rufipennis* (Sahota and Ibaraki, 1980).

Bay Sir 8514 was found effective against *T. pityocampa*, *Lymantria dispar*, *Diprion pini* (Schmidt and Dorntlein, 1980) and *Choristoneura occidentalis* (Robertson and Haverty, 1981). In the control of *Orgyia pseudotsugata* and *C. occidentalis*, Bay Sir 8514 was found to be at least three times as toxic as diflubenzuron (Rappaport and Robertson, 1981).

2.2.10 Pests of stored products.

Laboratory application of 1 to 10 ppm Dimilin prevented progeny development of *Sitophilus oryzae*, *S. granarius*, *S. zeamaiz*, *Rhizopertha dominica*, *Tribolium confusum* and *Oryzaephilus surinamensis* (McGregor and Kramer, 1976).

Diflubenzuron was effective in the control of *Tribolium castaneum* (Ishaaya and Ascher, 1977), *Callosobruchus chinensis* (Nagasawa *et al.*, 1978), *T. confusum* (Brown *et al.*, 1978) and *Tenebrio molitor* (Bene and Porcinai, 1980).

Cohen and Casida (1980) reported that both diflubenzuron and Bay Sir 8514 acted as chitin synthesis inhibitors in *T. castaneum*. Diflubenzuron 1% greatly reduced hatching (Saxena and Mathur, 1981). Triflumuron inhibited pupation totally at 0.2 ppm and diflubenzuron at 0.4 ppm (Ishaaya *et al.*, 1981). Both these compounds were recommended as potential insecticides to protect stored products from insect pests.

2.2.11 Other pests.

Yu and Terriere (1977) reported that TH 6040 controlled *Musca domestica*, *Sarcophaga bullata* and *Phormia regena*.

Dimilin at 1 ppm on *Simulium vittatum* (Lacey and Mulla, 1977), 18 ppm on *Musca domestica* (Martins *et al.*, 1979) and 0.1 mg a.i/l on *Aedes albopictus* (Siti Aminah and ten Houten, 1980) were found effective.

Madder and Lockhart (1980) and ten Houten *et al.* (1980) got good results with Dimilin for mosquito control, while Lineva and Chunina (1980), and Grosscurt and Tipker (1980) got similar successful results with *Musca domestica*.

Schistocerca gregaria (Strebler, 1979), *Poekilocerus pictus* (Saxena and Mathur, 1981), and *Heterotermes indicola* and Reticulitermes flavipes (Doppelreiter and Korioth, 1981) were also controlled by diflubenzuron.

2.3 Mode of action of chitin synthesis inhibitors

Post and Vincent (1973) first reported that TH 6040 acted on chitin synthesis. Bitloo (1975), Salamma *et al*. (1976), Fogal (1977), Mc Laughlin (1978), Bene *et al*. (1979 and 1980) all reported that after administration of Dimilin, the endocuticle was seen badly attached to the epidermis, and the treated larvae could not moult or form new endocuticle.

Salama *et al*. (1976), Ishaaya and Ascher (1977), and Ker (1977) agreed that the chitin synthesis inhibitors act as inhibitors of the terminal polymerisation step in insect chitin synthesis, which results in less rigid cuticle because of which insects are unable to withstand the internal pressure during ecdysis to give support to muscles involved, resulting in inability to cast off old skin and they ultimately cause death. This hypothesis was supported by Salama and El-Din (1977), Deul *et al*. (1978), Grosscurt (1978 a), Ker (1978), Gijswijt *et al*. (1979), Hajiar and Casida (1979), Cohen and Casida (1980), Grosscurt and Tipker (1980), Hammann and Sirrenberg (1980), Kaska *et al*. (1980), Mitsui *et al*. (1980 and 1981).

However, Yu and Terriere (1977) were of the opinion that the insect growth regulator Dimilin exerted its effect on pupal-adult ecdysis through its inhibition of ecdysone metabolism, while Lung (1980) stated that these compounds had an influence on the endocrine system rather than on chitin synthesis.

Salama et al. (1976) reported that the protein and lipid content of the integument was affected by the application of diflubenzuron. Further work on this aspect was done by Clarke et al. (1977), and Truchet et al. (1981).

Ascher and Nemny (1976) reported that chitin synthesis inhibitors displayed both stomach and contact action. Grosscurt (1978 b), Beevi (1979), Bull (1980), Hammann and Sirrenberg (1980), and Ascher and Eliyahu (1981) were of the same opinion.

Interference with chitin synthesis within eggs caused ovicidal effects (Grosscurt, 1977; Hajiar and Casida, 1979; and Bull, 1980). The embryos could not use their muscles to leave the eggs because of lack of rigidness in the cuticle (Bull and Ivie, 1980; Hammann and Sirrenberg, 1980).

Write et al. (1980) reported that diflubenzuron reduced sperm transfer in Anthonomus grandis, while Hajiar and Casida (1979) found that instar duration was slightly prolonged before moulting, following treatments with diflubenzuron.

The difference between species susceptibility to diflubenzuron had been attributed to differing excretion rates, or to the percentage of retained diflubenzuron (Granett *et al.*, 1980).

2.4 Field persistence of chitin synthesis inhibitors

Metcalf *et al.* (1975), El-Tantawi *et al.* (1976), and Schaefer and Dupras (1977) were of the opinion that chitin synthesis inhibitors were moderately persistent (upto four weeks in the case of diflubenzuron) and they did not cause long term persistence hazards. Beevi (1979) reported that Dimilin persisted upto fifty days when sprayed on potted rice. These pesticides were not concentrated through food chain or by direct absorption from water (Bull and Ivie, 1978; Diprima *et al.*, 1978; Bull, 1980; Hammann and Sirrenberg, 1980; Madder and Lockhart, 1980).

2.5 Effect of chitin synthesis inhibitors on treated plants

No phytotoxicity or fruiting variation in cotton was observed following Dimilin application (Harding and Wolfenbarger, 1980), but treatments of 0.04 and 0.06% apparently stimulated photosynthesis and respiration in leaves, and the accumulation of sugars, ascorbic acid and total acids in fruits (Iacob *et al.*, 1980).

2.6 Effect on beneficial organisms

2.6.1 Natural enemies.

In general, Dimilin was much less harmful to populations of useful fauna than most conventional insecticides. *Aphanteles melanoscelus* (Granett and Dunbar, 1975), chalcidoids on *Thaumetopoea pityocampa* (Ferrari and Tiberi, 1979), *E. chrysorrhoea* (Georgevitis, 1979), beneficial insects on cotton (Rummel *et al.*, 1979), natural enemy populations of *Psylla pyricola* (Westigard, 1979), *Geocoris punctipes*, *Apanteles marginiventris* and *Trichogramma pretiosum* (Ables *et al.*, 1980 b), and *Biosteres longicaudatus* (Lawrence, 1981) were not adversely affected by the compound.

Besides, Canivet *et al.* (1978) reported that Dimilin acted as a synergist to Dipel (*Bacillus thuringiensis*).

Not all reports, however, were favourable. Maleki-Milani and Burgerion (1980) and Mazzone and Viggiani (1980) found diflubenzuron incompatible with *Bacillus thuringiensis* and *Cryptolaemus montrouzieri* respectively.

2.6.2 *Bees.*

Barker and Waller (1978), and Johansen (1979), working with Dimilin, and Hammann and Sirrenberg (1980), and Zoebelein *et al.* (1980) with Bay Sir 8514, reported that chitin synthesis inhibitors did not significantly reduce bee populations.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Determination of dose-effect relationship of diflubenzuron and triflumuron

3.1.1 Rearing of test insects.

The insects used were the bhindi leaf roller *Sylepta derogata* Fabricius, the spotted beetle *Epilachna vigintioctopunctata* (Fabricius), and the amaranthus leaf webber *Psara basalis* Fabricius. Larvae of the insects collected from their respective host plants in the Instructional Farm, College of Agriculture, Vellayani, were reared in the laboratory. The adults emerged from these rearings were collected and maintained in cylindrical jars for egg laying. Eggs were allowed to hatch and the emerging larvae were kept in separate circular glass troughs with the respective food materials and the troughs were closed with muslin cloth. Each days' emergence was kept separately so that the age and stage of development of test insects could be identified for choosing appropriate test stages for the various experiments.

3.1.2 Preparation of different insecticide concentrations.

Diflubenzuron (Dimilin 25% WP) used in the experiments was obtained from Mysore Insecticides, Madras and triflumuron (Bay Sir 8514 6.5% EC) from Bayer (India) Ltd.

These insecticides were used at 0.1, 0.01, 0.001, 0.0001 and 0.00001 per cent concentrations. Different concentrations were prepared by mixing the required quantities of commercial formulations with water.

3.1.3 Application of insecticides.

Leaves of the host plants (bhindi, brinjal and amaranthus) were dipped in the different dilutions of insecticides, taking care to ensure complete wetting of both the surfaces. They were then air dried and leaves similarly dipped in water alone and dried served as control. Three replications were made for each treatment including control.

3.1.4 Exposure of insects on treated leaves.

After proper drying, treated leaves were taken in glass chimneys kept over petridishes. Ten larvae were released in each chimney, the upper end of which was closed with muslin cloth held in position by a rubber band. Second, third, and fourth instar larvae of each test insect were thus released and they were allowed to feed on treated leaves for twenty-four hours. Then the larvae in each replication were transferred to specimen tubes containing untreated leaves of the host plant. The openings of the tubes were closed with muslin cloth and were kept for further observations.

3.1.5 Assessment of results.

Larval mortality and the morphological and developmental changes in the surviving larvae were noted daily. The method adopted by Pradhan (1949) was used to assess the toxic effect of the compounds on the test insects. The data has been presented as average survival period in days for different instars and for the concentrations tested. The average survival period was calculated by finding a weighted mean of the survival period of all the insects treated with one concentration. Thus, if at 0.1 per cent concentration 19 per cent died after one day and before three days, the survival period of these 19 per cent was taken to be $(1 + 3)/2 = 2$ days. If, on the same concentration, another 19 per cent died after three days and before four days, the survival period of these other 19 per cent was taken to be $(3 + 4)/2 = 3.5$ days. Similarly, the survival period of the rest (62 per cent) was five days. Hence the weighted average of the survival period at 0.1 per cent concentration was $\left[(19\text{x}2) + (19\text{x}3.5) + (62\text{x}5)\right]/100$ $= 4.15$ days. Similarly, the survival period on all concentrations was calculated. The reciprocal of the average survival period multiplied by 100 was taken to be the speed-index of toxic effect ie. 100/Average survival period.

3.2 Determination of sterilant action of diflubenzuron and triflumuron

This was studied on E. *vigintioctopunctata* alone. Healthy adult beetles selected on the emerging day were used for the experiment. Suspensions/emulsions of the two chemicals were prepared in three different concentrations of 0.1, 0.01 and 0.001 per cent and brinjal leaves were dipped in these ensuring that the two surfaces were completely wetted and they were then air dried. These treated leaves were taken in glass chimneys kept on petridishes. For each concentration, three replications were set. Leaves dipped in water and dried served as control. Five pairs of one-day-old adults were exposed to each replication for twenty-four hours for feeding. Then they were transferred to fresh leaves taken in specimen tubes as in experiment 2.1.4. Observations were made on longevity and fecundity of the adults and on the number of eggs laid and their hatchability.

3.3 Determination of ovicidal activity of diflubenzuron and triflumuron

Eggs laid by *Epilachna* beetles maintained in the laboratory were used for the experiment. Eggs collected within twenty to twenty-four hours of laying were treated with 0.1, 0.01, 0.001, 0.0001 and 0.00001 per cent suspension/emulsion of the compounds. The eggs were kept immersed in the respective dilutions,taken in petridishes, for fifteen minutes. Treated eggs in each replication were then air dried and transferred to a specimen tube for further observations. Eggs immersed in distilled water for fifteen minutes and dried were maintained as control. The hatching larvae were fed with fresh brinjal leaves. The hatching percentage of the eggs and the survival as well as morphological and developmental abnormalities of the emerging larvae were noted.

3.4 Field evaluation of diflubenzuron and triflumuron for the control of vegetable pests

3.4.1 Experimental site.

The experiment was laid out on garden land of the Instructional Farm, College of Agriculture, Vellayani. The soil in the areawas of the red loam type.

3.4.2 Seeds.

Seeds of bhindi (Var. Pusa sawani), brinjal (Var. Pusa purple long) and red leafed amaranthus (Local variety) procured from the Instructional Farm were used for raising the crop.

3.4.3 Preparation of the experimental field.

The land selected for the experiment was ploughed well and the weeds were removed. Clods were broken to get a fine tilth and the whole area was levelled.

3.4.4 Layout of field experiment.

The three experiments relating to bhindi, brinjal and amaranthus were laid out, as in Fig. 1, adopting a randomized block design.

3.4.5 Planting.

In the case of brinjal and amaranthus, seeds were sown on nursery beds 5 cm apart. Seedlings were transplanted after five weeks at the rate of two seedlings per pit and when the seedlings were established, one of them was removed from each pit. For bhindi, four seeds per pit were dibbled and twenty days after germination all plants, except one in each pit, were removed.

3.4.6 Crop husbandry.

All the crop husbandry operations (except plant protection) were carried out as per the package of practices recommended by the Kerala Agricultural University (Anon., 1981).

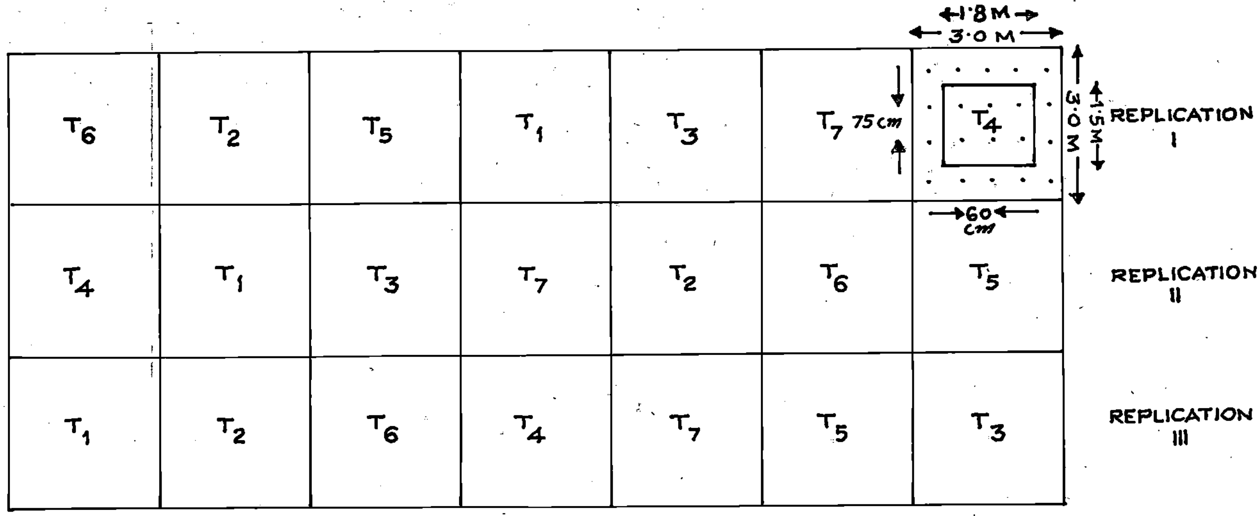
3.4.7 Preparation of insecticides.

Diflubenzuron was used at four levels of 0.01, 0.02, 0.03 and 0.04 per cent. Triflumuron was used

Lay out plan of field experiment

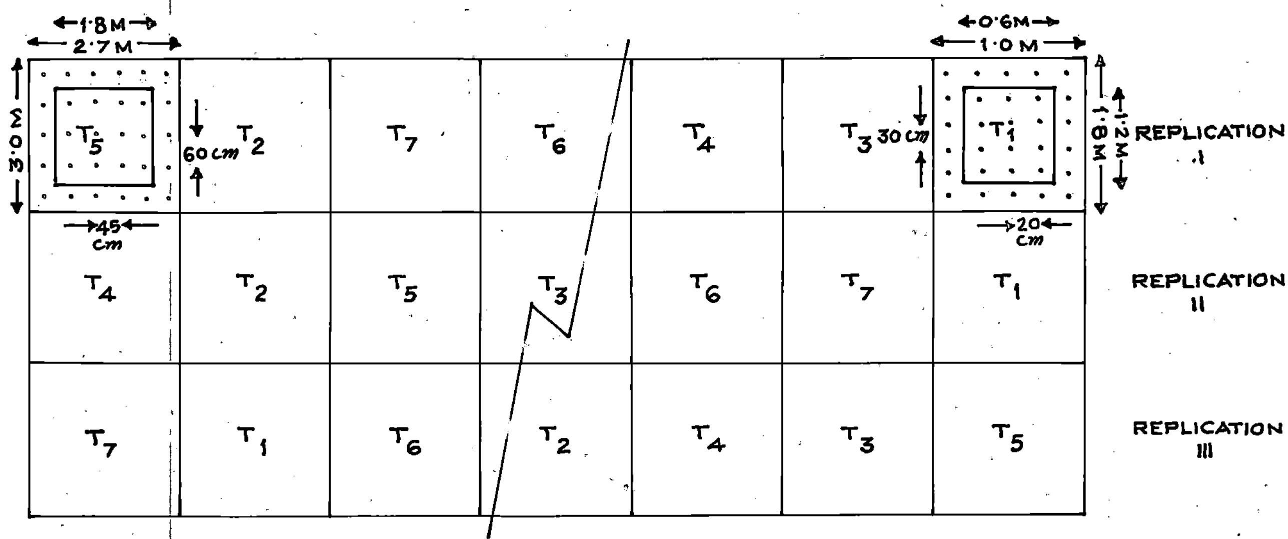
FIG. 1

BRINJAL



T_1 DIMILIN 0·01 %
T_2 DIMILIN 0·02 %
T_3 DIMILIN 0·03 %
T_4 DIMILIN 0·04 %
T_5 BAY SIR 8514 0·02 %
T_6 MALATHION 0·10 % (CHECK)
T_7 WATER SPRAY (CONTROL)

BHINDI AMARANTHUS



T_1 DIMILIN 0·01 %
T_2 DIMILIN 0·02 %
T_3 DIMILIN 0·03 %
T_4 DIMILIN 0·04 %
T_5 BAY SIR 8514 0·04 %
T_6 MALATHION 0·10 % (CHECK)
T_7 WATER SPRAY (CONTROL)

as 0.04 per cent emulsion on amaranthus and bhindi and 0.02 per cent on brinjal. Malathion, the standard, was sprayed as 0.1 per cent emulsion. Treatment with water alone served as control. The above concentrations were prepared by mixing required quantities of commercial formulations with water.

3.4.8 Application of insecticides.

Insecticide emulsions/suspensions were sprayed using a hand compression pheumatic sprayer. While spraying, screens were used round the pits to prevent insecticidal drift. Spraying was done ensuring a thorough coverage of plant parts.

3.4.9 Assessment of results.

The pest population on the crops were monitored at weekly intervals. When the population of the pest reached sizeable levels of intensity, the insecticides were applied. Post treatment count of pests were made at one day after spraying and thereafter, at weekly intervals. In the case of bhindi and brinjal, the shoots and fruits damaged by borers were also recorded. The data were collected from the net plot area only (Fig. 1).

3.4.10 Determination of total yield.

The yield obtained at different harvests were assessed and the data were statistically analysed.

3.5 Evaluation of field persistence of diflubenzuron and triflumuron

Leaves collected at weekly intervals from the experimental plots (Fig. 1) were fed to the fourth instar larvae of the corresponding test insects for twenty-four hours and their mortalities were recorded. The exposure was continued till the effect tailed out. The persistent toxicity was estimated in terms of PT indices following the methods elaborated by Pradhan (1967).

RESULTS

4. RESULTS

4.1 Dose-effect relationship of diflubenzuron and triflumuron on *Sylepta derogata*

The data relating to this are presented in Table 1. In the second instar larvae, the lowest average survival period of 2.500 days was recorded in the highest concentration of 0.1 per cent in the case of both insecticides. The survival periods in the next higher concentrations of 0.01 and 0.001 per cent were on par with those in 0.1 per cent. In the two lower concentrations of 0.0001 and 0.00001 per cent, the survival periods were significantly higher; 2.900 and 3.133 days for diflubenzuron and 2.800 and 3.183 days for triflumuron.

In the case of third instar caterpillars diflubenzuron 0.1 and 0.01 per cent gave low survival periods of 2.566 and 2.866 days respectively. In the case of triflumuron, 0.1, 0.01 and 0.001 per cent were effective there being no significant difference among the treatments. In the remaining doses the survival periods were significantly higher.

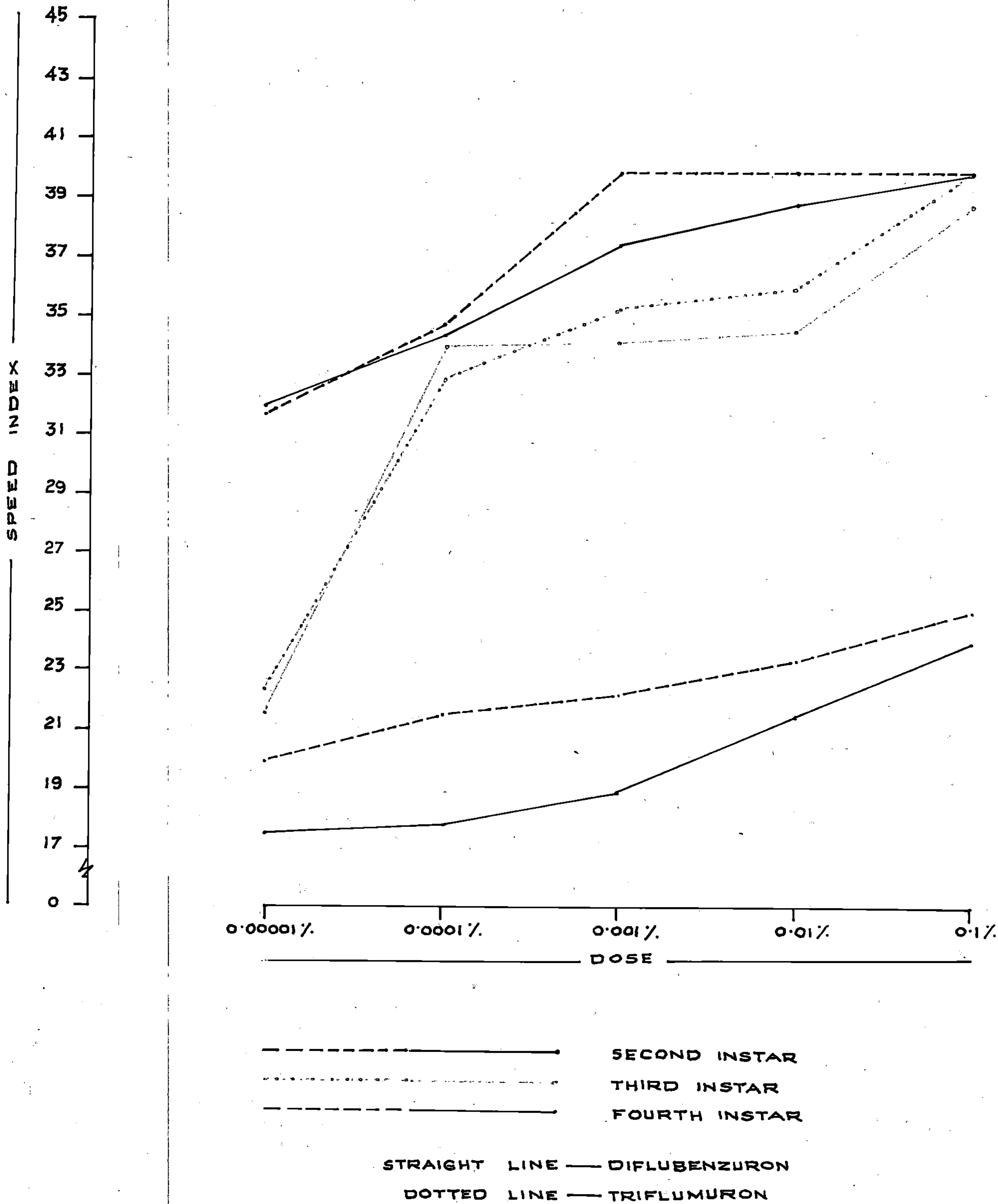
In the fourth instar caterpillars, diflubenzuron showed significantly low survival periods of 4.166 and

Table No.1 Dose-effect relationship of two chitin synthesis inhibitors on different larval instars of *Sylepta derogata* in terms of their average survival periods and speed indices of the toxic effect.

Treatments		Second instar		Third instar		Fourth instar	
		Average survival period	Speed Index	Average survival period	Speed Index	Average survival period	Speed Index
Diflubenzuron	0.1%	2.508	39.87	2.566	38.97	4.166	24.00
"	0.01%	2.566	38.97	2.866	34.89	4.700	21.27
"	0.001%	2.666	37.50	2.933	34.09	5.303	18.85
"	0.0001%	2.900	34.48	3.333	34.00	5.600	17.85
"	0.00001%	3.133	31.91	4.650	21.50	5.733	17.44
Triflumuron	0.1%	2.500	40.00	2.500	40.00	4.000	25.00
"	0.01%	2.500	40.00	2.766	36.15	4.266	23.44
"	0.001%	2.500	40.00	2.833	35.29	4.633	21.58
"	0.0001%	2.800	34.72	3.033	32.97	4.650	21.50
"	0.00001%	3.183	31.41	4.466	22.39	4.766	20.98
C.D		0.2110		0.3006		0.7031	

Dose-effect relationship of the chitin synthesis inhibitors, diflubenzuron and triflumuron on different larval instars of Sylepta derogata in terms of their speed indices of toxic effect.

FIG. 2


45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
0
SPEED INDEX
0·00001%
0·0001%
0·001%
0·01%
0·1%
DOSE
SECOND INSTAR
THIRD INSTAR
FOURTH INSTAR
STRAIGHT LINE — DIFLUBENZURON
DOTTED LINE — TRIFLUMURON

4.700 respectively. All the remaining doses were on par and less effective. Regarding triflumuron, the four higher doses were found effective and on par, the survival periods being in the range of 4.000 to 4.650. The lowest dose showed a survival of 4.766 days.

In comparing the efficacy of identical doses of the two insecticides (Fig. 2) it was seen that they did not show significant variations except in the case of the lower three doses of the insecticides on the fourth instar caterpillars. In these treatments the survival periods in triflumuron were significantly lower than the survivals in corresponding doses of diflubenzuron.

4.2 Dose-effect relationship of diflubenzuron and triflumuron on *Epilachna vigintioctopunctata*

The data relating to this are presented in Table 2. In the case of the second instar, the survival period in 0.1, 0.01, 0.001 and 0.0001 per cent of diflubenzuron and triflumuron were relatively lower and on par. The survival period in the lowest concentration of 0.00001 per cent alone was significantly higher.

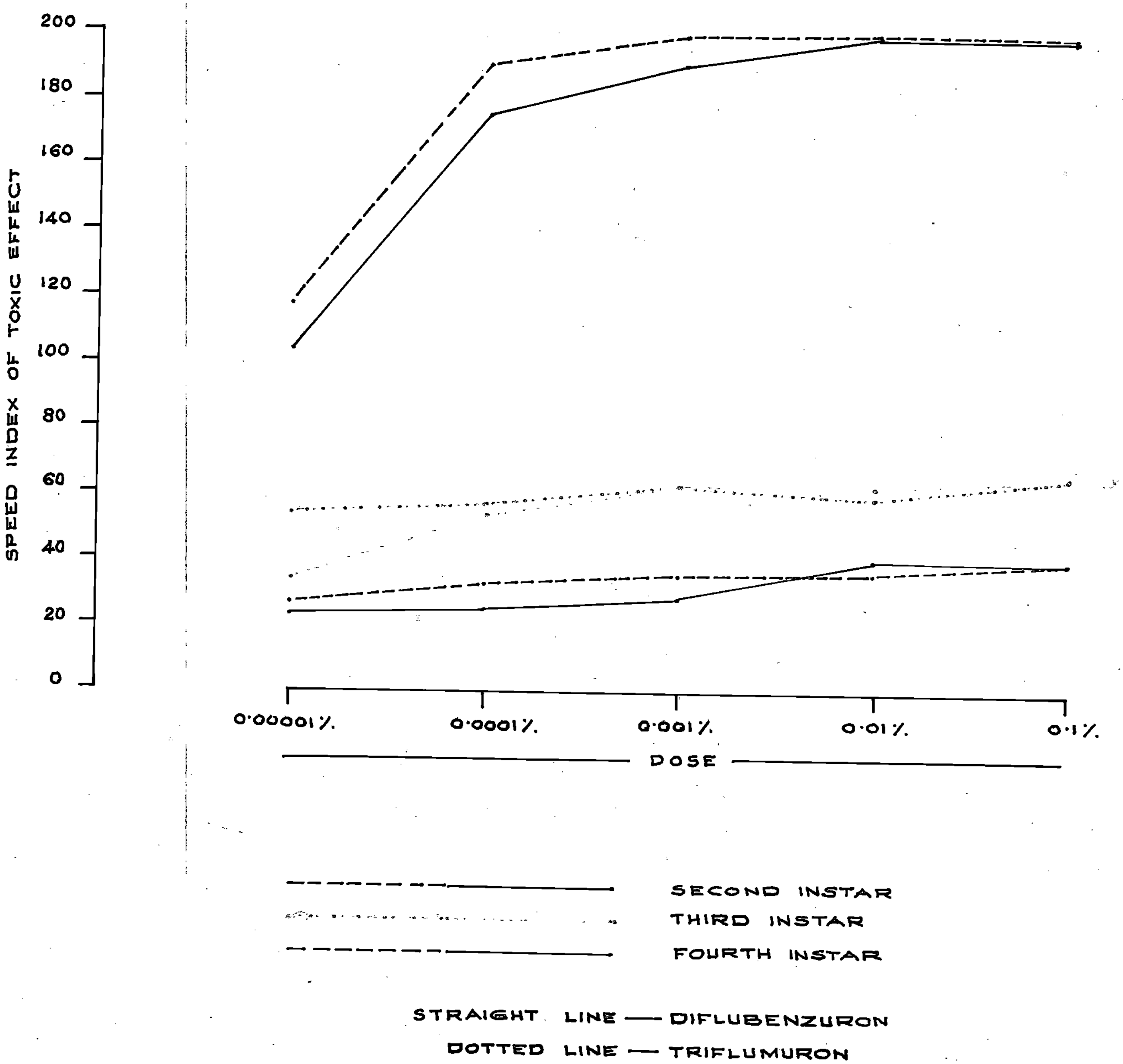
In the third instar larvae, the higher three doses of diflubenzuron and triflumuron were found to be more toxic as shown by the lower survival periods in those treatments. The lowest dose of diflubenzuron gave a high survival of 3.000 days, while the corresponding dose of triflumuron showed a survival of 1.820 days only.

Table No.2 Dose-effect relationship of two chitin synthesis inhibitors on different larval instars of <u>Epilachna vigintioctopunctata</u> in terms of their average survival periods and speed indices of the toxic effect.

Treatments		Second instar		Third instar		Fourth instar	
		Average survival period	Speed Index	Average survival period	Speed Index	Average survival period	Speed Index
Diflubenzuron	0.1%	0.500	200.00	1.500	66.67	2.513	39.79
"	0.01%	0.500	200.00	1.660	60.24	2.560	39.06
"	0.001%	0.523	191.20	1.640	60.98	3.613	27.68
"	0.0001%	0.570	175.44	1.850	54.05	3.873	25.82
"	0.00001%	0.950	105.26	3.000	33.33	4.433	22.56
Triflumuron	0.1%	0.500	200.00	1.500	66.67	2.523	39.64
"	0.01%	0.500	200.00	1.670	59.88	2.593	38.57
"	0.001%	0.500	200.00	1.660	60.24	2.710	36.90
"	0.0001%	0.523	191.20	1.760	56.82	3.030	33.00
"	0.00001%	0.843	118.62	1.820	54.95	3.700	27.03
C.D		0.1229		0.2310		0.7386	

Dose-effect relationship of the chitin synthesis inhibitors, diflubenzuron and triflumuron on different larval instars of *Epilachna vigintioctopunctata* in terms of their speed indices of toxic effect.

FIG.3


SPEED INDEX OF TOXIC EFFECT
200
180
160
140
120
100
80
60
40
20
0
0·00001%
0·0001%
0·001%
0·01%
0·1%
DOSE
SECOND INSTAR
THIRD INSTAR
FOURTH INSTAR
STRAIGHT LINE — DIFLUBENZURON
DOTTED LINE — TRIFLUMURON

Diflubenzuron 0.1 and 0.01 per cent gave low survivals of 2.513 and 2.560 days respectively in the case of the fourth instar larvae, there being no significant difference between the two treatments. In triflumuron, the four higher doses, giving survival periods 2.523, 2.593, 2.710 and 3.030 respectively, were found to be equally toxic, the difference among these being statistically insignificant. The lower doses of 0.00001 per cent of both insecticides gave significantly longer survivals.

While comparing the survivals of larvae treated with corresponding doses of the insecticides (Fig. 3) it may be seen that there were significant variations only with reference to the effect of 0.0001 and 0.00001 per cent of the two insecticides on the fourth instar larvae alone, the survival period in these treatments being significantly lower in triflumuron.

4.3 Dose-effect relationship of diflubenzuron and triflumuron on *Psara basalis*

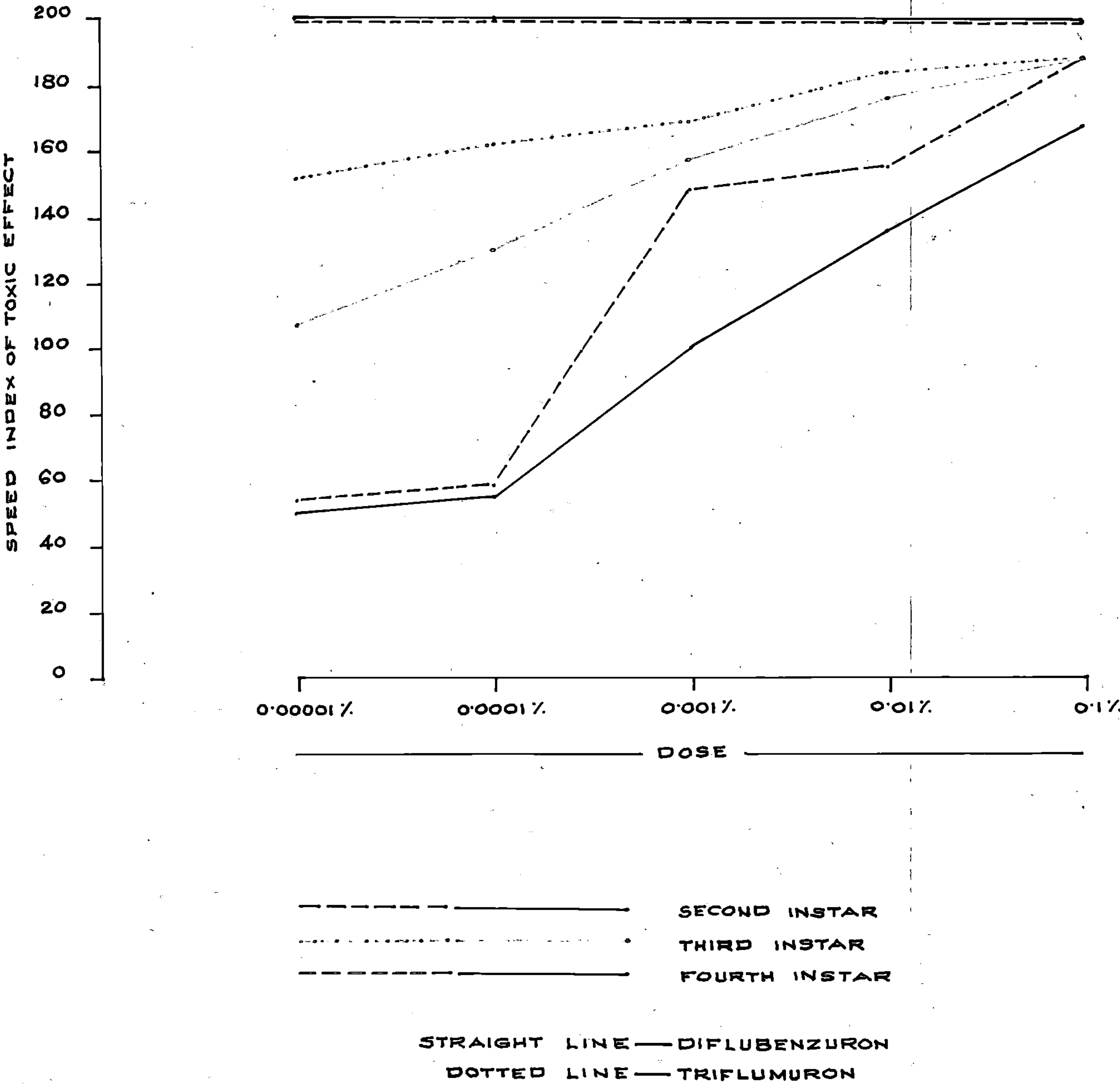
The data relating to this are presented in Table 3. Survival period of the second instar larvae in the various treatments did not show any significant variation, being 0.500 days in all the treatments. In the case of the third instar larvae, the lowest survival was found in the highest concentration of diflubenzuron. This was followed by the lower concentrations of 0.01 per cent and 0.001 per cent of

Table No. 3 Dose-effect relationship of two chitin synthesis inhibitors on different larval instars of Psara basalis in terms of their average survival periods and speed indices of the toxic effect.

Treatments		Second instar		Third instar		Fourth instar	
		Average survival period	Speed Index	Average survival period	Speed Index	Average survival period	Speed Index
Diflubenzuron	0.1%	0.500	200.00	0.533	187.61	0.600	166.66
"	0.01%	0.500	200.00	0.566	176.67	0.733	136.42
"	0.001%	0.500	200.00	0.633	157.97	1.000	100.00
"	0.0001%	0.500	200.00	0.766	130.54	1.800	55.55
"	0.00001%	0.500	200.00	0.933	107.18	1.933	51.73
Triflumuron	0.1%	0.500	200.00	0.566	176.67	0.566	176.67
"	0.01%	0.500	200.00	0.546	183.15	0.646	154.79
"	0.001%	0.500	200.00	0.593	168.63	0.673	148.58
"	0.0001%	0.500	200.00	0.620	161.29	1.736	57.60
"	0.00001%	0.500	200.00	0.666	150.15	1.986	50.35
C.D		-		0.1755		0.2600	

Dose-effect relationship of the chitin synthesis inhibitors, diflubenzuron and triflumuron on different larval instars of *Psara basalis* in terms of their speed indices of toxic effect.

FIG. 4



SPEED INDEX OF TOXIC EFFECT
200
180
160
140
120
100
80
60
40
20
0
0·00001%
0·0001%
0·001%
0·01%
0·1%
DOSE
SECOND INSTAR
THIRD INSTAR
FOURTH INSTAR
STRAIGHT LINE — DIFLUBENZURON
DOTTED LINE — TRIFLUMURON

the insecticide which gave survival periods of 0.566 and 0.633 days respectively. Variations among the survival periods of these three treatments were not statistically significant. With reference to triflumuron, all the five dosages tried, giving survivals ranging from 0.566 to 0.666 days, were found on par.

In the fourth instar larvae, diflubenzuron 0.1 and 0.01 per cent gave survivals which were on par and less than those of the remaining dosages of insecticide, these being 0.600 and 0.733 days respectively. In the case of the remaining three lower dosages of diflubenzuron, the survival periods were 1.000, 1.800 and 1.933 days respectively. The larvae treated with triflumuron 0.1, 0.01 and 0.001 per cent had survival periods of 0.566, 0.646 and 0.673 days respectively, the variations among these being statistically insignificant. The survival period of the two lower doses of this insecticide did not show significant variation between themselves and were significantly inferior to the higher three dosages.

While comparing the relative efficacy of the two insecticides (Fig. 4) to the different larval instars of <u>P. basalis</u> in the case of the second instar larvae, the survival periods of the corresponding doses of the two insecticides did not vary significantly, while on the third instar larvae, the lowest dose of 0.00001 per cent showed significant variation. In the fourth instar larvae, 0.001 per cent diflubenzuron gave a survival period of 1.000, while in the corresponding dose of triflumuron, the survival was 0.673 days only. The other doses of the two insecticides were on par.

4.4 Deformities observed on test insects exposed to chitin synthesis inhibitors

Besides the mortality caused by chitin synthesis inhibitors, various deformities and malformations were observed on the test insects in their larval, pupal and adult stages, prior to death.

When the second and third instars of S. derogata and P. basalis were treated, particularly with higher doses, their bodies shrunk and gradually turned black (Fig. 5 C). In the case of fourth instar larvae, two types of symptoms were noted. Some stopped feeding and their bodies gradually became black and stiff and before death the body got bent (Fig. 5 B and Fig. 6 B). Some of the treated larvae became soft bodied and their body wall ruptured, resulting in the oozing out of body fluids leading to death (Fig. 6 C) of the larvae.

A limited number of fourth instar caterpillars of S. derogata and P. basalis which survived, moulted to their fifth instar and later developed into larval-pupal mosaics. In S. derogata such mosaics showed a black larval head capsule which was split but not completely cast off below which the pupal head could be distinctly seen (Fig. 7 B).

Fig. 5 Caterpillars of <u>Sylepta derogata</u> fed on bhindi leaves treated with chitin synthesis inhibitors

A Normal larva

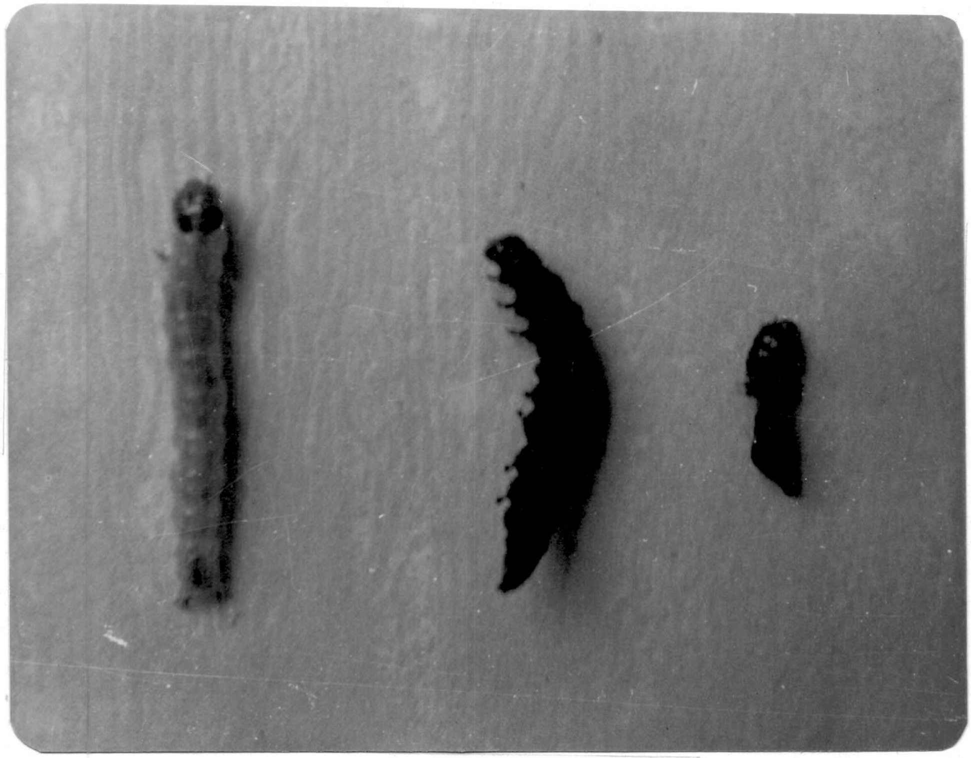
B Fourth instar treated

C Third instar treated

Fig. 6 Caterpillars of <u>Psara basalis</u> fed on amaranthus leaves treated with chitin synthesis inhibitors

A Healthy larva

B, C & D Fourth instar treated



A B C

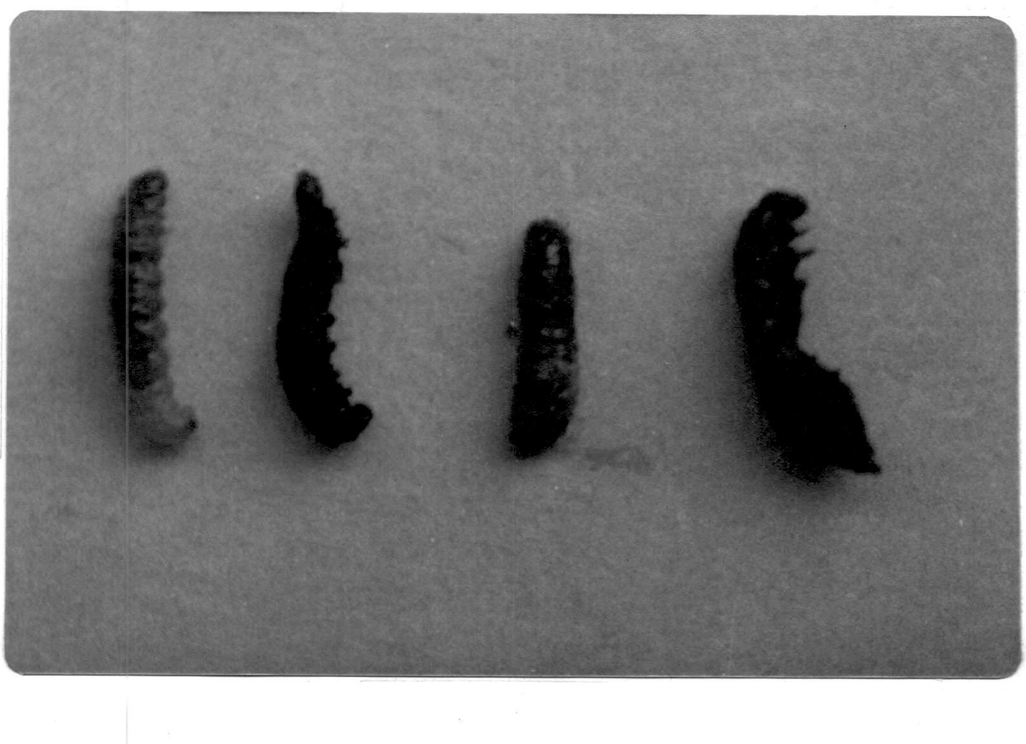


Fig. 7 Malformed pupae formed from caterpillars of *Sylepta derogata* fed on bhindi leaves treated with chitin synthesis inhibitors

A Normal pupa

B Dorsal view of larval-pupal mosaic

C Ventral view

D Lateral view

Fig. 8 Malformed pupae formed from caterpillars of *Psara basalis* fed on amaranthus leaves treated with chitin synthesis inhibitors

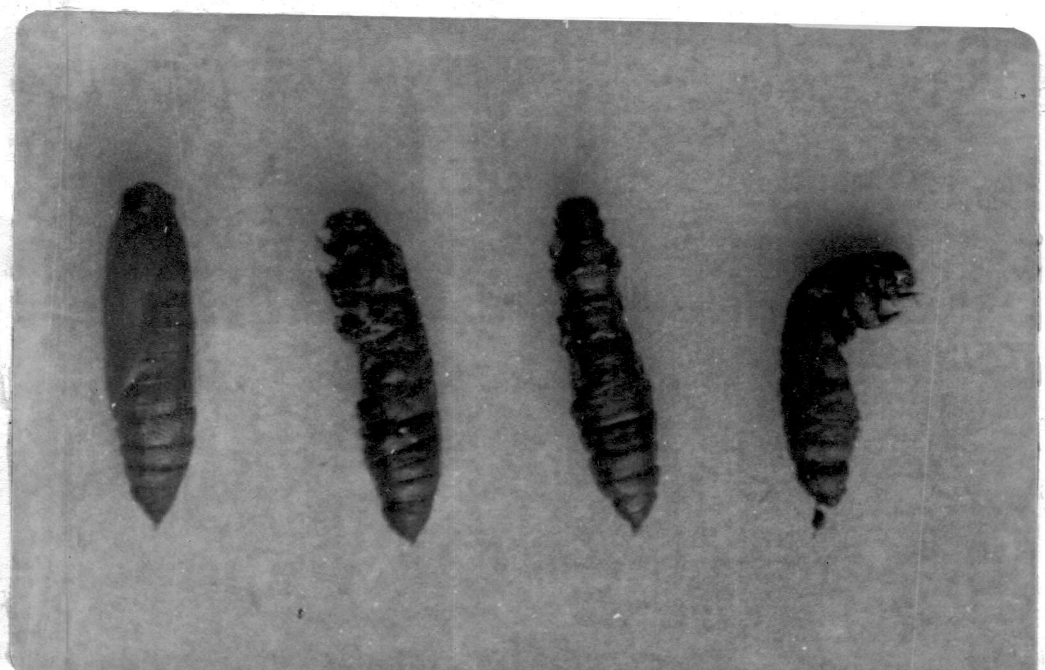
A Normal pupa

B Ventral view of larval-pupal mosaic

C Dorsal view

D Lateral view

A B C D



A B C D

The posterior part of the body had moulted into the pupal stage, while the anterior part remained largely larval in nature, with black twisted legs (Fig. 7 C). The second thoracic segment showed a humped appearance (Fig. 7 D). The wing pads were also seen developed but they remained malformed and free from the body unlike in the normal pupae (Fig. 7 B and D). Under the binocular microscope, patches of brown pupal skin could be seen developed beneath the green larval skin of the thoracic region.

In the case of P. basalis also, the posterior part of the body moulted into the pupa, while the anterior portion retained its larval nature. However, here the wing rudiments were not prominently developed, and the hump-like appearance of the thorax found in the case of S. derogata was also not discernible (Fig. 8 B and C). The anterior part of the body, including the thorax, showed a characteristic bent appearance (Fig. 8 D).

Some of the larval-pupal mosaics partly moulted as abnormal adults too. Such adults had crumpled and unstretched wings, short, stumpy and malformed abdomens and weak, brittle legs and antennae. The body was sparsely covered with scales (Fig. 9 B). In some cases, the pupal skin was split, but not cast off, and the thorax and abdomen moulted as the adult was seen thrust out of the same (Fig. 9 C). In a few specimens the larval-pupal mosaic largely remained unchanged with the abdominal portion alone metamorphosed as adult (Fig. 9 D).

Fig. 9 Malformed adults formed from caterpillars of <u>Syleota derogata</u> fed on bhindi leaves treated with chitin synthesis inhibitors

A Healthy adult

B Malformed adult

C & D Adult unable to moult from pupal covering

D C B A

Fig. 10 Larvae of _Epilachna vigintioctopunctata_ fed on brinjal leaves treated with chitin synthesis inhibitors

A Healthy larva

B Fourth instar treated

C & D Second instar treated

Fig. 11 Malformed pupae formed from larvae of _Epilachna vigintioctopunctata_ fed on leaves treated with chitin synthesis inhibitors

A Normal pupa

B & C Abnormal pupa

D & E Larval pupal mosaics

A B C D

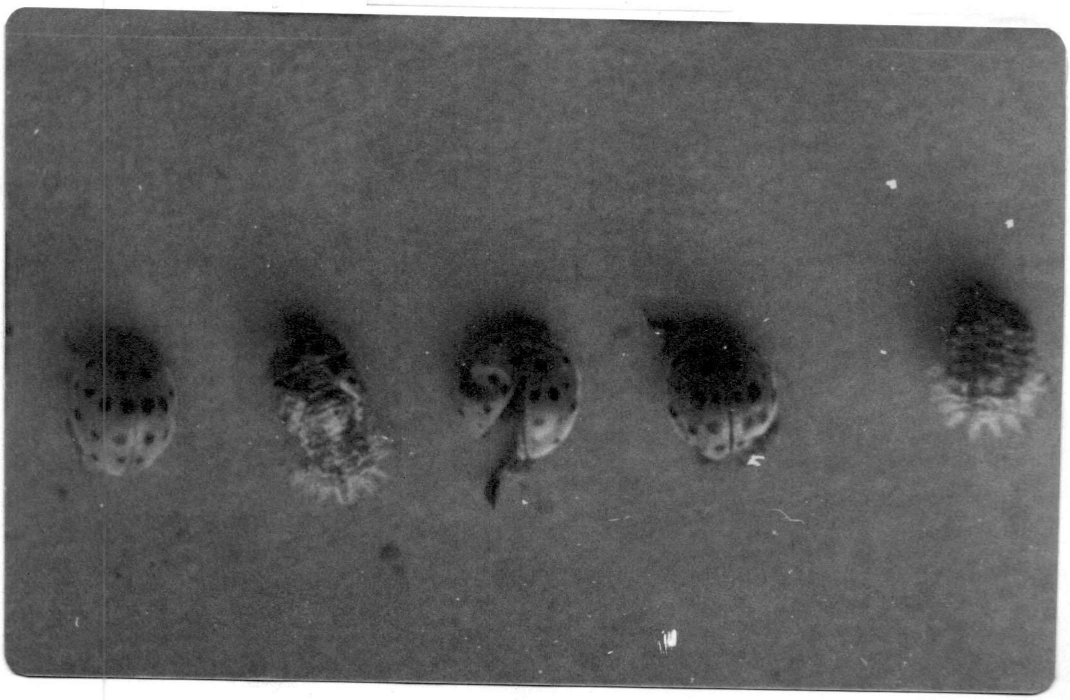
A B C D E

Fig. 12 Malformed adults formed from larvae of _Epilachna vigintioctopunctata_ fed on brinjal leaves treated with chitin synthesis inhibitors

A Healthy adult

B & E Larval-pupal mosaics incompletely moulted as adults

C & D Abnormal adults moulted from larval-pupal mosaic



A B C D E

In the case of E. vigintioctopunctata also, abnormalities could be seen in the different stages developing from treated larvae. The second instar larvae, when exposed to the insecticides died within a short time and some turned completely black, while others retained their tubercles in their natural yellow colour while the body turned black (Fig. 10 C and D). The fourth instar larvae similarly treated turned brownish and died (Fig. 10 B). Larval-pupal mosaics could be seen in this case also. The posterior end of these moulted as pupae while the anterior end retained the larval character (Fig. 11 D and E). In some cases the larvae moulted fully as pupae but their skin was seen with black patches all over and the body tubercles were also fewer in number (Fig. 11 B and C). Some of the larval-pupal mosaics metamorphosed as adults, but their pupal skin was not completely cast off and some emerged as apodous forms (Fig.12 B and E). Those adults which completely emerged from the pupal skin were highly abnormal with crinkled wings and twisted, underdeveloped abdomens (Fig. 12 C and D).

4.5 Sterilant effect of chitin synthesis inhibitors fed to the adults of E. vigintioctopunctata

The results are shown in Table 4. The average survival periods of the beetles were significantly lower in all the treatments when compared to control and in the highest concentration of 0.1 per cent the survival was 0.820 days.

Table No. 4 Sterilant effect of two chitin synthesis inhibitors fed to the adults of <u>Epilachna vigintioctopunctata</u>.

Treatments		Average survival period of adults	Mean number of eggs laid per female	Hatching percentage of the eggs
Diflubenzuron	0.1%	0.820	6.33 (2.477)[1]	23.36 (24.143)[2]
"	0.01%	4.363	56.66 (7.515)[1]	16.61 (23.960)[2]
"	0.001%	6.396	129.00 (11.376)[1]	24.76 (29.839)[2]
Triflumuron	0.1%	0.820	6.33 (2.568)[1]	13.80 (17.857)[2]
"	0.01%	3.710	61.00 (7.641)[1]	11.67 (19.693)[2]
"	0.001%	6.083	162.66(12.726)[1]	22.46 (27.913)[2]
Control		10.376	389.00(19.725)[1]	98.35 (83.149)[2]
C.D		1.476	2.501	18.799

Figures in parentheses[1] are values after $(x+1)^{\frac{1}{2}}$ transformation.
Figures in parentheses[2] are values after angular transformation.

While diflubenzuron 0.01 and 0.001 per cent gave survivals of 4.363 and 6.396 days respectively, similar doses of triflumuron gave survivals of 3.710 and 6.083 days respectively. The corresponding doses of the two insecticides did not show any significant difference in their toxicity to the adults of E. vigintioctopunctata.

The mean number of eggs laid by the females in various treatments were significantly lower than the number obtained in the control. The least number of eggs (6.33) was observed in the highest doses of both insecticides. This was followed by the next higher dose of 0.01 per cent, the mean numbers in diflubenzuron and triflumuron being 56.66 and 61.00 respectively. In the lowest dose of 0.001 per cent, the mean number in diflubenzuron was 129.00, while in triflumuron, it was 162.66. The corresponding doses of the two insecticides did not show significant variations in the mean number of eggs laid per female.

With reference to the percentage hatching of eggs laid by treated females, wide variation was seen between the control and treatments. While hatching was as high as 98.35 per cent in control, in treatments it varied from 11.67 to 24.46 per cent only. The mean percentage hatching in the various treatments, however, did not show significant variations.

4.6 Lethal effect of chitin synthesis inhibitors on the eggs of _E. vigintioctopunctata_

The data are presented in Table 5. All the treatments gave significantly lower percentages of egg hatch than control. The highest dose of 0.1 per cent of the two insecticides gave the least hatching and these were significantly lower than all the remaining treatments. In the case of diflubenzuron, the percentage hatch in 0.01 per cent (23.43) was significantly lower than that of the lower dose of 0.001 per cent (38.03). The hatch in the lower two doses were on par (59.19 and 55.86 per cent) and significantly higher than that of 0.001 per cent.

With reference to triflumuron, the hatching percentage in 0.01, 0.001 and 0.0001 per cent were 26.66, 33.73 and 32.70 per cent respectively. There was no significant difference among these treatments. The ovicidal effect of the corresponding doses of the two insecticides did not show significant variation, except at the 0.0001 per cent level.

The survival of the hatching larvae in various treatments also showed significant variations. The higher concentrations of 0.1 and 0.01 per cent of the two insecticides gave low survival, the differences between the average survival periods of these treatments being

Table No. 5 Effect of two chitin synthesis inhibitors on the eggs of *Epilachna vigintioctopunctata*.

Treatments		Percentage of eggs hatched	Average survival period of emerging larvae
Diflubenzuron	0.1%	10.03 (18.306)	0.506
"	0.01%	23.43 (28.263)	0.793
"	0.001%	38.03 (37.986)	2.233
"	0.0001%	59.19 (50.335)	1.730
"	0.00001%	55.86 (48.369)	4.076
Triflumuron	0.1%	6.53 (14.765)	0.526
"	0.01%	26.66 (31.010)	0.650
"	0.001%	33.73 (35.342)	1.570
"	0.0001%	32.70 (34.854)	1.610
"	0.00001%	58.83 (50.110)	4.376
Control		96.00 (78.460)	-
C.D (treatment vs control)		26.394	0.658
C.D (between treatments)		7.635	

Figures in parentheses are values after angular transformation.

statistically insignificant. The doses of 0.001 and 0.0001 per cent also did not show significant differences between themselves, while the average survival periods of these treatments were significantly less than that of the lowest dose of 0.00001 per cent, and higher than the three higher doses of the insecticides.

In this aspect also, the corresponding doses of the two insecticides did not show significant variations in effect, except at the 0.001 per cent level in which triflumuron was seen to be superior.

4.7 Control of pests of bhindi using chitin synthesis inhibitors and malathion

4.7.1 Bhindi leaf roller, *Sylepta derogata*.

The data and results of statistical analysis are presented in Table 6 and Appendix I. The mean number of *S. derogata* larvae in the treatment plots and control plots did not show significant variations prior to treatment. One day after spraying, the maximum reduction in population was observed in plots treated with malathion 0.1 per cent (1.33), closely followed by triflumuron 0.04 per cent treated plots (3.33) there being no significant difference between the two. The latter was on par with the three higher doses of diflubenzuron, the mean number per plot ranging from 3.66 to 5.66. Diflubenzuron 0.02 per cent

Table No. 6 Control of the bhindi leaf roller, *Sylepta derogata* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of larvae observed at different periods after spraying (days)				
			1	7	14	21	28
Diflubenzuron	0.01%	5.66 (2.570)	4.00 (2.228)	1.66 (1.550)	2.33 (1.745)	4.66 (2.270)	9.00 (2.918)
"	0.02%	9.33 (3.161)	7.33 (2.829)	1.00 (1.382)	2.00 (1.688)	4.66 (2.378)	16.33) (3.803)
"	0.03%	7.33 (2.878)	5.66 (2.570)	0.66 (1.276)	1.33 (1.488)	3.66 (2.031)	25.66 (4.882)
"	0.04%	7.00 (2.803)	3.66 (2.157)	1.00 (1.382)	3.00 (1.989)	3.66 (2.080)	11.00 (3.269)
Triflumuron	0.04%	6.33 (2.698)	3.33 (2.060)	0.33 (1.138)	0.00 (1.000)	1.33 (1.520)	24.33 (4.532)
Malathion	0.1%	5.00 (2.433)	1.33 (1.520)	0.66 (1.276)	4.00 (2.016)	11.00 (3.527)	8.33 (2.878)
Control		7.00 (2.824)	7.33 (2.885)	16.66 (4.168)	20.00 (4.533)	19.66 (4.250)	37.00 (5.958)
C.D		N.S	0.6042	0.7199	0.8621	1.9230	N.S

Figures in parentheses are values after $(x+1)^{\frac{1}{2}}$ transformation.

was least effective and was on par with control. Seven days after spraying, the mean number in the treatment plots showed a drastic reduction (ranging from 0.33 to 1.66). There was no significant variation amongst the treatments. In the meantime the mean population in control plots showed a significant increase (7.33 to 16.66). During the second week after spraying, the plots treated with triflumuron were completely free from the pest. Populations in plots treated with diflubenzuron 0.01, 0.02 and 0.03 per cent (2.33, 2.00 and 1.33 respectively) were on par and closely followed triflumuron 0.04 per cent. Malathion which ranked high in the first observation, ranked last among the treatments in the observation taken at the end of the second week. Population in the control plots still remained at a high level (20.00 per plot). At the end of the third week after spraying there was a gradual build up of the pest population in all the treated plots. The lowest population (1.33 per plot) was seen in plots treated with triflumuron and the maximum was observed in plots treated with malathion 0.1 per cent (11.00). There was no reduction in the level of population in control plots. In general, the population showed an increase during the fourth week in the treated as well as untreated plots and the treatment effect was seen lost as revealed from the lack of significant variations in the mean number of larvae observed in different plots.

4.7.2 Bhindi jassid, *Amrasca biguttula biguttula*.

The data and results of statistical analysis are presented in Table 7 and Appendix I. In this case also, the pre-treatment count of the pest population in the different plots did not show significant variations. The mean number of jassids, observed one day after spraying, in plots treated with malathion 0.1 per cent was 6.66 and it was significantly lower than the mean number in other treatments. In the remaining treated plots, the population did not vary significantly (mean number ranging from 16.66 to 20.00). Diflubenzuron 0.04, 0.02 and 0.01 per cent were also seen on par with control. In the observation taken seven days after spraying, malathion 0.1 per cent showed the least population (7.33 per plot) and this was closely followed by diflubenzuron 0.02 per cent and 0.01 per cent, having populations of 14.00 and 14.33 respectively. The difference among these treatments were not statistically significant. The remaining treatments were on par with these two doses of diflubenzuron, but they were inferior to malathion. The population in the control was significantly higher than any of the treated plots. At the end of fourteen days after spraying, the populations in the treated plots

Table No. 7 Control of the bhindi jassid, Amrasca biguttula biguttula in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of jassids observed at different periods after spraying (days)				
			1	7	14	21	28
Diflubenzuron	0.01%	30.00 (5.291)	18.66 (4.267)	14.33 (3.718)	16.66 (4.044)	17.66 (4.200)	12.00 (3.041)
"	0.02%	22.00 (4.674)	20.00 (4.460)	14.00 (3.705)	17.66 (4.168)	23.00 (4.718)	18.33 (4.036)
"	0.03%	19.00 (4.204)	16.66 (4.059)	20.33 (4.494)	17.66 (4.201)	15.66 (3.949)	29.33 (5.197)
"	0.04%	20.33 (4.279)	18.00 (4.152)	19.00 (4.340)	16.66 (4.047)	15.66 (3.893)	12.00 (3.414)
Triflumuron	0.04%	16.66 (4.056)	16.66 (4.077)	19.00 (4.349)	20.00 (4.401)	19.33 (4.328)	35.28 (5.948)
Malathion	0.1%	12.66 (3.423)	6.66 (2.517)	7.33 (2.631)	17.00 (4.118)	20.00 (4.401)	15.33 (3.898)
Control		24.33 (4.767)	25.00 (4.945)	29.33 (5.338)	24.66 (5.585)	28.66 (5.327)	27.66 (5.104)
C.D		N.S	0.851	1.169	0.903	N.S	N.S

Figures in parentheses are mean values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant

were significantly lower than that of control but there was no significant variation among the treatments. In the subsequent observations the effect of treatments was seen lost since the populations in various plots did not show significant variations.

4.7.3 Bhindi aphid, *Aphis gossypii*.

The data and results of statistical analysis are presented in Table 8 and Appendix I. The mean number of aphids recorded in various plots prior to spraying and at weekly intervals after spraying upto the twenty-eighth day revealed that the chitin synthesis inhibitors did not cause appreciable reduction of aphid populations on bhindi. Though there was an initial reduction of the population in plots treated with malathion as observed on the first and seventh days after spraying, the effect was seen lost in subsequent observations. The data did not vary significantly in any of the observations.

4.7.4 Bhindi fruit and shoot borer, *Earias* sp. and *Melanagromyza obtusa*.

The data and results of statistical analysis are presented in Tables 9 and 10 and Appendix I. The incidence of fruit borer in various plots did not show significant variations prior to treatment and two days after spraying. Nine days after spraying the population in various plots

Table No.8 Control of the bhindi aphid, *Aphis gossypii* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of aphids observed at different periods after spraying (days)				
			1	7	14	21	28
Diflubenzuron	0.01%	8.66 (3.402)	9.00 (2.917)	12.00 (3.445)	22.00 (4.599)	35.33 (5.902)	36.66 (6.008)
"	0.02%	18.33 (3.303)	16.33 (3.703)	10.66 (3.151)	18.66 (4.232)	54.33 (7.290)	28.33 (5.325)
"	0.03%	29.33 (5.198)	25.66 (4.782)	15.66 (3.954)	23.00 (4.660)	64.00 (7.741)	28.66 (5.440)
"	0.04%	12.00 (3.314)	11.00 (3.263)	15.00 (3.676)	27.66 (5.212)	66.66 (7.871)	44.66 (6.755)
Triflumuron	0.04%	34.00 (5.948)	24.33 (4.533)	12.00 (3.299)	23.33 (4.668)	75.66 (8.304)	31.33 (5.675)
Malathion	0.1%	15.33 (3.798)	8.33 (2.877)	7.00 (2.622)	16.00 (3.833)	41.66 (6.405)	37.33 (6.153)
Control		27.66 (5.204)	37.00 (5.857)	29.66 (5.433)	33.33 (5.653)	90.33 (9.428)	50.66 (7.184)
C.D		N.S	N.S	N.S	N.S	N.S	N.S

Figures in parentheses are mean values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant.

Table No. 9 Control of the bhindi fruit borer, _Earias_ sp. in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean percentages of fruit borer incidence observed at different periods after spraying (days)					
			2	9	16	23	29	36
Diflubenzuron	0.01%	9.94 (17.78)	4.17 (11.89)	2.75 (9.26)	5.35 (13.34)	5.51 (13.25)	5.55 (12.83)	4.03 (11.47)
"	0.02%	9.83 (18.42)	6.51 (14.56)	2.76 (7.63)	6.60 (14.89)	6.30 (13.92)	7.98 (14.64)	4.47 (12.35)
"	0.03%	6.55 (14.38)	4.37 (9.45)	5.24 (12.80)	7.19 (15.25)	4.98 (12.12)	4.91 (7.76)	9.57 (17.44)
"	0.04%	6.30 (11.44)	7.26 (15.60)	0.00 (0.00)	4.51 (12.28)	4.11 (12.00)	2.35 (11.98)	5.92 (14.43)
Triflumuron	0.04%	9.63 (18.01)	2.82 (9.35)	3.23 (10.14)	1.91 (6.55)	1.70 (7.33)	0.83 (3.32)	4.21 (10.94)
Malathion	0.1%	2.47 (7.63)	2.38 (5.11)	5.26 (13.34)	4.04 (11.47)	8.84 (17.01)	7.31 (16.42)	7.37 (15.17)
Control		10.13 (18.00)	6.35 (13.91)	6.68 (14.19)	16.45 (23.70)	11.64 (19.68)	8.94 (16.88)	16.42 (23.71)
C.D		N.S	N.S	7.150	5.408	N.S	N.S	N.S

Figures in parentheses are mean values after angular transformation.

N.S Not Significant.

Table No. 10 Control of the bhindi stem borer, *Melanagromyza obtusa* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean percentages of stem borer incidence observed at different periods after spraying (days)			
			7	14	21	28
Diflubenzuron	0.01%	0.00 (0.00)	0.00 (0.00)	2.77 (5.47)	2.77 (5.47)	0.00 (0.00)
"	0.02%	0.00 (0.00)	0.00 (0.00)	2.77 (5.47)	2.77 (5.47)	0.00 (0.00)
"	0.03%	0.00 (0.00)	0.00 (0.00)	11.11 (16.23)	2.77 (5.47)	2.77 (5.47)
"	0.04%	0.00 (0.00)	0.00 (0.00)	8.33 (10.00)	2.77 (5.47)	5.55 (8.11)
Triflumuron	0.04%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.77 (5.47)	2.77 (5.47)
Malathion	0.1%	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.77 (5.47)	2.77 (5.47)
Control		0.00 (0.00)	0.00 (0.00)	8.33 (13.59)	16.66 (19.80)	11.11 (16.23)
C.D		-	-	N.S	N.S	N.S

Figures in parentheses are mean values after angular transformation.

N.S Not Significant.

showed significant variations. No fruit borer incidence was recorded in plots treated with diflubenzuron 0.04 per cent. Though there was a lower incidence of damaged fruits in plots treated with the remaining doses of diflubenzuron, triflumuron and malathion, when compared to control, the variations were not statistically significant. The data collected at sixteen days after spraying showed that triflumuron 0.04 per cent was the best for the control of the pest, the percentage of damaged fruits being 1.91 only. This was closely followed by malathion, and the latter was on par with the remaining treatments. The data collected in the subsequent observations did not show significant variations. The incidence of shoot borer was less in the treated plots when compared to control in the various observations recorded though the data did not show statistically significant variations.

4.7.5 <u>Yield</u>.

The mean yield obtained from the plots subjected to the various treatments are presented in Table 11 and the details of statistical analysis are presented in Appendix I. The highest yield was recorded in plots treated with triflumuron 0.04 per cent, and this was closely followed by yield in plots treated with diflubenzuron 0.04 per cent, the yields being 6.90 and 6.49 kg per plot

Table No. 11 Effect of chitin synthesis inhibitors and malathion on the yield of bhindi.

Treatments		Mean yield (kg/plot)
Diflubenzuron	0.01%	5.47
"	0.02%	5.92
"	0.03%	5.67
"	0.04%	6.49
Triflumuron	0.04%	6.90
Malathion	0.1%	5.59
Control		3.19
	C.D	1.000

respectively. The yield in the latter treatment was on par with those obtained from the remaining treatments except diflubenzuron 0.01 per cent, but there was no significant variation in yield obtained from plots treated with the three higher doses of diflubenzuron. The control, with a mean yield of 3.19 kg per plot, was significantly inferior to the different treatments.

4.8 Control of pests of brinjal using chitin synthesis inhibitors

4.8.1 Brinjal spotted beetle, *Epilachna vigintioctopunctata*

The data and results of statistical analysis are presented in Table 12 and Appendix I. The pre-treatment

Table No. 12 Control of the brinjal spotted beetle, *Epilachna vigintioctopunctata* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of larvae observed at different periods after spraying (days)					
			1	7	14	21	28	35
Diflubenzuron	0.01%	25.00 (4.947)	22.33 (4.576)	4.33 (2.158)	0.66 (1.244)	3.00 (1.954)	18.33 (4.325)	12.00 (3.445)
"	0.02%	13.66 (3.823)	9.66 (3.238)	3.00 (1.881)	0.66 (1.244)	2.33 (1.794)	16.66 (4.161)	10.66 (3.151)
"	0.03%	11.66 (3.445)	9.00 (2.973)	4.66 (2.154)	1.00 (1.382)	2.66 (1.910)	14.00 (3.866)	15.66 (3.954)
"	0.04%	19.33 (4.252)	12.33 (3.208)	1.66 (1.550)	1.00 (1.382)	2.33 (1.747)	17.66 (4.310)	15.00 (3.676)
Triflumuron	0.04%	19.66 (4.341)	18.66 (4.396)	0.33 (1.138)	0.00 (1.000)	7.00 (2.903)	17.33 (4.256)	12.00 (3.299)
Malathion	0.1%	10.66 (3.315)	1.33 (1.471)	4.66 (2.354)	5.33 (2.339)	13.66 (3.584)	14.66 (3.951)	7.00 (2.627)
Control		30.66 (5.549)	36.66 (6.132)	58.33 (7.655)	25.00 (5.097)	32.00 (5.723)	24.33 (5.031)	29.66 (5.421)
C.D		N.S	2.159	1.304	0.815	1.123	N.S	N.S

Figures in parantheses are values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant.

count of the beetles in the plots did not show significant variations. The effect of treatment was obvious one day after spraying and maximum reduction of population was observed in plots treated with malathion 0.1 per cent. This was followed by diflubenzuron 0.03, 0.04 and 0.02 per cent concentrations. The differences among the populations in these treatments were not statistically significant. Triflumuron 0.02 per cent and diflubenzuron 0.01 per cent were found on par with control, the population levels being 18.66, 22.33 and 36.66 respectively. The populations observed at seven days after spraying showed highly significant difference between the control and treatments. The mean number of beetles ranged from 0.33 in plots treated with triflumuron 0.02 per cent to 4.66 in plots treated with malathion 0.1 per cent, while the mean number in control plots was as high as 58.33. At fourteen days after spraying also the population of the beetles in treated plots remained low. The chitin synthesis inhibitors were found significantly superior to malathion, there being no significant variation among the doses of the two chitin synthesis inhibitors. Malathion was significantly inferior to the remaining treatments but was seen far superior to control. At twenty-one days after spraying, diflubenzuron 0.04 per cent was found to be the best, and it was followed by the remaining doses of the same insecticide. Triflumuron and malathion were on par and inferior to diflubenzuron 0.02 and 0.04 per cent. All the treatments were significantly superior to control. The data did not show significant variation in the fourth and fifth weeks following spraying.

4.8.2 Brinjal jassid, *Amrasca biguttula biguttula*.

The data and results of statistical analysis are presented in Table 13 and Appendix I. The observations made one day after spraying varied significantly. The least jassid population (0.33 per plot) was found in plots treated with malathion, and it was significantly superior to all other treatments. The population in plots treated with triflumuron 0.02 per cent (12.66) also was less than that of control. The remaining treatments, having populations ranging from 11.66 to 14.66, were on par with control which had a population of 22.66. In the observations made at seven and fourteen days after spraying, diflubenzuron 0.03 per cent, recording populations of 17.66 and 16.33 respectively, were on par with controls which had populations of 25.33 and 20.66 respectively. The remaining doses of diflubenzuron as well as triflumuron and malathion were on par and superior to control. The data collected at twenty-one, twenty-eight and thirty-five days after spraying did not show significant variations.

4.8.3 Brinjal aphid, *Aphis gossypii*.

The data and results of statistical analysis are presented in Table 14 and Appendix I. The chitin synthesis

Table No. 13 Control of the brinjal jassid, <u>Amrasca biguttula biguttula</u> in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of jassids observed at different periods after spraying (days)					
			1	7	14	21	28	35
Diflubenzuron	0.01%	15.00 (3.926)	11.66 (3.398)	12.33 (3.604)	13.00 (3.721)	36.66 (6.008)	26.66 (5.248)	22.00 (4.597)
"	0.02%	11.33 (3.440)	12.00 (3.568)	12.33 (3.598)	13.33 (3.778)	28.33 (5.325)	21.66 (4.726)	18.66 (4.267)
"	0.03%	15.00 (3.923)	14.66 (3.865)	17.66 (4.280)	16.33 (4.143)	44.66 (6.775)	25.33 (5.125)	23.00 (4.642)
"	0.04%	9.66 (3.233)	11.00 (3.449)	13.00 (3.670)	11.00 (3.456)	28.66 (5.440)	21.33 (4.720)	27.66 (5.221)
Triflumuron	0.02%	12.00 (3.506)	12.66 (3.140)	10.33 (3.309)	12.33 (3.630)	37.33 (6.153)	24.00 (4.995)	23.33 (4.684
Malathion	0.1%	17.66 (4.316)	0.33 (1.138)	5.66 (2.468)	14.66 (3.957)	31.33 (5.675)	24.00 (4.997)	16.00 (3.831)
Control		23.33 (4.921)	22.66 (4.820)	25.33 (5.111)	20.66 (4.636)	50.66 (7.184)	27.66 (5.340)	33.33 (5.753)
C.D		N.S	1.442	1.378	0.672	N.S	N.S	N.S

Figures in parentheses are values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant.

Table No. 14 Control of the brinjal aphid, *Aphis gossypii* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of aphids observed at different periods after spraying (days)					
			1	7	14	21	28	35
Diflubenzuron	0.01%	55.00 (7.039)	84.00 (9.122)	63.66 (7.728)	59.33 (7.623)	55.00 (7.479)	27.33 (5.311)	40.24 (6.322)
"	0.02%	43.66 (6.431)	80.00 (8.960)	35.00 (5.865)	100.66 (10.077)	68.66 (8.284)	22.00 (4.763)	33.20 (5.764)
"	0.03%	55.33 (6.950)	107.33 (10.334)	53.00 (6.464)	76.66 (8.735)	69.22 (8.197)	22.00 (4.788)	32.33 (5.688)
"	0.04%	44.33 (6.407)	117.00 (10.632)	65.33 (7.209)	101.66 (9.647)	87.33 (8.865)	21.66 (4.753)	34.60 (5.883)
Triflumuron	0.02%	86.66 (9.006)	99.66 (9.639)	86.00 (9.208)	54.33 (7.295)	47.00 (6.858)	23.66 (4.954)	32.62 (5.711)
Malathion	0.1%	59.66 (7.461)	7.66 (2.650)	5.00 (2.000)	33.66 (5.757)	67.00 (7.888)	24.33 (4.999)	34.60 (5.881)
Control		44.00 (6.652)	136.66 (11.688)	47.00 (6.825)	125.66 (11.237)	130.33 (11.448)	27.00 (5.282)	46.56 (6.822)
C.D		N.S	3.945	N.S	N.S	N.S	N.S	N.S

Figures in parentheses are values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant.

inhibitors did not show any significant reduction in the population of aphids on brinjal. Malathion 0.1 per cent controlled the pest significantly for the first week and subsequently the population in those plots also increased and came on par with that of the control plots.

4.8.4 Brinjal fruit and shoot borer, *Leucinodes orbonalis* and *Euzophera perticella*.

The data and results of statistical analysis are presented in Tables 15 and 16 and Appendix I. The effect of treatment was obvious from the percentage of infested fruits collected between 16 and 23 days after spraying. Here, diflubenzuron 0.01 per cent was least effective and on par with control. The other treatments were on par and superior to control. The percentage of infested fruits collected between twenty-three and thirty-one days after spraying was least in plots treated with diflubenzuron 0.04 per cent and it was significantly superior to all the other treatments. This treatment was followed by diflubenzuron 0.03 and 0.01 per cent and triflumuron 0.02 per cent, there being no significant difference among the treatments. Diflubenzuron 0.02 per cent was on par with malathion and the latter was on par with control. In the percentage of incidence observed between thirty-one and thirty-eight days after spraying also the least incidence of infested fruits was seen in plots treated with

Table No. 15 Control of the brinjal fruit borer, *Leucinodes orbonalis* in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Mean percentages of fruit borer incidence observed at different periods after spraying (days)					
		9	16	23	31	38	47
Diflubenzuron	0.01%	39.52 (38.93)	15.72 (23.11)	11.49 (20.23)	4.33 (12.00)	2.75 (9.26)	5.32 (13.34)
"	0.02%	38.33 (38.07)	13.34 (21.00)	8.59 (16.82)	4.49 (12.35)	2.76 (7.63)	6.15 (14.09)
"	0.03%	34.44 (35.54)	11.36 (15.82)	7.02 (15.09)	2.07 (8.13)	5.24 (12.80)	6.16 (14.27)
"	0.04%	41.66 (39.76)	5.55 (8.22)	3.96 (11.28)	0.77 (2.71)	0.90 (3.32)	2.67 (9.26)
Triflumuron	0.02%	27.77 (26.68)	9.44 (14.33)	5.90 (13.68)	3.91 (11.37)	1.11 (5.42)	4.32 (11.76)
Malathion	0.1%	38.88 (38.37)	29.67 (32.54)	4.92 (12.80)	5.88 (14.18)	6.39 (14.95)	4.85 (12.42)
Control		36.11 (36.68)	50.95 (36.77)	14.83 (22.76)	9.19 (17.78)	8.20 (16.52)	16.46 (23.99)
C.D		N.S	N.S	5.589	4.051	6.783	6.845

Figures in parentheses are values after angular transformation.

N.S Not Significant.

Table No. 16 Control of the brinjal stem borer, <u>Euzophera perticella</u> in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Mean percentages of stem borer incidence observed at different periods after spraying (days)		
		7	21	35
Diflubenzuron	0.01%	0.00 (0.00)	27.77 (26.68)	27.77 (31.20)
"	0.02%	5.53 (8.11)	16.66 (15.00)	33.33 (35.06)
"	0.03%	11.11 (11.68)	22.22 (23.11)	16.66 (19.80)
"	0.04%	11.10 (16.23)	5.53 (8.11)	33.33 (34.80)
Triflumuron	0.02%	16.66 (19.80)	11.10 (16.23)	16.66 (19.80)
Malathion	0.1%	11.10 (16.23)	5.53 (8.11)	22.22 (23.11)
Control		16.66 (19.80)	11.10 (16.23)	44.44 (47.58)
C.D		N.S	N.S	N.S

Figures in parentheses are values after angular transformation.

N.S Not Significant.

diflubenzuron 0.04 per cent. But this treatment was also on par with triflumuron 0.02 per cent and diflubenzuron 0.02 and 0.01 per cent. Diflubenzuron 0.03 per cent and malathion 0.1 per cent were found on par with control. Percentage of infested fruits collected between thirty-eight and forty-seven days after spraying was also significantly lower in treated plots than in control plots, there being no significant variation among the different treatments. The data relating to the incidence of brinjal shoot borer did not show significant variations.

4.8.5 Yield

The yield obtained from the various plots and the results of statistical analysis are presented in Table 17 and Appendix I.

Table No. 17 Effect of chitin synthesis inhibitors and malathion on the yield of brinjal.

Treatments		Mean yield (kg/plot)
Diflubenzuron	0.01%	6.33
"	0.02%	6.10
"	0.03%	6.30
"	0.04%	6.40
Triflumuron	0.02%	5.95
Malathion	0.1%	4.06
Control		3.01
	C.D	1.05

The yield obtained from plots treated with diflubenzuron 0.04, 0.01, 0.03, 0.02 per cent and triflumuron 0.02 per cent were 6.40, 6.33, 6.30, 6.10 and 5.95 kg per plot respectively. The difference among these treatments were not statistically significant. The malathion treatment which gave a mean yield of 4.06 kg per plot was found on par with control which gave an yield of 3.01 kg per plot.

4.9 Control of pests of amaranthus using chitin synthesis inhibitors

4.9.1 Amaranthus leaf webber, *Psara bassalis*.

The data and results of statistical analysis relating to this are presented in Table 18 and Appendix I. The pre-treatment count of the pest in various plots did not vary significantly. All the treatments, except diflubenzuron 0.01 per cent brought about a drastic reduction in the pest population as observed one day after spraying, the population ranging from 3.66 to 8.33 per plot. Diflubenzuron 0.01 per cent, with a mean population of 10.66 per plot, was on par with control which had a population of 18.53 per plot. The population observed seven days after spraying showed that all treatments including diflubenzuron 0.01 per cent, were significantly superior to the control, though the former was significantly inferior to triflumuron 0.04 per cent and diflubenzuron 0.03 per cent which completely controlled the pest.

Table No. 18 Control of the amaranthus leaf webber, Psara basalis in field using chitin synthesis inhibitors and a standard insecticide (Malathion).

Treatments		Pre-treatment count	Mean number of larvae observed at different periods after spraying (days)			
			1	7	14	21
Diflubenzuron	0.01%	12.00 (3.592)	10.66 (3.410)	2.00 (1.715)	1.66 (1.609)	2.00 (1.715)
"	0.02%	12.33 (3.597)	8.33 (3.040)	0.33 (1.138)	0.66 (1.244)	2.00 (1.715)
"	0.03%	11.00 (3.410)	5.00 (2.440)	0.00 (1.000)	0.66 (1.244)	2.66 (1.883)
"	0.04%	9.66 (3.154)	6.33 (2.490)	0.66 (1.244)	0.00 (1.000)	2.66 (1.883)
Triflumuron	0.04%	6.33 (2.681)	3.66 (2.021)	0.00 (1.000)	0.33 (1.138)	2.66 (1.865)
Malathion	0.1%	10.00 (3.307)	4.00 (2.228)	1.66 (1.609)	7.00 (2.781)	2.66 (1.900)
Control		17.66 (4.267)	18.53 (4.340)	15.66 (4.040)	20.00 (4.550)	3.00 (1.989)
C.D		N.S	1.3490	0.6809	0.8355	N.S

Figures in parentheses are values after $(x+1)^{\frac{1}{2}}$ transformation.

N.S Not Significant.

At fourteen days after spraying, the population in plots treated with malathion and the untreated plots increased significantly while in other treatments it remained without significant change. The chitin synthesis inhibitors were significantly superior to control while they were on par among themselves. The effect of treatment were lost at twenty-one days after spraying as revealed from the non significant variation in the data collected.

4.9.2 Yield

The yield obtained from various treatments and control are presented in Table 19 and the results of statistical analysis are presented in Appendix I.

Table No 19 Effect of chitin synthesis inhibitors and malathion on the yield of amaranthus.

Treatments		Mean yield (kg/plot)
Diflubenzuron	0.01%	2.18
"	0.02%	2.12
"	0.03%	2.06
"	0.04%	2.23
Triflumuron	0.04%	2.24
Malathion	0.1%	1.52
Control		1.22
	C.D	0.57

The maximum yield was obtained in plots treated with triflumuron 0.04 per cent (2.24 kg per plot) and it was closely followed by plots treated with diflubenzuron 0.04, 0.01, 0.02 and 0.03 per cent (2.23, 2.18, 2.12 and 2.06 kg per plot respectively), there being no significant differences among these treatments. Malathion treated plots (1.52 kg per plot) were on par with control plots which yielded 1.22 kg per plot.

4.10 Persistent toxicity of chitin synthesis inhibitors and malathion applied on bhindi to the fourth instar larvae of *Sylepta derogata*

The data are presented in Table 20 and Fig. 13. The toxicity of triflumuron and the lower doses of diflubenzuron persisted upto twenty-eight days, while that of the higher doses of diflubenzuron and malathion persisted upto twenty-one and fourteen days respectively. The persistent toxicity of the insecticide to *S. derogata* was found to be maximum for triflumuron which had a PT index of 955.5. This was followed by diflubenzuron 0.04, 0.03, 0.02 and 0.01 per cent, the PT indices being 932.4, 791.7, 653.1 and 581.7 respectively. Malathion had the lowest PT index (303.1).

4.11 Persistent toxicity of chitin synthesis inhibitors and malathion applied on brinjal to the fourth instar larvae of *Epilachna vigintioctopunctata*

The data are presented in Table 21 and Fig. 13. Triflumuron 0.02 per cent and diflubenzuron 0.04 per cent

Table No. 20 Persistent toxicity of two chitin synthesis inhibitors and malathion applied on bhindi to the larvae of <u>*Sylepta derogata*</u>.

Treatments		Per cent mortality of larvae exposed at different intervals after spraying (days)					P	T	PT
		7	14	21	28	35			
Diflubenzuron	0.01%	46.6	26.6	6.6	3.3	0.0	28	20.7	581.7
"	0.02%	43.3	30.0	10.0	10.0	0.0	28	23.3	653.1
"	0.03%	50.0	43.3	20.0	0.0	0.0	21	37.7	791.7
"	0.04%	53.3	56.6	23.3	0.0	0.0	21	44.4	932.4
Triflumuron	0.04%	46.6	53.3	26.6	10.0	0.0	28	34.1	955.5
Malathion	0.1%	30.0	13.3	0.0	0.0	0.0	14	21.6	303.1

P Period after treatment in days.

T Average residual toxicity.

PT Index of persistent toxicity.

Table No. 21 Persistent toxicity of two chitin synthesis inhibitors and malathion applied on brinjal to the larvae of *Epilachna vigintioctopunctata*.

Treatments		Per cent mortality of larvae exposed at different intervals after spraying (days)					P	T	PT
		7	14	21	28	35			
Diflubenzuron	0.01%	43.3	26.6	3.3	0.0	0.0	21	24.4	512.4
"	0.02%	46.6	33.3	6.6	0.0	0.0	21	28.8	604.8
"	0.03%	50.0	33.3	6.6	0.0	0.0	21	29.9	627.9
"	0.04%	53.3	36.6	10.0	3.3	0.0	28	25.8	722.4
Triflumuron	0.02%	40.0	43.3	6.6	3.3	0.0	28	23.3	652.4
Malathion	0.1%	26.6	3.3	0.0	0.0	0.0	14	14.8	207.2

P Period after treatment in days.

T Average residual toxicity.

PT Index of persistent toxicity.

remained toxic to the insect upto twenty-eight days, while the remaining dose of diflubenzuron persisted upto twenty-one days and malathion upto fourteen days. The persistent toxicity based on PT indices was found to be highest for diflubenzuron 0.04 per cent and this was followed in the descending order by triflumuron, diflubenzuron 0.03 per cent, diflubenzuron 0.02 per cent, diflubenzuron 0.01 per cent and malathion, the PT indices being 722.4, 652.4, 627.9, 604.8, 512.4 and 207.2 respectively.

4.12 Persistent toxicity of chitin synthesis inhibitors and malathion applied on amaranthus to the fourth instar larvae of Psara basalis

The data are presented in Table 22 and Fig. 13. The toxicity of chitin synthesis inhibitors persisted upto twenty-one days, while that of malathion remained only for fourteen days. Based on PT indices the persistent toxicity of the various treatments could be ranked in the following descending order: triflumuron 0.04 per cent (PT index 606.1), diflubenzuron 0.04 per cent (558.6), diflubenzuron 0.03 per cent (536.1), diflubenzuron 0.02 per cent (373.0), diflubenzuron 0.01 per cent (348.6) and malathion 0.1 per cent (280.0).

Unlike the juvenile hormone analogues which killed only later instars, chitin synthesis inhibitors effectively killed all larval instars as shown by the dose-effect relationship. Even if larvae were not killed, these

Table No. 22 Persistent toxicity of chitin synthesis inhibitors and malathion applied on amaranthus to the larvae of *Psara basalis*.

Treatments		Per cent mortality of larvae exposed at different intervals after spraying (days)				P	T	PT
		7	14	21	28			
Diflubenzuron	0.01%	26.6	16.6	6.6	0.0	21	16.6	348.6
"	0.02%	30.0	13.3	10.0	0.0	21	17.7	373.0
"	0.03%	43.3	20.0	13.3	0.0	21	25.5	536.1
"	0.04%	46.6	26.6	6.6	0.0	21	26.6	558.6
Triflumuron	0.04%	50.0	23.3	13.3	0.0	21	28.8	606.1
Malathion	0.1%	30.0	10.0	0.0	0.0	14	20.0	280.0

P Period after treatment in days.

T Average residual toxicity.

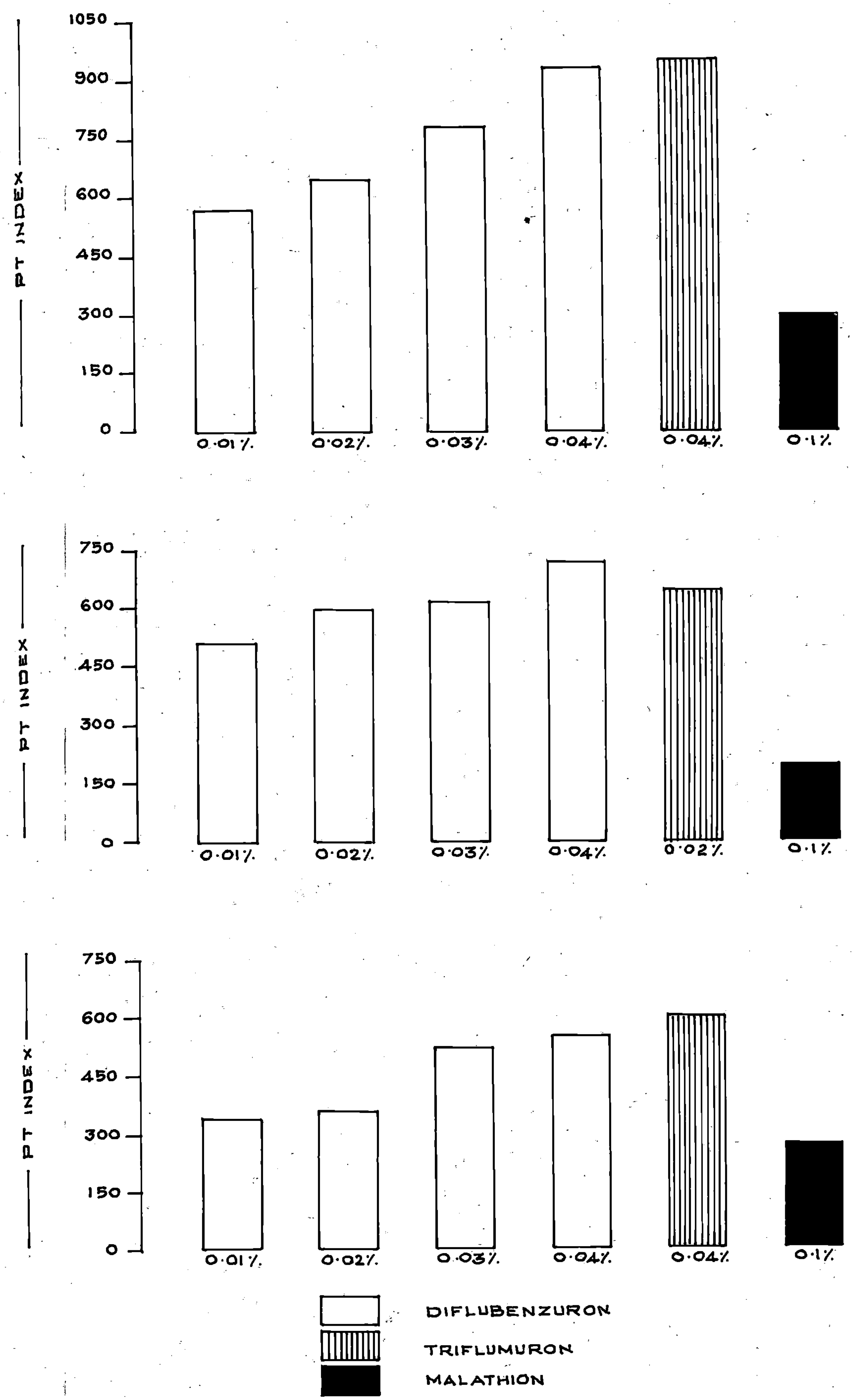
PT Index of persistent toxicity.

Persistent toxicity of chitin synthesis inhibitors and malathion applied on Bhindi to *Sylepta derogata*

Persistent toxicity of chitin synthesis inhibitors and malathion applied on Brinjal to *Epilachna vigintioctopunctata*

Persistent toxicity of chitin synthesis inhibitors and malathion applied on Amaranthus to *Psara basalis*

FIG. 13.


PT INDEX
1050
900
750
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DIFLUBENZURON
TRIFLUMURON
MALATHION

chemicals were seen to disrupt the later life stages and even affect fecundity of adults and hatchability of eggs laid by them. Besides this, their moderate persistence, coupled with the fact that they are less toxic to non-target organisms seems to indicate that chitin synthesis inhibitors are preferable to most conventional insecticides in use today.

DISCUSSION

5. DISCUSSION

The dose-effect relationship of the chitin synthesis inhibitors and the test insects was assessed in terms of average survival periods and speed indices as the treated larvae usually died from the third day after treatment onwards, though some survived longer. Similar observations were made by Beevi and Dale (1980) also. The dose-effect relation to the two chitin synthesis inhibitors on Sylepta derogata was found to be positive and linear. The toxic effect on the second and third instar caterpillars was more or less the same, while the average survival period of the treated fourth instar caterpillars was significantly longer. Such negative relationship between the toxicity of chitin synthesis inhibitors and age of the insect treated has been reported by earlier workers also (Grosscurt, 1978b; House et al., 1978; Ascher et al., 1978a).

The relative toxicity of the two chemicals was found to be more or less the same as shown by the average survival periods of the second and third instar larvae of S. derogata. In lower doses tried against fourth instar larvae, triflumuron was found to be slightly more toxic than the corresponding doses of diflubenzuron (Fig. 2). The relative toxicity of the two chemicals had not been studied earlier.

In the case of Epilachna vigintioctopunctata, the second and third instar larvae were found to be more susceptible and the positive and linear nature of the dose-effect relationship was not clearly manifested since the survival periods in various treatments were almost on par. The survival of the third instar larvae treated with 0.00001 per cent concentration of the insecticides survived for a significantly longer period (Table 2).

As in the case of S. derogata, the fourth instar larvae of E. vigintioctopunctata were also less susceptible. The corresponding higher three doses of triflumuron and diflubenzuron were equitoxic in the case of second and third instar larvae while the two lower doses of triflumuron were slightly more toxic than the corresponding doses of diflubenzuron.

The average survival period of the second instar larvae of Psara basalis was 0.500 in all the treatments. This low survival period indicated the high toxicity of chitin synthesis inhibitors to this instar of the insect (Table 3). The higher two dosages of diflubenzuron and the higher three dosages of triflumuron were found to be more effective for the control of fourth instar caterpillars while the two lower dosages of both insecticides were relatively less toxic. In general, the relative toxicity of the two insecticides at the different doses tried were on par against the different larval instars of P. basalis.

Among the three insects, P. basalis was found to be most susceptible to the chitin synthesis inhibitors. The average survival period of second instar larvae of *P. basalis* treated with these toxicants in different doses was 0.500 days only, while in the case of *E. vigintioctopunctata* it ranged from 0.500 to 0.950 days and for *S. derogata* the range was from 2.500 to 3.183 days. In the case of the third instar larvae of *P. basalis*, *E. vigintioctopunctata* and *S. derogata*, the average survival periods ranged from 0.533 to 0.933, 1.500 to 3.000 and 2.500 to 4.650 days respectively. In the fourth instar larvae of the above insects, the average survival periods ranged from 0.566 to 1.986, 2.513 to 4.433 and 4.000 to 5.733 days respectively.

Besides the mortality caused by chitin synthesis inhibitors, various malformations and deformities, as described under results, were observed in the different life stages of the test insects. The sublethal doses of the chitin synthesis inhibitors, especially on the later instars, resulted in the development of larval-pupal mosaics in *P. basalis*, *S. derogata* as well as in *E. vigintioctopunctata*. Such larval-pupal mosaics were observed in *Nephantis serinopa* treated with diflubenzuron by Sundaramurthy and Santhakrishnan (1979). As observed in the present studies, these scientists had also noted the development of mosaics with larval heads and untransformed thoracic legs. Sometimes, the pupal skin was seen split but the adults were unable to emerge and even when the adults emerged they were found highly malformed with crumpled wings. The incomplete moulting and malformations observed in the present study may be attributed to the blockage of chitin deposition as reported by many earlier workers (Post and Vincent, 1973; Salama *et al.*, 1976; Ishaaya and Ascher, 1977; Ker, 1978; Hammann and Sirrenberg, 1980). Such incomplete moulting and chimeric morphological deformities are also suggestive of hormonal interference. Yu and Terriere (1977) suggested that ecdysone was inhibited in three different species of diptera. Lung (1980) had also suggested that chitin synthesis inhibitors had an effect on the endocrine system of the insect. While the juvenile hormone did not exhibit a lethal action on earlier instars of insects, the chitin synthesis inhibitors were found highly toxic to these stages. This gave an added advantage to these chemicals over JH analogues for use in the field of plant protection.

Feeding of adults of *E. vigintioctopunctata* on brinjal leaves treated with the chitin synthesis inhibitors showed that the two chemicals reduced the average survival period of the insect significantly. The dose-response relationship was both positive and linear. Between the corresponding doses of the two insecticides, there were no significant variations.

The number of eggs laid by the treated females were significantly lower than the number obtained in the control. Between the two insecticides, there was no significant difference in the sterilant effect. The hatching percentage of eggs laid by treated females was also far less than that obtained in control. However, between the corresponding doses of insecticides the variations were not statistically significant. Chemosterilant action of Dimilin was earlier reported on adult fruit fly (Arambourg, 1977) and cotton boll weevils (McLaughlin, 1977). Schroeder (1976) described Dimilin as a disruptive chemical in oogenesis and embryonic development in insects.

The ovicidal effect caused by dipping of eggs in different dilutions of chitin synthesis inhibitors for 15 minutes showed that the effect was positive and linear. All the treatments significantly reduced the hatching percentage of eggs. Between the two chemicals, there was no significant difference in effect. Ovicidal action of diflubenzuron was reported by earlier workers also (Grosscurt, 1977, 1978b; Hajiar and Casida, 1979; Bull, 1980). The mode of ovicidal action was attributed to an interference of chitin synthesis within the eggs (Grosscurt, 1978b). Bull and Ivie (1980) and Hammann and Sirrenberg (1980) attributed the lack of larval emergence due to the weakness of the cuticle which could not provide adequate rigidness for supporting muscles involved in the eclosion process.

The average survival period of the larvae which emerged from the treated eggs also showed significant variations.

The dose of 0.1 and 0.01 per cent were most effective and 0.001 and 0.0001 per cent were of intermediate efficacy while the lowest dose of 0.00001 per cent was relatively ineffective though superior to control. Between the two insecticides there was no significant difference.

The field evaluation of chitin synthesis inhibitors in comparison with malathion was done against the pests of bhindi, brinjal and amaranthus. Against bhindi leaf roller, S. derogata malathion showed maximum reduction of pest population one day after spraying, and it was on par with triflumuron. The latter was on par with the three higher doses of diflubenzuron. One week after spraying, the population in all treatments were on par and superior to control. In subsequent observations, the pest build up was more in malathion treated plots than in plots treated with chitin synthesis inhibitors. In all these observations, triflumuron showed the lowest level of larval population. However, the difference in the efficacy of triflumuron and various doses of diflubenzuron was not significant. It can be concluded that the chitin synthesis inhibitors even at low doses of 0.01 per cent can effectively control the pest. The slight superiority in the performance of triflumuron observed in this field experiment was also noted in the dose-effect relationship of the two chemicals discussed earlier.

Against the bhindi jassid Amrasca biguttula biguttula, malathion was found to be significantly superior to the chitin synthesis inhibitors as observed one day after spraying, while the latter at the various levels tried were on par in effectiveness. At seven days after spraying, malathion was found to be on par with the two higher doses of diflubenzuron and fourteen days after spraying, all the treatments were found superior to control while there were no significant variations among the treatments.

The population of bhindi aphid Aphis gossypii observed at different occasions after spraying showed that the chitin synthesis inhibitors were not very effective against the pest, while malathion brought down the population. This effect lasted upto one week after spraying. Subsequently the populations in these plots also increased and came on par with control.

The effect of treatment on the incidence of bhindi fruit borer, Earias sp. was obvious from the percentage of infested fruits observed during the first nine days after spraying and during the period from nine to sixteen days after spraying. The least incidence was observed in plots treated with diflubenzuron 0.04 per cent during the first week. During the second week this treatment was found on par with malathion, and the latter was on par with the other treatments except control. The treatments did not significantly control the incidence of shoot borer.

The results showed that the two chitin synthesis inhibitors were superior to malathion or atleast on par with it in controlling the major pests in bhindi. Between the two chitin synthesis inhibitors there was no significant difference in efficacy at the doses at which they were tried.

The yield data also showed favourable influence of the treatments on the crop. The maximum yield was obtained in plots treated with triflumuron, and it was on par with the yield from diflubenzuron treated plots. The doses of 0.03 and 0.02 per cent of diflubenzuron were also on par with the higher dose of 0.04 per cent. The yield in control was significantly lower. Since the level of pest incidence on the crop was not very high, the above increase in yield cannot reasonably be attributed to the extent of protection offered to the crop from pest injury. This increase may, as in the case of many insecticides, be attributed to the phytotonic effect of the chemicals. Iacob _et al._ (1980) reported that doses of 0.04 and 0.06 per cent Dimilin apparently stimulated photosynthesis in leaves and accumulation of sugars, ascorbic acid and total acids in fruits, thereby improving the quality and quantity of produce in peaches.

Among the pests of brinjal the most important one observed was the spotted beetle, _E. vigintioctopunctata_.

Against this pest, malathion was found to give the best results initially as observed one day after spraying and it was also on par with the three higher doses of diflubenzuron. All the treatments were found superior and very effective against the pest seven days after spraying, when compared to the population in the control plots. At fourteen days after spraying, malathion was found inferior to chitin synthesis inhibitors in controlling the pest while all the treatments were keeping the pest in check. The population was least in plots treated with triflumuron. The subsequent build up in population was less in plots treated with diflubenzuron and malathion as observed twenty-one days after spraying. The population in control was still high. At twenty-eight days after spraying, the population in treatments came on par with that of control.

The brinjal jassid, Amrasca biguttula biguttula was also effectively controlled by various treatments. Initially malathion gave the best control, but as observed at seven and fourteen days after spraying, malathion came on par with other treatments except with diflubenzuron 0.03 per cent, the latter being on par with the control. As in the case of bhindi aphid, the brinjal aphid, Aphis gossypii was not effectively controlled by chitin synthesis inhibitors. The population in malathion treated plots remained low for a period of one week after spraying and subsequently got built up.

The brinjal fruit borer, Leucinodes orbonalis was also found controlled by the various treatments. The chitin synthesis inhibitors reduced the percentage of fruits damaged by L. orbonalis as observed at twenty-three, thirty-one, thirty-eight and forty-seven days after spraying. In general the different doses of diflubenzuron and triflumuron 0.02 per cent were found to be on par and were also on par with malathion or slightly superior to the same. The treatments did not give significant control of shoot borer incidence.

The data presented in Table 17 showed that chitin synthesis inhibitors had a favourable influence on the yield. The yield obtained from malathion treated plots was on par with that from control plots.

On amaranthus, the leaf webber P. basalis was the only pest observed during the period of the experiment. All the doses of diflubenzuron and triflumuron 0.04 per cent gave effective control of the pest upto fourteen days after spraying. The plots treated with malathion 0.1 per cent also showed the same level of population upto seven days after spraying, but subsequently there was an increase of population in these plots.

The yield of amaranthus was also favourably influenced by chitin synthesis inhibitors while the yield obtained from the plot treated with malathion was slightly higher than control.

The persistent toxicity of chitin synthesis inhibitors to S. derogata was found to be higher than that of malathion. Among the chitin synthesis inhibitors, triflumuron had a higher persistent toxicity to the pest than diflubenzuron. Regarding the different dosages of diflubenzuron tried, a positive linear relationship was observed between doses and persistent toxicity (Fig. 13). The maximum persistent toxicity was noted for diflubenzuron 0.04 per cent and it was followed by triflumuron 0.02 per cent and diflubenzuron 0.03, 0.02 and 0.01 per cent. The PT index obtained for malathion was relatively very low (Fig. 13). Based on the persistent toxicity to P. basalis, the treatments could be ranked in the following descending order: triflumuron 0.04 per cent, diflubenzuron 0.04, 0.03, 0.02 and 0.01 per cent. Based on the response of the three test insects tried, it can be concluded that the chitin synthesis inhibitors are much more persistent under field conditions than malathion.

El-Tantawi et al. (1976) have reported that residues of Dimilin remained effective on cotton leaves against S. littoralis for over fifteen days, while Schaefer and Dupras (1977) found it persisting upto twenty-six days in field. Beevi (1979) reported persistence of diflubenzuron on potted rice seedlings upto fifty days under protected conditions. As the chitin synthesis inhibitors appear to be moderately persistent they seem to be favourable insecticides for the control of vegetable pests.

SUMMARY

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The dose-effect relationship of two chitin synthesis inhibitors viz., diflubenzuron and triflumuron against three vegetable pests viz., *Sylepta derogata*, *Epilachna vigintioctopunctata*, and *Psara basalis* was assessed in terms of the average survival periods and speed indices following the method developed by Pradhan (1949). The chemicals were administered orally by making the larvae feed on treated food materials. The dose-effect relation of the chemicals on *Sylepta derogata* was found to be positive and linear. The toxic effect of the various doses on the second and third instar caterpillars was more or less the same while the average survival period of the fourth instar caterpillar was significantly longer. The toxicity of the corresponding doses of the two insecticides against the second and third instar larvae did not vary significantly. Against the fourth instar larvae, at the lower doses, triflumuron was found to be more toxic.

The larval stages of *Epilachna vigintioctopunctata* were more susceptible than *S. derogata* larvae. The different doses tried were almost equitoxic to the second and third instar caterpillars. The average survival period was significantly high in the lowest dose of 0.00001 per cent. At lower

doses triflumuron was slightly more toxic to forth instar larvae.

The larvae of Psara basalis were most susceptible to the chitin synthesis inhibitors. The survival period of the second instar larvae was 0.500 days only. The higher doses of the chemicals were found to be effective for the control of fourth instar larvae. The two chemicals did not differ significantly in their toxicity to the various larval instars of P. basalis.

Besides the mortality caused by chitin synthesis inhibitors, various malformations and deformities were observed in the various life stages of the insects, especially when the chemicals were applied at lower concentrations and on the later larval instars. In larvae the effect was manifested as the blackening, shortening or softening of the body prior to death. In pupae, characteristic larval-pupal mosaics were formed. Pupae could not moult out of the pupal skin completely, or moulted as adults deformed with crumpled wings, twisted and shortened abdomens and brittle antennae and legs. These malformations are suggestive of the chemicals interfering with chitin synthesis and the moulting processes of the test insects. Interference of normal hormonal control of metamorphosis is also suggested.

The sterilant action of the two chitin synthesis inhibitors on E. vigintioctopunctata was assessed by feeding freshly emerged adults with treated brinjal leaves. The treatments significantly affected the average survival period of adults when compared to control. The mean number of eggs laid by the surviving adults was also adversely affected by the sterilant effect of the chemicals and the hatching percentage of eggs laid also less than that in control. The different doses of the chemicals showed an overall linear response with reference to these chemosterilant effects. There was no significant variation in the sterilant effect of the two chitin synthesis inhibitors tried.

The ovicidal effect caused by dipping the eggs of E. vigintioctopunctata for fifteen minutes in suspensions/emulsions of the compounds was shown by the significant reduction in the hatching percentage in all the treatments. Between the two chemicals there was no significant difference in effect.

The relative efficacy of the two chitin synthesis inhibitors in comparison with malathion (as insecticide commonly used for the control of vegetable pests) was assessed under field conditions against the pests of bhindi, brinjal and amaranthus. A randomised block design was adopted for the experiment. Malathion was found superior in controlling the bhindi leaf roller, S. derogata initially, but later the pest build up was faster in malathion treated plots than in plots treated with the two chitin synthesis inhibitors. In general, the various doses of diflubenzuron and the single dose of triflumuron tried were found to be on par. Results showed that 0.01 per cent of chitin synthesis inhibitors could be advantageously used for the control of the pest. Against the bhindi jassid, Amrasca biguttula biguttula, malathion was found to be superior in initial control but in subsequent observations all the treatments came on par and significantly superior to control. None of the treatments in the present experiment effectively controlled the aphid, Aphis gossypii on bhindi, though the population was kept low by malathion upto one week after spraying. The chitin synthesis inhibitors were found effective in controlling bhindi fruit borer Earias sp. also. Diflubenzuron 0.04 per cent was found superior during the first week after spraying. In the second week it was on par with malathion and subsequently all treatments came on par. Shoot borne incidence in the various plots was very low and the chitin synthesis inhibitors did not seem to control this pest.

The yield data indicated that the chitin synthesis inhibitors probably exerted phytotonic effect on the crop the yield being superior to those from plots treated with malathion and untreated plots.

Among the pests of brinjal the spotted beetle *E. vigintioctopunctata* were predominantly available. The population was least in plots treated with triflumuron in the initial observation, but subsequent build up was less in plots treated with diflubenzuron. As in previous cases, though malathion was superior for initial control, the build up of population was more in plots treated with this chemical. The treatment effect was seen lost in plots four weeks after spraying. The brinjal jassid, *Amrasca biguttula biguttula* was also controlled by the various treatments, there being no significant variation among them. The brinjal aphid, *Aphis gossypii* was not controlled by the treatments except malathion. The different doses of diflubenzuron and triflumuron 0.02 per cent was found to be on par and effective against brinjal fruit borer, *Leucinodes orbonalis* while malathion was found to be inferior to them, all the treatments being significantly superior to control. The chitin synthesis inhibitors had a favourable influence on the yield of brinjal also while the yield obtained from malathion treated plots was on par with control.

On amaranthus, *P. basalis* was the only pest observed during the experiment. Seven days after spraying, the population was low in all the treated plots, while in subsequent observations, the population level became relatively higher in malathion treated plots. The yield obtained from plots treated with the chitin synthesis inhibitors was significantly higher than that of the malathion treated plots and of the untreated plots.

The persistent toxicity of the two chitin synthesis inhibitors and malathion to fourth instar larvae of S. derogata, E. vigintioctopunctata and P. basalis was assessed by exposing the larvae in the laboratory on treated leaves of the food plants collected at different intervals after spraying and then noting their mortality. In general, the chitin synthesis inhibitors had much higher persistent toxicity than malathion. The chitin synthesis inhibitors persisted for 21 to 28 days, while malathion persisted only upto 14 days.

As observed from the dose-effect relationship chitin synthesis inhibitors killed all larval instars, unlike the juvenile hormone analogues, a similar category of third generation insecticides, effectively controlled the later instars only. The overall mortality caused by the chitin synthesis inhibitors was near cent per cent since the surviving larvae failed to pupate normally and even when pupated, produced only abnormal adults which had limited egg production capacity. The hatching percentage of the laid eggs was also very low. Due to this multiple effect, the build up of subsequent generations would be less in plots treated with these insecticides. This effect was patent in the field experiments as well. Being chemicals which are less toxic to non-target organisms and with only moderate field persistence, they are preferable to the conventional pesticides. These attributes strongly suggest the desirability of using chitin synthesis inhibitors in preference to the conventional insecticides for the control of the various pest populations.

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* Original not seen

APPENDIX

APPENDIX - I

Abstract of ANOVA		Mean Square		
		Block	Treatment	Error
			(9)	(20)
Table No.1	2nd instar		0.213*	0.015
	3rd instar		1.715*	0.311
	4th instar		1.049*	0.170
Table No.2	2nd instar		0.081*	0.104
	3rd instar		0.568*	0.367
	4th instar		1.450*	0.188
Table No.3	2nd instar		..	..
	3rd instar		0.045*	0.010
	4th instar		1.132*	0.023
			(6)	(14)
Table No.4	Average survival period (adults)		204.572*	9.947
	Eggs/female		111.181*	2.040
	Hatching percentage		9343.138*	1613.144
			(10)	(21)
Table No.5	Hatching percentage		261.932*	936.471
			(9)	(20)
	Average survival period (larvae)		53.200*	2.949
		(2)	(6)	(12)
Table No.6	Pre-treatment	0.621	0.163	0.172
	1 DAS	0.138	0.691*	0.115
	7 DAS	0.293	3.490*	0.163
	14 DAS	1.563	3.906*	0.234
	21 DAS	1.171	3.066*	0.449
	28 DAS	0.933	3.945	2.298

Abstract of ANOVA		Mean square Block	Treatment	Error
		(2)	(6)	(12)
Table No.7	Pre-treatment	1.260	2.937	3.414
	1 DAS	0.257	1.686*	0.229
	7 DAS	1.009	2.132*	0.431
	14 DAS	1.004	0.910*	0.258
	21 DAS	1.082	0.732	0.533
	28 DAS	1.260	2.937	3.414
Table No.8	Pre-treatment	1.260	2.933	3.033
	1 DAS	0.933	3.935	2.378
	7 DAS	0.286	2.344	0.915
	14 DAS	0.548	1.167	0.361
	21 DAS	6.309	4.163	3.751
	28 DAS	1.325	1.414	0.596
Table No.9	Pre-treatment	89.910	56.203	36.352
	2 DAS	2.555	40.872	27.772
	9 DAS	8.762	70.908*	15.890
	16 DAS	29.548	80.861*	9.090
	23 DAS	0.936	46.478	19.257
	29 DAS	4.422	72.175	87.850
	36 DAS	6.326	59.505	32.576
Table No.10	14 DAS	23.035	59.978	134.778
	21 DAS	99.588	305.429	103.591
	28 DAS	38.671	90.906	104.420
Table No.11	Bhindi yield	0.930	4.222*	0.322

Abstract of ANOVA		Mean Square Block	Treatment	Error
		(2)	(6)	(12)
Table No.12	Pre-treatment	3.988	1.943	1.328
	1 DAS	2.170	6.557*	1.473
	7 DAS	1.733	14.849*	0.537
	14 DAS	0.681	6.300*	0.210
	21 DAS	0.178	6.397*	0.398
	28 DAS	0.429	0.533	0.152
	35 DAS	0.286	2.344	0.915
Table No.13	Pre-treatment	1.793	1.013	0.387
	1 DAS	0.692	3.719*	0.657
	7 DAS	0.530	2.008*	0.600
	14 DAS	0.270	0.461*	0.142
	21 DAS	1.325	1.414	0.593
	28 DAS	0.606	0.171	0.183
	35 DAS	0.548	1.167	0.361
Table No.14	Pre-treatment	10.976	2.453	6.755
	1 DAS	0.607	26.207*	4.917
	7 DAS	9.351	15.052	8.116
	14 DAS	3.324	10.492	3.771
	21 DAS	1.661	6.522	2.522
	28 DAS	0.457	0.188	0.202
	35 DAS	0.630	0.416	0.375
Table No.15	9 DAS	42.150	59.880	195.900
	16 DAS	116.670	308.611	114.060
	23 DAS	12.425	51.461*	9.709
	31 DAS	2.900	67.861*	5.100
	38 DAS	37.633	79.580*	14.300
	47 DAS	8.955	65.058*	5.825

Abstract of ANOVA		Mean Square		
		Block	Treatment	Error
		(2)	(6)	(12)
Table No.16	7 DAS	28.230	153.971	270.000
	21 DAS	695.920	144.960	305.970
	35 DAS	132.519	307.148	376.081
Table No.17	Brinjal yield	0.138	4.516*	0.343
Table No.18	Pre-treatment	0.403	0.703	0.489
	1 DAS	0.107	1.968*	0.575
	7 DAS	0.022	3.502*	0.146
	14 DAS	0.040	5.063*	0.220
	21 DAS	0.223	0.030	0.122
Table No.19	Amaranthus yield	0.125	0.485*	0.108

* Significant at 0.05 level.

Figures in parentheses indicate degree of freedom.

DAS Days after spraying.

ABSTRACT

The dose-effect relationship of two chitin synthesis inhibitors diflubenzuron and triflumuron against three vegetables pests viz., _Sylepta derogata_, _Epilachna vigintioctopunctata_ and _Psara basalis_ was assessed in terms of the average survival periods when the different larval instars were exposed on treated food materials in the laboratory. The results showed that the earlier instars were significantly more susceptible than the later instars. In general, the dose-effect relationship had a positive linear trend. The three test insects showed different susceptibility to the chitin synthesis inhibitors. _S. derogata_ was least susceptible and it was followed by _E. vigintioctopunctata_ and _P. basalis_ in susceptibility.

Besides the mortality observed, various malformations and deformities were also noted in the different life stages of the insects. At the various doses tried the mortality of the larval stages was, in effect, total. The later instars fed with lower concentrations survived in small percentages and pupated. Some of these pupae were abnormal and some gave rise to abnormal adults fully or partly emerged from the pupal skin.

The two chemicals had significant chemosterilant effect also when fed to the adults along with the food materials. The average survival period of the treated adults was significantly lower, the egg production was retarded and the hatching percentages of eggs laid was also significantly low.

The dipping of the eggs in the emulsions/suspensions of the chemicals for fifteen minutes resulted in a low hatching percentage in all the treatments. The emerging larvae showed low survival as well.

In a field experiment against the pests of bhindi, the two chitin synthesis inhibitors were found effective against S. derogata, Amrasca biguttula biguttula, and Earias sp. Against brinjal pests the chemicals significantly controlled the populations of E. vigintioctopunctata, A. biguttula biguttula and Leucinodes orbonalis, while in amaranthus they were effective against P. basalis, a major pest of this crop. Malathion, the standard used, was found slightly better than chitin synthesis inhibitors in the earlier observations, while the population in plots treated with this insecticide had a more rapid increase later. In subsequent observations the population came on par with chitin synthesis inhibitors or even rose to higher levels.

The persistent toxicity of the two chitin synthesis inhibitors and malathion assessed using *S. derogata*, *E. vigintioctopunctata* and *P. basalis* as test insects showed that the chitin synthesis inhibitors were much more persistent on treated plants than malathion. The studies revealed that chitin synthesis inhibitors were effective against the major pests of bhindi, brinjal and amaranthus in field and that they may be preferred to conventional insecticides as they are safer.