RESURGENCE OF BROWN PLANTHOPPER *Nilaparvata lugens* (Stal) ON RICE TREATED WITH VARIOUS INSECTICIDES

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Resurgence of Brown plant hopper, Nilaparvata lugens (Stål) on rice treated with various insecticides" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any other University or Society.

THOMAS BIJU MATHEW

Vellayani,
2nd March, 1989.

CERTIFICATE

Certified that this thesis entitled "Resurgence of Brown plant hopper, _Nilaparvata lugens_ (Stål) on rice treated with various insecticides" is a record of research work done independently by Sri. THOMAS BIJU MATHEW 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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INTRODUCTION

INTRODUCTION

Insecticides have saved human beings from the disasters of many contageous diseases and frequent occurrences of famine. Several developing countries which experienced big deficits in food in late 1960's could tide over the crisis and get themselves comfortably placed in food front, either through the green revolution realised in their own country or through the surplus food made available in the developed countries through a miraculous increase in crop productivity which they could achieve through modern farming technologies. Plant protection and insecticides played a pivotal role in these memorable achievements of humanity. In spite of all that is said against the continued use of pesticides, there is no two opinion about the vast benefits derived from insecticides in different walks of human life. Though intensive efforts are now being made to keep insecticides out of the arena of plant protection none of the alternatives discovered or projected for the immediate future has indicated the emergence of an effective technique economically viable, for tackling the numerous problems posed by insects. In this context insecticides are bound to stay as a part of modern technology in agriculture, public health, trade and in several other areas of human life for years to come. Plant protection scientists must hence know all the good and bad effects of insecticides so that adequate precautions can be taken while recommending them for different needs in varying situations and the potent hazards from these toxicants can be brought down to the minimum.

From the very commencement of chemical control of insect pests in fields the odd phenomenon of the pesticide treated plots holding populations higher than those of control plots, after an initial reduction, and the occurrence of greater damage in treatments compared to control had been of regular occurrence. For a long time this paradoxical situation was being attributed to the destruction of natural enemies in treated plots. The destruction of natural enemies would cause an upsurge of the residual population after treatment while the population in control was being kept low by the activity of natural enemies. In 1950's this phenomenon was identified as one of the direct adverse effect of insecticides on insects and the term resurgence was coined to refer the same. In subsequent years insecticide induced resurgence was reported from different parts of the world (Bartlett and Ortega, 1952; Saini and Cutkomp, 1966; Dittrich et al., 1974; Mc Clure, 1977; Oka, 1978; Chelliah, 1979; Raman and Uthamasamy, 1983). At International Rice Research Institute in Philippines resurgence was being observed regularly especially with the population of N. lugens, which was being controlled with all sorts of insecticides used extensively for a number of years (IRRI, 1969, 1971, 1974, 1977). Having recognised as an important limiting factor in the use of insecticides in an agroecosystem extensive researches on resurgence had been initiated all over the world.

In Kerala also the most serious pest of rice, especially in Kuttanad the known rice bowl of the state, is undoubtedly the rice brown plant hopper, N. lugens. This pest emerged in devastating proportions in 1973 rendering thousands of acres of paddy land left with no straw or grain to harvest. Since then N. lugens has remained as potent menace in the agricultural sector. The insecticides which proved effective in earlier days had become ineffective in course of time and the odd situations of the treated plots giving lesser yield than the untreated plots also occur in the area quite frequently. This may also be attributed to the resurging pest populations in the area.

Though a lot of basic informations on the inducement of resurgence in N. lugens by certain insecticides have been generated in recent years, particularly through the persistent efforts of Chelliah (1979), Heinrichs et al. (1982 a & b) and Reissig et al. (1982 a & b) at IRRI, many aspects are yet to be investigated. In this context the following green house studies, laboratory experiments and field trial were taken up at the College of Agriculture, Vellayani, during 1984-1986.

8. Correlating the variations observed in the factors studied under item 7 and the varying levels of resurgence in the populations of *N. lugens* in the corresponding treatments with a view to understanding the mechanism of resurgence.

9. Assessment of the direct effect of resurgence inducing insecticides on the reproductive potential of *N. lugens* by exposing last instar nymphs of the insect to varying sublethal levels of insecticides.

10. Confirmation of the results obtained from green house studies and laboratory experiments through a field trial and also to study the extent of suppression of natural enemies of *N. lugens* due to insecticide application and to ascertain its role in causing the resurgence of the insect.

1. A series of green house experiments were carried out for screening the insecticides recommended for the control of rice pests in Kerala for their resurgence inducement in N. lugens and to standardise the procedure for the screening of insecticides for resurgence, eliminating possibilities of errors, if any.

2. Assessing the persistence of plant mediated resurgence effect, induced by the insecticides, on rice plants.

3. Screening all the insecticides available in Kerala for resurgence inducement since they may get recommended for paddy pest control at the exigencies of non-availability of the recommended pesticides.

4. Ascertaining the resurgence effect, if any, of the weedicides and fungicides commonly used in paddy fields.

5. Studying the influence of different varieties of rice on the inducement of resurgence caused by insecticides in N. lugens.

6. Assessing the role of plant growth stimulation caused by insecticides on the resurgence inducement in N. lugens.

7. Assessment of the effect of resurgence inducing insecticides on the nutrient content and biochemical constituents of the treated rice plants and on the feeding rate of N. lugens exposed on treated plants for progeny production.

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

A brief review of literature related to the different aspects covered in the present investigations is given below.

1.1. Definitions of resurgence

Ripper (1956) recognised resurgence as a problem in plant protection for the first time. He defined resurgence as a tremendous increase in pest population brought about by an insecticide, within a relatively short time, in spite of the good initial kill at the time of treatment. He listed 50 species of arthropods whose population showed resurgence after treatment with diverse chemicals. He also recognised another type of resurgence in which economically unimportant non-target species developed in serious proportions when chemicals were applied against a target species.

Heinrichs *et al*. (1982 a) suggested that a statistically significant increase in population of the target pest in insecticide-treated plots or in the damage caused by the pest, over that of untreated plots, may be called resurgence. Chelliah (1987) suggested that an abnormal increase in pest populations far exceeding the economic injury level must be evident in resurgence. Jayaraj and Regupathy (1987) opined that statistically significant increase of the population in treated plots over that of control plots, at any particular period after insecticide application, would not be sufficient for recognising resurgence and overall rate of increase or decrease in population over a considerable period of time in treated and untreated plots should be taken into account.

1.2. Resurgence of pests reported on different crops

1.2.1. RICE

1.2.1.1. *Nilaparvata lugens* Stål

The first report of increased incidence of this pest in tropics, due to the application of insecticides (hexachlorocyclohexane - HCH), was from the International Rice Research Institute, Philippines and a population three times higher than that of control plots was observed (IRRI., 1969). In a field experiment conducted during 1976, resurgence was recorded in plots treated with NRDC 161 (deltamethrin), methyl parathion and diazinon and the increases in pest populations observed were 16.4, 6.0 and 4.7 fold respectively. In another experiment conducted during the same period with variety IR 22, insecticides FMC 35001, FMC 31768 and AC 64475 were also found to induce resurgence, the increases in populations being 28.1, 17.9 and 12.1 fold respectively. In these trials perthane, acephate and vamidothion were seen consistently reducing the reproductive rate, when compared to control (IRRI., 1977). Chelliah and Heinrichs (1978) observed that nymphs of N. lugens reared on plants treated earlier with methyl parathion and diazinon developed as adults laying significantly higher number of eggs than the insects reared on untreated plants. They also observed that the hopper burn caused by BPH to rice plants, sprayed with NRDC 161 and methyl parathion, was significantly greater than that caused by the same number of hoppers feeding on untreated plants. Aquino et al. (1979) observed higher damage by N. lugens in fields treated thrice, at 4, 7 and 10 weeks after planting with azinphos ethyl, triazophos, methyl parathion, dimethoate, monocrotophos and fenthion. In a laboratory study Chelliah and Heinrichs (1979 a&b) screened twenty four insecticides for resurgence inducement in N. lugens and found that methyl parathion, fenitrothion, deltamethrin, diazinon and fenthion increased the reproductive rate of the insect significantly. Carbophenothion, FMC 27289, FMC 31768, endosulfan, acephate, phosphamidon, methomyl, azinphos ethyl, AC 64475, DS 15647, cypermethrin and triazophos were on par with control while A 47171, FMC 35001, vamidothion, BPMC and perthane reduced the reproductive rate of the insect. Among granular insecticides tested, diazinon, cartap and aldicarb induced resurgence while carbofuran, dacamox and FMC 31768 were on par with control.

Heinrichs et al. (1982 a) found that spraying rice four times with deltamethrin and carbofuran resulted in 385 and

20 fold increases in nymphal populations of N. lugens respectively when compared to the population in control. Reissig et al. (1982 b) evaluated thirty five insecticides in five consecutive field trials at IRRI, Philippines and found that azinphos ethyl, quinalphos, phenthoate, methomyl, monocrotophos, triazophos, deltamethrin and fenvalerate increased BPH population 5 - 10 times than that of control, tetrachlorvinphos and pyridafenthion caused 15 times increase, diazinon, isazophos, carbofuran and methyl parathion caused 30 - 35 times increase and cyanofenphos caused 72 times increase when compared to the population in control.

Raman and Uthamasamy (1983) identified deltamethrin, methyl parathion, quinalphos, cypermethrin, permethrin and fenvalerate as resurgence inducers of N. lugens with 1.19 to 2.24 times increase in the reproductive rate when compared to the reproductive rate in control.

1.2.1.2. Sogatella furcifera Horvath

Application of deltamethrin, methyl parathion and cypermethrin on rice at 20, 30 and 40 days after planting (DAP) increased the progeny production of S. furcifera to the extent of 28.5 to 60.9% over that of control (IRRI., 1978). Cypermethrin and cis-cypermethrin were reported to induce resurgence of S. furcifera in Malaysia (Vorley, 1985)

1.2.1.3. Nephotettix spp.

Resurgence of rice green leaf hopper N. cincticeps, following insecticidal treatment was extensively reported from Japan (Kobayashi, 1961; Kiritani et al., 1971; Kiritani, 1979). Field experiments conducted in Tamil Nadu showed that phorate granules applied at 2 kg ai/ha induced resurgence of N. virescens (Distant) the population in treated plots being twice that of control (Velusamy, 1987).

1.2.1.4. Zygina maculifrons (Motch.)

Mani and Jayaraj (1976) reported resurgence of blue leaf hopper Z. maculifrons in rice fields 5 - 6 weeks after planting, consequent on seed treatment or seedling root dip with phosphamidon, acephate, monocrotophos, dimethoate or dicrotophos and the increase in population ranged from 1.6 to 2.6 times than that of control.

1.2.1.5. Chilo suppressalis (Walker)

Miyashita (1963) observed an increase in the population of striped stem borer C. suppressalis in many areas of Japan after the large scale use of HCH and parathion for the control of the pest.

1.2.1.6. Cnaphalocrocis medinalis Guen.

Resurgence of leaf folder was noticed in fields treated with phorate coupled with the adoption of closer planting and the application of a higher dose of nitrogenous fertilizers (Chelliah and Heinrichs, 1980). Subramaniam et al. (1985) reported that seedling root dip with chlorpyriphos for 12 h followed by broadcasting of carbofuran at 20, 40 and 60 DAP induced high levels of leaf folder infestation at 75 DAP.

1.2.2. COTTON

1.2.2.1. *Aphis gossypii* G.

As early as 1952 Bartlett and Ortega observed increased incidence of *A. gossypii* in fields treated with ferbam, methoxychlor, dioxathion, calcium arsenate and nicotine sulphate. Application of DDT was found to stimulate the build up of aphids on cotton (Kulkarni and Katagihallimath, 1955; Patel et al., 1956). With the introduction and subsequent widespread use of synthetic pyrethroids for boll worm control in cotton, resurgence of *A. gossypii* was repeatedly observed. Application of pyrethroids like cypermethrin, fenvalerate, permethrin (Balasubramanian et al., 1980), deltamethrin, fenvalerate and permethrin (Sellammal et al., 1979) increased the population of *A. gossypii*. Sithananthan et al. (1973) observed that the use of systemic insecticides, disulfoton, phorate and dimethoate on cotton, for the control of sucking pests, caused significantly higher population of cotton aphid after an initial period of efficacy, in contrast to a distinctly lower population on untreated plants.

Deltamethrin, cypermethrin and fenvalerate induced resurgence of A. gossypii to the tune of 5 to 6 fold (Natarajan et al., 1987 b) and 10 to 15 fold (Rengarajan et al., 1987) over control. Three rounds of application of synthetic pyrethroids viz. fenpropathrin, flucythrinate, fluvalinate (Rengarajan et al., 1987) and S 524 a new pyrethroid (Surulivelu and Sundaramurthy, 1987) induced population build up of cotton to two to three times of the population in control plots. Natarajan et al. (1987 a) observed a reduction in aphid population when cypermethrin, fenvalerate and fenpropathrin were alternated with monocrotophos. Dusting with carbaryl increased aphid population by 37 to 71 per cent over control (Thimmiah and Kadapa, 1987) and spraying with endosulfan increased the populations 5 to 6 times of the population in control plots (Natarajan et al., 1987 b).

1.2.2.2. Bemisia tabaci (Gennadius)

Flare up of white fly population was reported subsequent to the application of DDT, dimethoate (Joyce, 1959; Van der Laan, 1961), endosulfan (El-Bashir, 1974), phosalone (Satpute and Subramanian, 1983) and monocrotophos (Dittrich et al., 1985; Ajri et al., 1987). David et al. (1986) observed that the population of B. tabaci in plots treated with cypermethrin and deltamethrin (cotton variety MCU 5) was 35 and 27 per cent higher than that of control. Natarajan *et al*. (1987 a) reported that the application of cypermethrin, fenvalerate and fenpropathrin when alternated with monocrotophos increased the whitefly population two fold over the population in plots treated with pyrethroids alone.

1.2.2.3. *Ferrisia virgata* (Cockrell)

In Tamil Nadu, Uthamasamy *et al*. (1987) found 4.7 fold higher infestation of cotton mealy bug *F. virgata* over control in plots treated with fenvaletate. Permethrin, cypermethrin and deltamethrin also induced higher build up of the mealy bug and the increase in population ranged from two to four times of the population in control (Patel *et al*., 1987).

1.2.2.4. *Tetranychus* spp.

Application of synthetic pyrethroids on cotton resulted in the resurgence of *T. cinnabarinus* Boisduval (Kuppusamy *et al*., 1979; Ramesh Babu and Azam, 1983). In Gujarat, high population of *T. cinnabarinus* was recorded on cotton treated with permethrin, cypermethrin, deltamethrin, fenvalerate and cyfloxylate (Patel *et al*., 1987). Reddy *et al*. (1987) concluded that continuous use of fenvalerate resulted in resurgence of *Tetranychus neocaledonicus* Andre. on cotton. Pasupathy and Venugopal (1987) observed lesser extent of mite resurgence on cotton treated with cypermethrin using electrodyn sprayer than when the same chemical was applied with knapsack, mist blower or ULV sprayers.

1.2.2.5. Amrasca biguttula biguttula Ishida.

Significant increase in the population of A. biguttula was reported on cotton subsequent to the application of disulfoton granules (Sithanantham, 1968; Navaneethan, 1970; Regupathy and Jayaraj, 1973b). However spraying synthetic pyrethroids or conventional insecticides even up to five rounds on cotton in Haryana did not induce resurgence of the leaf hopper (Singh et al., 1987).

1.2.3. BHINDI

1.2.3.1. Amrasca biguttula biguttula Ishida.

Population of bhindi jassid A. biguttula on plants treated with disulfoton at sowing showed an increasing trend from eighth week after sowing (Regupathy and Jayaraj, 1973b).

1.2.3.2. Aphis gossypii G.

Regupathy and Jayaraj (1973a) observed that the application of phorate on bhendi could control A. gossypii up to five weeks after treatment and it caused an increase in the population up to the extent of twice than that of the control plants at the eighth week after treatment. But dimethoate, methyl demeton or disulfoton did not increase the population.

1.2.3.3. Tetranychus urticae Koch.

Resurgence of T. urticae was noticed on bhendi two weeks after the third round of spraying with ethion and the populations in treated plots were about four fold higher than that of control plots (Narasimha Rao et al., 1987).

1.2.4. BITTER GOURD

1.2.4.1. Aphis malvae K.

Ravindranath and Pillai (1987) reported that 80 per cent increase in the population of A. malvae was observed on bitter gourd following two sprayings with deltamethrin.

1.2.5. BRINJAL

1.2.5.1. Myzus persicae Sulzer.

Subba Rami Reddi et al. (1987) recorded resurgence of M. persicae on brinjal following five rounds of spraying with cypermethrin and deltamethrin, the increase in treatments being 314.5 and 129.5 per cent respectively of the population in control plots.

1.2.5.2. Tetranychus cinnabarinus Boisduval

Uthamasamy et al. (1976) reported that the application of acephate induced more number of T.cinnabarinus on brinjal.

Spider mite resurgence was also observed on brinjal treated with endosulfan, fluvalinate and deltamethrin, the increase being 2.9, 9.6 and 3.1 times that of control respectively (Verma and Bose, 1987).

1.2.5.3. Bemisia tabaci (Gennadius)

In Tamil Nadu, increased incidence of B. tabaci was noticed on brinjal repeatedly sprayed with pyrethroids (David et al., 1987).

1.2.6. CHILLIES

1.2.6.1. Polyphagotarsonemus latus Banks.

Resurgence of P. latus was reported on chillies caused by three rounds of spraying with monocrotophos, methyl demeton, thiometon, phosphamidon, formothion and phosalone, the populations observed two weeks after the third spraying being 34.8, 33.9, 30.1, 33.3, 33.6 and 12.7 fold higher than that of control respectively (David, 1987). In another experiment synthetic pyrethroids deltamethrin, fenvalerate, permethrin and cypermethrin were also seen inducing resurgence of chilli mite (Mallikarjuna Rao and Ahmed, 1987).

1.3. Factors influencing the resurgence of pests

Several factors influencing the inducement of resurgence of insect pests have been recognised.

1.3.1. Type of insecticide

No definite relationship could be established between the degree of resurgence inducement and the nature of the insecticides used. The resurgence inducing insecticides were found among synthetic pyrethroids, organophosphates and carbamates (Chelliah, 1979; Reissig et al., 1982 b; Chelliah, 1987).

1.3.2. Dosage of insecticides

In several laboratory and field experiments the doses of insecticides used were shown to have significant effect on the degree of resurgence. Methyl parathion 0.04 per cent emulsion gave high reproductive stimulation of N. lugens while the reproductive rate was reduced at concentrations higher and lower than 0.04 per cent (Chelliah and Heinrichs, 1978). Chelliah and Heinrichs (1979 a) observed that aldicarb at 1 kg ai/ha caused reproductive stimulation of N. lugens and it was on par with control at the lower dose of 0.5 kg ai/ha. Diazinon and cartap had stimulatory effect at the doses of 0.5 and 1 kg ai/ha.

Application of sublethal concentration of methyl parathion and cypermethrin (WL 43467) on the fifth instar nymphs of N. lugens increased the fecundity of the insect and there was an inverse relationship between the dose and the stimulatory effect (Chelliah and Heinrichs, 1978). Heinrichs _et al_. (1982 b) investigated the effect of varying doses of insecticides on resurgence of _N. lugens_ in a field experiment and they found that the higher doses of deltamethrin and methyl parathion gave higher level of resurgence. Balaji _et al_. (1987) reported increased progeny production of _N. lugens_ on rice plants sprayed with lower dose of fenvalerate while in the case of deltamethrin both higher and lower doses were found resurgence inducing.

1.3.3. Number of application

Chelliah (1979) reported significant increase in the reproductive rate of _N. lugens_ exposed to plants sprayed thrice with methyl parathion as compared to the population on plants sprayed once, while the progeny production on plants sprayed with deltamethrin once, twice or thrice did not show significant differences. Heinrichs _et al_. (1982 a) observed that the degree of resurgence increased with increase in the number of insecticide applications on crops. In the surveys conducted in Tamil Nadu, the population of _B. tabaci_ on cotton was found to increase in proportion with the increase in number of applications of pyrethroids (Jayaraj _et al_., 1987; David _et al_., 1987).

1.3.4. Growth stage of the crop

Raman (1981) reported that the application of resurgence inducing insecticides at 20 and 30 DAP markedly increased the progeny production of *N. lugens* compared to the treatments done at 40 DAP alone or at 10, 20 and 30 DAP. Heinrichs *et al*. (1982 a) found that deltamethrin and methyl parathion applied either at 50 and 65 DAP or at 20, 35, 50 and 65 DAP caused greater degree of resurgence when compared with any other timing of insecticide application. Kenmore and Mochida (1984) observed that the application of deltamethrin and methyl parathion at 42 and 49 DAP was more stimulatory in Mindanao.

1.3.5. Method of application

Heinrichs *et al*. (1982 a) recorded 20 fold increase in the population of *N. lugens* in fields sprayed with carbofuran while the root zone application of the insecticide showed only a four-fold increase in the population. But Reissig *et al*. (1982 b) observed that carbofuran applied in soil induced higher resurgence of *N. lugens* while the chemical sprayed on foliage controlled the pest effectively.

1.3.6. Variety of the crop

Chelliah (1979) reported that deltamethrin and methyl parathion on a susceptible variety, T(N)-1 increased the reproductive rate of N. lugens while these insecticides did not cause resurgence on the three resistant cultivars IR 26, Mudgo and ASD 7. Aquino and Heinrichs (1979) found that cypermethrin did not show any resurgence effect on varieties with inherent resistance to N. lugens compared to susceptible varieties. The degrees of resurgence of N. lugens and S. furcifera on different varieties of rice was studied by Reissig et al. (1982 a) and Salim and Heinrichs (1987) respectively and they found that the degree of resurgence was inversely related to the levels of resistance. But such a relationship between resurgence of BPH and levels of resistance could not be established in the studies conducted by Raman (1981) or Mathew and Das (1987).

1.4. Mechanism of resurgence inducement

1.4.1. Resurgence of insects through the phytotonic effect of insecticides on host plants

Chelliah and Heinrichs (1978) found that the resurgence inducing insecticides (methyl parathion, diazinon, WL 43467) and noninducing insecticides (FMC 35001 and perthane) increased the tiller number and height of rice plants. Number of leaves was observed to be higher in plants treated with certain resurgence inducing insecticides like deltamethrin, methyl parathion and carbofuran (Heinrichs et al., 1979; Raman and Uthamasamy, 1984). Direct relationship between the growth and archetecture of the plants and the number of insects alighting on them was observed by the authors though a direct relationship between the resurgence and phytotonic effect could not be established. Chelliah and Heinrichs (1980) observed that the application of resurgence inducing and non-inducing insecticides did not influence the percentage of macropterous forms of N. lugens alighting on rice plants.

1.4.2. Nutritional status of host plants and resurgence of pests

1.4.2.1. Major elements

Rodriguez et al. (1957) observed higher incidence of mites on beans and cotton treated with HCH. Further studies revealed that N, P and K content and plant growth in treated plants were higher. Higher nitrogen and sugar content was noted in beans treated with DDT and the higher population build up of T. urticae observed on treated plants was attributed to the variations in nutrient content (Saini and Cutkomp, 1966). Increases in the nitrogen content of the plants treated with insecticides and consequent increase in pest population was observed in the case of Aphis fabae Scop. on sugar beet (Smirnova, 1965) and Tetranychus sp. on apple (Lobzhanidze, 1977). Oka and Pimental (1974) observed similar increase in nitrogen content of corn caused by the application of 2, 4-D which resulted in a three-fold increase in corn leaf aphid population and one-third more fecundity in corn borer.

Mani and Jayaraj (1976) observed that the higher build up of rice blue leaf hopper Z. maculifrons on plants subjected to seed treatment or seedling root dip with phosphamidon, monocrotophos, dimethoate and dicrotophos was due to high levels of nitrogen and phosphorus, lower calcium and sugar content and narrowed carbohydrate nitrogen ratio in treated plants than in untreated plants.

1.4.2.2. Minor elements

Cole et al. (1968) reported that the application of organo-chlorine insecticides increased the content of calcium, magnesium, manganese, iron, boron and zinc in corn and beans. Chelliah and Heinrichs (1978) and Raman (1981) did chemical analysis of rice plants, which received foliar sprays of resurgence inducing insecticides. They did not find significant differences in Ca, Mg, Zn and Mn content of the treated plants when compared to untreated plants. But there were significant differences in copper and iron content of the plants.

1.4.2.3. Amino acids and sugars

Thakre and Saxena (1972) observed that the application of DDT, aldrin, endrin and lindane on beans stimulated synthesis of the important amino acids argenine, histidine, leucine, lysine, proline and tyrosine in corn and decreased the content of tryptophan. Application of disulfoton, phorate and dimethoate on cotton lowered the carbohydrate content resulting in narrower carbohydrate nitrogen ratio and greater quantities of free amino acids, especially cystine, asparagine and tryptophan. The improved biochemical status of the host plant was suggested to induce development and higher reproduction in A. gossypii resulting in resurgence of the pest (Sithanantham et al., 1973). Regupathy and Jayaraj (1973 a, 1973 b, 1974) reported that the application of phorate on bhendi resulted in an increase in nonprotein nitrogen, ammoniacal nitrogen, total free amino acids, sucrose and potassium content and a decrease in the calcium content. High incidence of A. gossypii and A. biguttula observed on treated plants was attributed to the above changes in the biochemical content of the plants. Uthamasamy et al. (1976) attributed resurgence of Tetranychus sp. on brinjal, to increased levels of total and reducing sugars, proteins and phosphorus and lower contents of phenols and potassium in plants following the application of acephate.

Buenaflor (1981) investigated the biochemical basis of brown plant hopper resurgence on rice in Philippines. The levels of free amino nitrogen and total nitrogen in the leaf sheaths of rice plants treated with deltamethrin were significantly higher than the levels in plants treated with perthane.

Carbohydrate-nitrogen ratio in deltamethrin treated plants was lower than the ratio in the control or perthane treated plants. Kempraj (1982) observed that the number of amino acids in the ovarian tissues of N. lugens fed on rice plants treated with methyl parathion was higher than that of the insects fed on untreated plants.

1.4.3. Effects of insecticides applied on host plants on the biology of the insect pests

1.4.3.1. Nymphal duration

Chelliah (1979) observed a reduction in nymphal duration of N. lugens when lower doses of resurgence inducing chemicals diazinon and metalkamate were applied in granular formulation to rice plants and he suggested that the shortened life cycle might have accelerated the resurgence inducement. But carbofuran and aldicarb caused no significant difference in nymphal duration as compared to control though these insecticides also induced resurgence. Application of deltamethrin was also found to induce resurgence and a reduction of nymphal duration was attributed as one of the mechanisms of resurgence inducement in the case (Chelliah and Heinrichs, 1980). But a significant extension of larval period of Pieris brassicae L. was observed when the larvae were fed on leaves treated with sublethal doses of resurgence inducing cypermethrin and permethrin (Tan, 1981).

1.4.3.2. Adult longevity

Knutson (1955) attributed the increased reproductive rate of *Drosophila melanogaster* Mg., exposed to sublethal doses of dieldrin, to the increased adult longevity as a result of which the fly had a longer reproductive period. Sublethal doses of carbaryl (LD_{30}) significantly increased the adult longevity of *Spodoptera litura* Fb. (Abo-Elghar *et al.*, 1972), carbofuran and carbaryl increased the longevity in *Diabortica virgifera* Lec. (Ball and Su, 1979). Chelliah and Heinrichs (1980) reported that adult longevity of *N. lugens* was increased significantly on rice treated with deltamethrin while it remained unchanged on plants treated with methyl parathion, diazinon or perthane.

Adkinson and Wellso (1962) found that the longevity of *Pectinophora gossypiella* Saund., which survived sublethal doses of DDT, was shortened. Chelliah and Heinrichs (1978) observed that direct application of methyl parathion, deltamethrin, cypermethrin and FMC 35001, at their sublethal dosages, on the fifth instar nymphs of *N. lugens* did not significantly influence the longevity of adults.

1.4.3.3. Sex ratio

Dittrich *et al.* (1974) and Raman (1981) observed a positive correlation between sex ratio and resurgence of

T. urticae and *N. lugens*. Favourable influence of deltamethrin, methyl parathion, quinalphos, cypermethrin, permethrin, fenvalerate and fenthion on the sex ratio of *N. lugens* was reported by Raman and Uthamasamy (1983).

But Chelliah and Heinrichs (1978 and 1980) reported that the application of resurgence inducing insecticides did not significantly influence the sex ratio of *N. lugens*.

1.4.3.4. Feeding rate

Chelliah and Heinrichs (1980) reported that the feeding rate of *N. lugens* was significantly higher on plants treated with deltamethrin, methyl parathion and diazinon compared to the feeding on plants treated with perthane or water. Raman and Uthamasamy (1983) also observed an increase in the feeding rate of *N. lugens* caused by quinalphos, cypermethrin, fenthion, permethrin and fenvalerate. Gajendran (1984) reported an increase in the feeding rate of *A. gossypii* exposed on cotton plants treated with deltamethrin and methyl parathion at low doses.

But a reduction in feeding rate was reported on the larvae of *Pieris brassicae* exposed to sublethal doses of cypermethrin and permethrin (Tan, 1981).

1.4.3.5. Reproductive rate / progeny production

Sitophilus granarius L. exposed to sublethal doses of DDT had higher progeny production (Kuenen, 1958). Bartlett (1968) found that among 55 pesticides tested, ferbam, calcium arsenate, methoxychlor and dioxathion stimulated the reproduction of A. gossypii while dieldrin, nicotine sulphate, phosphamidon and carbaryl stimulated reproduction of T. urticae.

Moriarty (1969) reviewed the literature on the effect of sublethal doses of synthetic insecticides on insects and concluded that the insecticides might increase or decrease the reproductive potential, change the behaviour of insects and also affect the enzyme induction. Hart and Ingle (1971) observed an enormous upsurge of brown soft scale Coccus hesperidium L. on citrus by sublethal exposure to methyl parathion. Resurgence was observed with sublethal doses of DDT, toxaphene, and endrin on Coleomegilla maculata DeGeer (Atallah and Newsom, 1966), phosphamidon on M. persicae (Parry and Ford, 1971), carbaryl and fenitrothion on Spodoptera littoralis (Boisd.) (Abo-Elghar et al., 1972), dimethoate on Fiorinia externa L. (McClure, 1977), methyl parathion and methomyl on insect pests of soybean (Shepard et al., 1977), phosfolan, monocrotophos and leptophos on S. littoralis (El-Lakwah and Abdel Salam, 1974), carbaryl and DDT on T. urticae (Dittrich et al., 1974), carbofuran and carbaryl on Diabortica vergifera Lec. (Ball and Su, 1979). Reproductive stimulation was observed as the main mechanism of insecticide induced resurgence of N. lugens was evidenced by the higher fecundity of insects feeding on plants treated with resurgence inducing insecticides like deltamethrin, methyl parathion, diazinon, fenitrothion and fenthion (Chelliah, 1979). Chelliah et al. (1980) topically applied LD_5 & LD_{25} doses of methyl parathion and deltamethrin on fifth instar nymphs of N. lugens and found increased reproductive rate in the resulting adults although the doses for maximum stimulation differed between the two insecticides. Similar studies by Gajendran (1984) showed that deltamethrin at LD_{10} and LD_{20} and carbaryl at LD_{35} doses stimulated the reproductive rate of A. gossypii and methyl parathion and monocrotophos at LD_{10} level stimulated the reproduction of Dysdercus cingulatus Fb. on cotton. It was also observed that applications of sublethal doses of resurgence inducing insecticides on successive generations of pests resulted in a progressive increase in their reproductive rates. Exposure to sublethal doses of pesticides caused a stimulatory effect on the ovarian development, oocyte maturation and secretory activity of corpora allata in the treated insects and these might have caused higher reproduction rates (Gajendran, 1984; Kono and Ozeki, 1987).

Evidences were also available on the reduction in reproductive rate of phytophagous insects consequent to the exposure on sublethal doses of insecticides (Attiah and Bordeaux, 1964; Beard, 1965; Zetler and Lecah, 1974; Hodges and Meik, 1986; Alford and Holmes, 1986).

1.4.4. Destruction of natural enemies as a cause of resurgence

Bartlett and Ortega (1952) observed that the DDT induced resurgence of *Chromaphis juglandicola* (Ketb.), *Tetranychus bimaculatus* Harvey, *Paratetranychus pilosus* (C and F) and *Lecanium pruinosum* Coq. on walnut in Southern California was due to the adverse effects on the natural enemy complex of these pests. Suppression of natural enemies following extensive use of broad spectrum insecticide was suggested as an important factor contributing to BPH resurgence in rice (Kobayashi, 1961; Miyashita, 1963; Kiritani *et al*., 1971; Kiritani, 1972 and 1975). Bartlett and Evart (1951) attributed the removal of parasite *Metaphycus luteolus* (Thumb.) for parathion induced resurgence of the soft (brown) scale *C. hesperidium* on citrus. Elimination of natural enemies was considered to be the main factor responsible for the outbreaks of many secondary pests of crops like *Spodoptera exigua* Hb. following dimethoate application on cotton (Eveleens *et al*., 1973), *Plathypera scabra* (F.), *Heliothis* spp., *Pseudoplusia includens* (Wlk.), *Anticarsia gemmatalis* Hb. and

Epilachna varivestis Muls. following application of methyl parathion and methomyl on soybeans (Shepard et al., 1977).

Dyck and Orlido (1977) observed that methyl parathion and diazinon reduced populations of C. lividipennis and L. pseudoannulata in paddy fields and Vorley (1985) found that cypermethrin and Cis-2-cypermethrin reduced the spider population significantly and these resulted in the ultimate resurgence of N. lugens.

Huffacker and Spitzer (1950) established that the resurgence of P. pilosus C & F on pears in California was not due to destruction of natural enemies. They attributed the phenomenon to an indirect influence of some favourable physiological effects on the host trees brought about by the insecticides. Chelliah (1979) also could not find any correlation between the reduction in the natural enemies of brown plant hopper caused by resurgence inducing insecticides and the levels of resurgence of the pest. Subsequent studies carried out at IRRI, Philippines also showed that BPH resurgence was apparently not caused by the suppression of natural enemy population and it appeared as a minor factor contributing to resurgence (Heinrichs et al., 1982 a and 1982 b).

MATERIALS AND METHODS

2. MATERIALS AND METHODS

2.1. Raising rice plants for the experiments

Rice variety T(N)-1 was raised in cylindrical clay pots (15 x 15 cm). Wetland soil was collected, dried, homogenised and filled in pots. Ammonium sulphate, potassium chloride and dicalcium phosphate were applied in solution in each pot in required quantities to give half nitrogen, full phosphorus and half potash of the NPK doses of 90, 45 and 45 kg/ha respectively. The remaining quantities of nitrogen and potash were applied in two equal splits at active tillering and panicle initiation stages of the crop.

Twenty one day old rice seedlings were transplanted at the rate of one seedling per pot. The water level in each pot was maintained at two cm throughout the growth period of the crop. At 10 DAP (days after planting) the plants were covered with cylindrical cages (13 x 100 cm) of transparent, 250 micron thick polyester film supplied by M/s. Karnataka Sales Corporation, Bangalore. Each cage was provided with two voil cloth lined ventilations (5 x 10 cm) and the distal end was covered with close meshed nylon net which was tightened around the cage with a rubber band (Plate 1). The caged plants were kept inside a glass house and were maintained under normal temperature, humidity and light intensity.

PLATE I. Rice plant enclosed in polyester cage for exposing test insect in various experiments.

PLATE I

2.2. Mass culturing of N. lugens

Since large number of insects of uniform size and age were required for different experiments, a culture of the test insect was continuously maintained in the laboratory. Rice seedlings planted in pots at weekly intervals and protected with polyester cages were used for this purpose. N. lugens collected from field and reared in the laboratory for four to five generations, for stabilising the population, was used as stock for the culture. From the stock ten gravid female hoppers were collected and released on each caged plant for egg laying. For collection and release of insects, a simple aspirator was made by connecting a plastic tube (3 x 200mm) on either ends of a glass tube (2 x 60 mm). Distal end of the glass tube was closed with a piece of voil cloth before inserting the plastic tube. This arrangement helped to retain the insects sucked in within the distal plastic tube so that they could easily be blown out on to the rice plants kept for oviposition. The insects were transferred to fresh plants every fifteenth hour so that the eggs laid on each plant would not vary significantly in age. Adequate number of plants with eggs were thus set, at regular intervals, so as to ensure the availability of sufficient numbers of the required instars of the insect throughout the period of the experiments. Emerging nymphs were maintained on the same plants till the outer leaves showed yellowing. Then the plants were cut at the base with a blade and the nymphs were gently tapped on other fresh caged plants. The growing life stages of the insect were fed on plants within the panicle initiation stage so as to minimise variations on the test insect due to the influence of the growth stage of the host plant.

2.3. Assessment of the resurgence inducement of different insecticides in *N. lugens* in relation to the dosages of the insecticides, and the number of insecticidal applications at different growth stages of the crop

The experiment was conducted adopting a completely randomised design and each treatment was replicated thrice. There were forty treatments including control. Thirteen insecticides commonly recommended for paddy pest control in Kerala *viz.* HCH (BHC 50 WP of Hindustan Insecticides Ltd.), fenitrothion (Sumithion 50 EC of Rallis India Ltd.), fenthion (Lebaycid 1000 of Bayer India Ltd.), methyl parathion (Metacid 50 EC of Bayer India ltd.), quinalphos (Ekalux 25 EC of Sandoz India Ltd.), dimethoate (Rogor 30 EC of Rallis India Ltd.), monocrotophos (Nuvacron 36 WSC of Hindustan Ciba Ltd.), phosphamidon (Dimecron 86 WSC of Hindustan Ciba Ltd.), phorate (Thimet 10 G of Cyanamide India Ltd.), BPMC (BPMC 50 EC of Union Carbide India Ltd.), carbaryl (Sevin 50 WP of Union carbide India Ltd.), carbofuran (Furadan 3 G of Rallis India Ltd.) and deltamethrin (Decis 2.8 EC of Coromandel Indag

(P) Ltd.) were included in the experiment and each insecticide was tried at three levels (vide Table 1). The application of insecticides was done at tillering, panicle initiation or booting stages of the crop. Repeated applications of insecticides at (a) tillering and panicle initiation, (b) tillering and booting, (c) panicle initiation and booting and (d) at tillering, panicle initiation and booting stages also were included in the treatments.

2.3.1. Application of insecticides

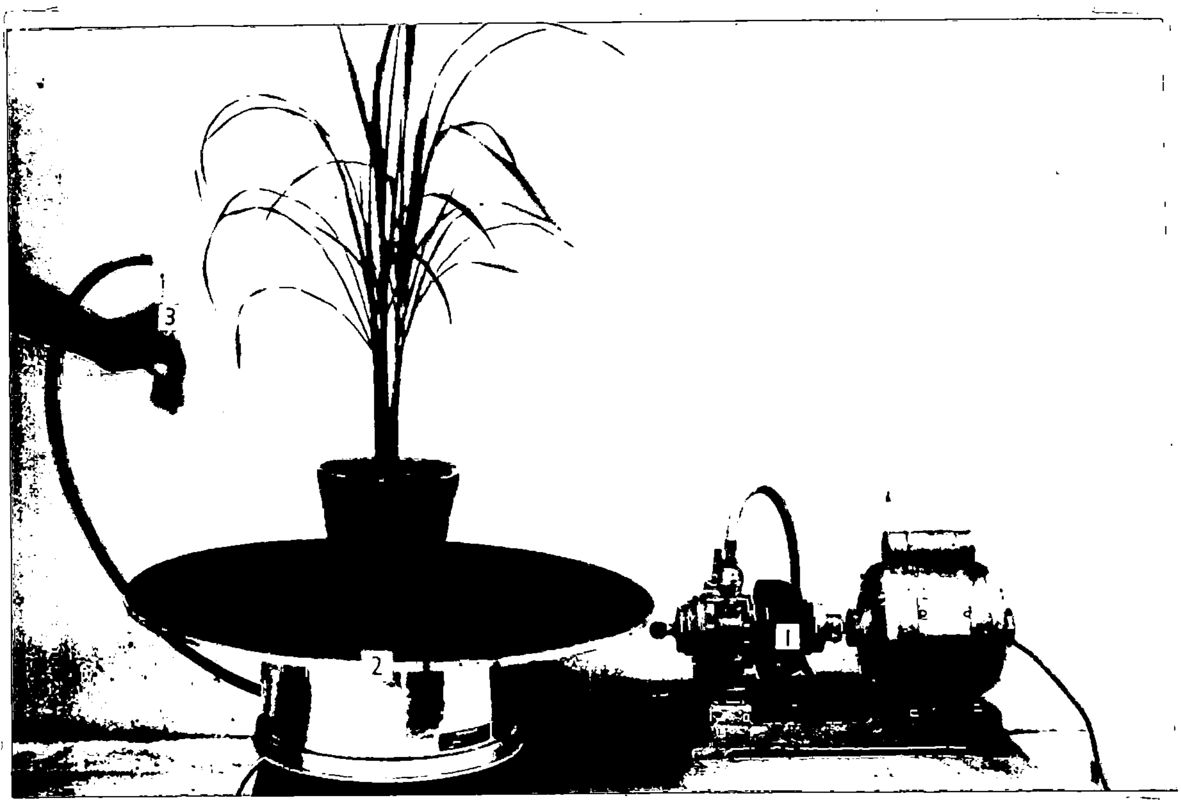
The suspensions/emulsions of the insecticides were prepared from commercial formulations by mixing required quantities of the formulations with distilled water. Each treatment was done on four plants and they were caged and maintained in the glass house. The plants selected for each experiment were ensured to be of the same growth stage and stand.

Each potted plant to be sprayed was kept at the centre of the platform of a revolvolite machine (Plate 2). The spraying was done with an atomiser connected to an electrically operated pressure pump maintained at 0.6 kg/cm^2 pressure. The quantity of spray fluid required to give complete coverage of the stem and leaf portion of the plants at each growth stage was fixed by repeated trials. The optimum quantity for spraying plants at tillering, P.I. and booting stages were

PLATE II. Method adopted for spraying potted plants in green house experiments

1. Atomiser
2. Revolvolite machine
3. Pressure pump

PLATE II



found as 5, 7.5 and 10 ml respectively. Uniform distribution of spray fluid on the plant surface was ensured by maintaining a steady vertical motion of the atomiser nozzle from the bottom to the top of the plant and by keeping the platform of the revolvolite rotating at a steady speed during spraying. In case of granular insecticides (carbofuran and phorate) the required quantities were directly applied to the soil in the pots.

Two hours after treatment the plants were enclosed in cages. The control plants were similarly treated with water and caged. The plants were regularly examined for presence of pests if any and they were removed when noted.

2.3.2. Assessment of progeny production of *N. lugens* on treated plants

Three gravid macropterous female hoppers were collected with the aspirator from the stock culture and were released on each of the treated plants fourteen days after the treatment. Four such plants were set up for each treatment. Three of those were used as the three replications of the treatment. On the fourth plant ten macropterous females were released and maintained. This was used as a culture for replacing the insects dying in the treatments if any. Such replacement was done daily for seven days. The plants thus exposed for egg laying for one week were kept, in the glass house arranged in completely randomised design, after removing the insects released for egg laying and caging the plants individually.

2.3.3. Observations

Nymphs emerging from the above treated plants were collected and counted daily for a period of ten days. The progeny production in each treatment was calculated in terms of cumulative number of nymphs emerging during the period of observations.

Thirty nymphs from each treatment were transferred to separate caged plants and were reared to the adult stage for assessment of the effect of treatment on the progeny production in the second generation. Three gravid female hoppers collected from each of the above lots were exposed on a caged plant and three such replications were set up for each treatment. They were allowed to oviposit for seven days and the nymphs emerging over a period of next ten days were recorded as done earlier. It was reckoned as the number in the second generation.

The data on progeny production on plants treated at different growth stages of the crop were analysed using ANOVA after logarithimic transformation. The retransformed means were presented in the tables and the values were compared with Duncan's Multiple Range Test (DMRT).

For assessing the influence of growth stages of the crop on resurgence inducement the data obtained from the above experiment were regrouped stagewise. The progeny productions of N. lugens on plants treated with each resurgence inducing insecticide at the tillering, panicle initiation or booting stage and at the combinations of the growth stages were assessed and the per cent increase in the population of the insect in treatments compared to corresponding controls were calculated. These data were subjected to analysis of variance and the means were compared with DMRT.

2.4. Assessment of the persistence of the resurgence effect of different insecticides on rice plants treated at tillering, P.I. and booting stages

From the results of the experiment 2.3 six resurgence inducing insecticides viz. fenitrothion, fenthion, methyl parathion, quinalphos, carbaryl and deltamethrin were identified and they were used in this experiment. The insecticides were applied thrice (at tillering, P.I. and booting stages) and the plants were kept caged in a glass house. Plants sprayed with water alone served as control. Three caged plants each were taken from the treated and control lots at 10, 15, 20 and 25 days after the last spraying. The plants were exposed to N. lugens for egg laying and the progeny production (one generation) was assessed following the method described in para 2.3.3.

2.5. Screening of insecticides for the inducement of resurgence in *N. lugens*

All insecticides readily available in the market (excluding those covered in para 2.3) were screened for resurgence after giving three consecutive sprayings. Fifteen insecticides *viz.* endosulfan (Thiodan 35 EC of M/s. Hoechst Pharmaceuticals and chemicals), malathion (Cythion 50 EC of M/s. Cyanamid India Ltd.), formothion (Anthio 25 EC of M/s. Sandoz India Ltd.), phosalone (Zolone 35 EC of M/s. Voltas India Ltd.), methyl demeton (Metasystox 50 EC of M/s. Bayer India Ltd.), DDVP (Nuvan 100 EC of M/s. Hindustan Ciba Ltd.), chlorpyriphos (Coroban 20 EC of M/s. Coromandel Indag (P) Ltd.), methamidophos (Tamaron 40 EC of M/s. Bayer India Ltd.), FMC 35001 (FMC 35001 24 EC of M/s. Rallis India Ltd.), carbaryl + DDVP, HCH + DDVP, fenvalerate (Sumicidin 20 EC of M/s. Rallis India Ltd.), permethrin (Permasect 10 EC of M/s. Bharat Pulverising Mills Ltd.), cypermethrin (Cymbush 25 EC of M/s. Alkali and Chemicals Corporation of India Ltd.), flucythrinate (Pay Off 10 EC of M/s. Cyanamid India Ltd.) and control were included in the experiment. The insecticides were sprayed at their higher doses (vide Table 10) once each at tillering, panicle initiation and booting stages of the plants. Progeny production of *N. lugens* on treated plants exposed for egg laying fifteen days after the last spraying was assessed following the methods described in para 2.3.2 and 2.3.3. The data were subjected to analysis of variance and the means were compared by DMRT.

2.6. Assessment of the resurgence caused by different granular insecticides in *N. lugens* when applied at tillering and P.I. stages

Seven granular insecticides *viz.* diazinon (Basudin 10 G of M/s. Hindustan Ciba Ltd.), phorate (Thimet 10 G of M/s. Cyanamide India Ltd.), quinalphos (Ekalux 5 G of M/s. Sandoz India Ltd.), aldicarb (Temik 10 G of M/s. Union Carbide India Ltd.), carbofuran (Furadan 3 G of M/s. Rallis India Ltd.), carbaryl + lindane (Sevidol 8 G of M/s. Union Carbide India Ltd.) and cartap (Padan 4 G of M/s. Coromandel Indag (P) Ltd.) were applied at 1 kg ai/ha each at tillering and panicle initiation stages of rice. Untreated plants served as control. Treatments were arranged in RBD and the progeny production of *N. lugens* was assessed by exposing the plants for egg laying at thirty days after the second application of insecticides and then following the methods described in para 2.3.2 and 2.3.3. The data were subjected to analysis of variance and the means were compared by DMRT.

2.7. Assessment of the resurgence caused by fungicides and herbicides in *N. lugens*

Seven fungicides *viz.* zineb (Dithane Z 78 of M/s. Indofil Chemicals), mancozeb (Dithane M 45 of M/s. Indofil Chemicals), captafol (Difolatan 80 WP of M/s. Rallis India Ltd.), ediphenphos (Hinosan 50 EC of M/s. Bayer India Ltd.), kitazin (Kitazin 50 EC of M/s. Rallis India Ltd.), carbendazim (Bavistin WP of M/s. BASF India Ltd.), carboxin (Vitavax 75 WP of M/s. Hindustan Insecticides Ltd.) were sprayed at their field doses (vide Table 12) at tillering, P.I. and booting stages of the plants. Plants treated with water alone served as control. Progeny productions of N. lugens on treated plants exposed at 15 days after treatment for egg laying were assessed following the methods described in para 2.3.2 and 2.3.3.

Seven herbicides viz. 2,4-D sodium salt (Fernoxone 80 WP of M/s. Atul Products Ltd.), 2,4-D ester (Weedone 18% WP of M/s. Agromore Ltd.), pendimethalin (Stomp 30 EC of M/s. Cyanamide India Ltd.), fluchloralin (Basalin 45 EC of M/s. BASF India Ltd.), butachlor (Delchlor 50 EC of M/s. Coromandel Indag (P) Ltd.), thiobencarb (Saturn 50 EC of M/s. Pesticides India Ltd.) and propanil (Stam F 34 of M/s. Indofil Chemicals) were applied at their recommended field doses (vide Table 13) at the stages stipulated in the package of practices recommended for rice cultivation by Kerala Agricultural University (1986). Treatments were arranged in a glass house in CRD and the progeny production of N. lugens was assessed following the methods described in para 2.3.2 and 2.3.3.

2.8. Assessment of the influence of rice varieties on the insecticide induced resurgence of N. lugens

Eighteen varieties viz. Ptb 4, Ptb 20, Ptb 33, Annapoorna, Rohini, Triveni, Jaya, Jyothi, Bharathi, Bhadra, Asha, Pavizham, Karthika, C 1727, IR 20, IR 36, Mashuri and T(N)-1 were included in this experiment. Fenitrothion (0.05%) was sprayed on sufficient number of potted plants of each variety at their tillering, panicle initiation and booting stages. A similar set of plants of different varieties sprayed with water alone served as control. The treated and untreated plants were protected with polyester cages. They were arranged in glass house in split plot design with varieties as the main treatment and insecticide as subtreatment. Fifteen days after the last spraying, four caged plants were selected from treated and control lots of each variety and the plants were exposed to N. lugens for egg laying as described in para 2.3.2. Progeny production of N. lugens in one generation was assessed as described in para 2.3.3 and the data were analysed after logarithmic transformation. The resurgence was assessed by comparing the progeny produced in different treatments in comparison with the progeny in corresponding controls.

2.9. Studies on the mechanism of resurgence

Six resurgence inducing insecticides mentioned in para 2.4 and one reproduction inhibiting insecticide (HCH) were chosen for detailed studies on the mechanisms of resurgence.

The insecticides were applied on plants raised in clay pots and maintained in glass house as described in para 2.1. Three lots of plants were sprayed once at tillering, panicle initiation or booting stage of the crop. In a fourth lot the treatments were given thrice, once each at tillering, panicle initiation and booting stages. Plants sprayed with water at the respective stage/s served as corresponding controls. Twenty five plants were treated in each lot and kept in a glass house for the following experiments.

2.9.1. Assessment of the influence of insecticides on the growth of rice plants

Observations on the height, tiller number and number of leaves of the treated and control plants in experiment 2.9 were recorded fifteen days after the treatment. Leaf area indices were calculated adopting the method suggested by Gomez (1972). The progeny production of *N. lugens* also was assessed in different treatments following the method described in para 2.3.2 and 2.3.3. The data collected from the experiment were subjected to analysis of variance and the treatment means were compared by DMRT. Factors showing significant variations were correlated with the progeny produced by *N. lugens*.

2.9.2. Assessment of the nutrient content and biochemical constituents of treated plants

Fifteen days after the insecticide application (vide para 2.8) required samples of leaf sheath were collected from each treatment and the major and minor nutrients, free amino acid and free sugars in the samples were estimated.

2.9.2.1. Estimation of nutrient content of rice plants

Samples of leaf sheath were dried in an oven maintained at 70°C. One gram of dry powdered leaf sheath was digested with conc. sulphuric acid and the extract was used for the determination of major and minor nutrient content. Total nitrogen in the extract was estimated adopting the modified micro-Kjeldahl method. Phosphorus was estimated colorimetrically adopting vanado molybdo biphosphoric method using Spectronic 20 at a wave length of 470 nm. Potassium content was determined using an EEL flame photometer (Jackson, 1973). The calcium, magnesium, zinc, manganese, copper and iron contents were determined using a Perkin Elmer Model atomic absorption spectroscope.

2.9.2.2. Estimation of free amino acids

Ten g sample of cut leaf sheath of each replication was plunged into boiling ethanol and kept for ten minutes. The extract was collected and the tissues were crushed in a mortar and pestle and the content was filtered through two layers of cheese cloth. The residue was re-extracted with hot ethanol 80%. The two extracts were combined and filtered through Whatman No.41 filter paper and the filtrate was concentrated in a water bath. The total free amino acid content of the extract was determined by the ninhydrin method of Moore and Stein (1948) using leucine as standard.

2.9.2.3. Estimation of free sugars

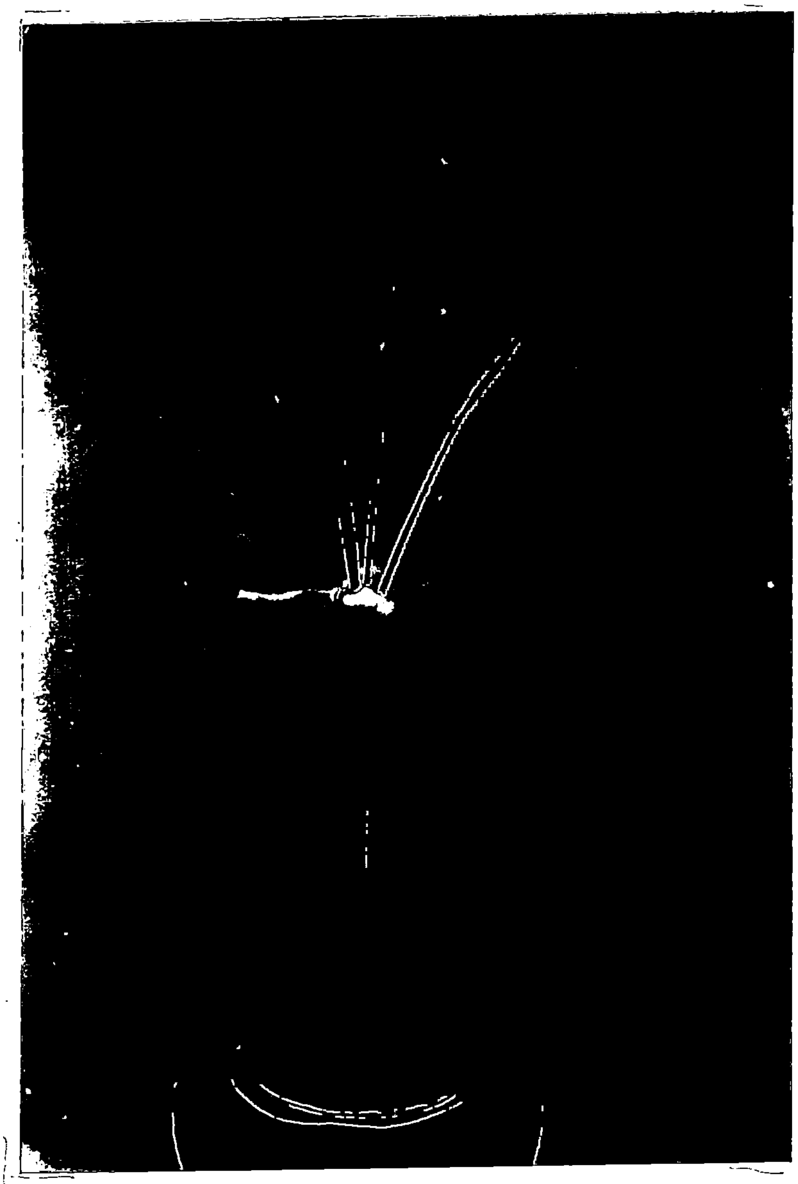
One g of dry powdered leaf sheath from each sample was extracted in boiling ethanol 80% for 30 minutes and the supernatent was collected. The residue was reextracted serially with 60, 40 and 30% ethanol and finally with distilled water and the supernatents were pooled and the volume was reduced to 20 ml in a water bath. One ml of saturated lead acetate was added to the supernatent for precipitating the soluble proteins. It was then filtered through Whatman No.1 filter paper and the filtrate was collected in a volumetric flask containing three ml of saturated Na_2HPO_4. The total free sugars in the extract was estimated by the anthrone sulphuric acid method described by Deiraz (1961).

2.9.3. Assessment of the feeding indices of *N. lugens* on plants under different treatments

The technique developed by Pathak and Heinrichs (1982) was slightly modified and employed for the study. Fifteen days after the treatment three caged plants each were selected from different treatments and also from corresponding controls. Tillers of each plant were thinned leaving the main culm alone.

PLATE III. Rice plant, set for assessing the feeding index of *N. lugens* adopting bromocresol green method (Pathak & Heinrichs, 1982).

PLATE III



The culm was passed through a hole at the centre of a circular polyester film disc of 18 cm dia and the latter was positioned above the water level in the pot using four pegs as seen in Plate 3. A Whatman No.1 filter paper disc (11 cm dia) dipped in bromocresol green solution twice and dried after each dipping, was passed down the culm through a central hole and was placed over the polyester film disc. A cylindrical polyester cage of 9 cm dia and of sufficient height to enclose the stem portion of the plant was placed above the filter paper. The bottom of the cage was fixed to the filter paper all round using cellotape. A tubular device stitched out of nylon cloth was fixed around the upper end of the cage with a rubber band. The free end of the device was tied around the stem of the rice plant at the level of the leaves, with a thread after placing a cotton wad. This device kept the leaves of the plant out of the cage and also prevented condensation of moisture inside. Five fifth instar nymphs collected from laboratory culture and starved for five hours were released on the stem, using an aspirator, through a horizontal cut of two cm length made on one side of the cage. The nymphs were allowed to feed on the plant for 24 h. The honeydew excreted by them during the period fell on the filter paper and got absorbed. The honeydew produced blue spots. The filter paper was removed 24 h after the commencement of feeding and the total area of the spots on each paper was measured by keeping a transparent graph paper above the spots and the area thus obtained in each replication was treated as the feeding index (mm^2).

The data relating to the different resurgence inducing factors covered in 2.9.2 and 2.9.3 were subjected to analysis of variance after working out the increase in percentage of each factor in treatments over corresponding controls.

2.9.4. Correlation studies

The association between each of the factors covered in para 2.9.1 to 2.9.3 (growth parameters, nutrients and biochemical constituents of the plant and feeding index of *N. lugens*) and the progeny production of *N. lugens* was studied by subjecting the data in Tables 14 to 25 to simple correlation analysis.

The direct and indirect effect of the factors on resurgence was studied through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

The data in the above tables were regrouped so as to find the resurgence caused by the application of each insecticide at the tillering, panicle initiation or booting stage and at tillering + panicle initiation + booting stages of the crop. The association between the resurgence inducing factors and progeny production was assessed through simple correlation analysis. The direct and indirect effects were assessed through path coefficient analysis.

2.9.5. Assessment of the effect of direct application of sublethal concentrations of different insecticides on the progeny production of N. lugens

Bioassay of HCH, fenitrothion, fenthion, methyl parathion, quinalphos, monocrotophos, carbaryl and deltamethrin against the fifth instar nymphs of N. lugens was done.

Graded concentrations of each insecticide was prepared from the technical grades using benzene as the solvent and triton X 100 as emulsifier. Fifth instar nymphs of N. lugens were anaesthetized with carbon dioxide at a flow rate of 8 ml/10 seconds for a period of 50 seconds. A quantity of two ml of each insecticide formulation was applied directly on 20 anaesthetized nymphs of N. lugens taken in a petri dish and placed under a Potter's tower. The treated insects were transferred to T(N)-1 seedlings (30 day old) raised in pots and kept covered with polyester cages. Mortality was recorded 24 hours after treatment. The data were subjected to probit analysis following Finney (1971) and from the regression equations LC_{10}, LC_{20}, LC_{30}, LC_{40} and LC_{50} values of each insecticide were estimated.

The above five sublethal concentrations of each insecticide were prepared and applied on fifth instar nymphs of N. lugens, anaesthetized and taken in petridishes, under Potter's tower and the treated insects were transferred to

T(N)-1 seedlings and kept caged. Each treatment was replicated thrice. When the nymphs moulted as adults availability of sufficient males to mate with the surviving females was ensured by releasing additional males into each replication. The mean progeny production of three gravid females selected from each replicate was assessed following the procedure described in para 2.3.3. The data were transformed to logarithm and subjected to statistical analysis (ANOVA with DMRT).

2.10. Field experiment to assess the effect of insecticides on the population build up of *N. lugens* and its natural enemies

2.10.1. Lay out of the experiment

The experiment was conducted during the punja (third crop) season of 1986 in a farmer's field at Nedumudi (Kuttanad), Alleppey district. Twenty one day old T(N)-1 seedlings were transplanted at 2 seedlings/hill with a spacing of 20 x 15 cm. Plot size was 5 x 3 m^2 and a buffer area of 1 m width was left around each plot. Randomised Block Design was adopted for the experiment. The crop husbandry operations as recommended in the package of practices of Kerala Agricultural University were adopted (Kerala Agricultural University, 1986).

2.10.2. Treatments

The insecticides, deltamethrin at 6, 12 and 24 g ai/ha methyl parathion and quinalphos at 0.125, 0.25 and 0.5 kg ai/ha and HCH at 0.75, 1 and 1.25 kg ai/ha were included in the treatments. Each treatment was replicated thrice. The spray fluid was applied in each plot with a pneumatic knapsack sprayer. Gunny screens of one metre height were provided around each plot at the time of spraying to avoid the effect of inter plot drift in the experiment. The treatments were given at 30, 45 and 60 days after planting.

2.10.3. Observations

The populations of *N. lugens* and its predators were assessed at different intervals (vide Table 29) during the period of the experiment. Nymphs and adults of *N. lugens* present on ten randomly selected hills in each plot were directly counted. The numbers of *Microvelia atrolineata* on the water surface in 20 x 15 cm areas were counted by trapping the insects. This was done by suddenly immersing a rectangular plastic frame (20 x 15 x 30 cm) at randomly selected spots. The bugs trapped at ten such spots in each plot were directly counted and the mean number per spot was calculated and recorded. Other predators (vide Table 30 to 33) were collected with a hand net. The collection from five semicircular sweeps, made diagonally in each plot, was carefully transferred to a polythene bag containing a cotton wad dipped in benzene. The anaesthetized insects were sorted out and counted in the laboratory.

The data collected from the experiment were subjected to $\sqrt{x + 1}$ transformation and then to analysis of variance. The means were compared by DMRT. Since the pretreatment populations of N. lugens in different plots showed heterogeneity and also because the insects were subjected to the toxic effect of insecticides which also caused heterogeneity in the population levels after each treatment, the data were subjected to multiple covariance analysis. The variations in the resurging populations of N. lugens observed in the experiment were correlated with the variations in the predator populations observed 15 days prior to the period of the observation on pest population.

RESULTS

RESULTS

3.1. Resurgence of N. lugens caused by different insecticides applied on rice, at different doses and at different growth stages of the crop

3.1.1. Progeny production on plants treated at tillering stage

The data on progeny production of N. lugens (two generations) exposed to rice plants treated with insecticides at the tillering stage and the results of statistical analysis of the same are presented in Table 1.

When the higher doses of insecticides (L_3, vide Table 1) were applied, deltamethrin 0.004% showed the highest resurgence of N. lugens in the first generation with a mean progeny production of 346.8. Fenitrothion 0.1%, fenthion 0.1%, methyl parathion 0.1%, BPMC 0.1% and monocrotophos 0.1% came on par with deltamethrin, the mean number of insects produced in the treatments being 316.2, 295.1, 295.1, 288.4 and 281.8 respectively. Among the treatments deltamethrin, fenitrothion, fenthion and methyl parathion produced significantly higher number of nymphs than in control while BPMC and monocrotophos came on par with control also. Progeny production was least on plants treated with dimethoate 0.1% (166) and it was on par with carbofuran 1 kg ai/ha, HCH 0.25%, phosphamidon 0.1%, control, quinalphos 0.1% and phorate 1 kg ai/ha. The mean number of insects in the above treatments ranged from 177.8 to 239.9.

Table 1. Progeny production of N. lugens on rice plants (var. T(N) 1) treated with different insecticides at the tillering stage

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	263.0 abcdefg	269.2 abcdefg	186.2 ijklm
Fenitrothion	234.4 defghij	338.8 abc	316.2 abcd
Fenthion	204.2 ghijk	263.0 abcdefgh	295.1 abcde
Methyl parathion	218.8 efghijk	288.4 abcdef	295.1 abcde
Quinalphos	229.1 defghijk	288.4 abcdef	213.8 efghijk
Dimethoate	234.4 defghij	269.2 abcdefg	166.0 klm
Monocrotophos	269.2 abcdefg	257.0 bcdefgh	281.8 abcdefg
Phosphamidon	186.2 ijklm	190.6 hijkl	190.6 hijkl
Phorate	147.9 lmn	263.0 abcdefgh	239.9 defghijk
BPMC	138.0 mn	275.4 abcdefg	288.4 abcdef
Carbaryl	263.0 abcdefgh	269.2 abcdefg	245.5 cdefghij
Carbofuran	114.8 n	269.2 abcdefg	177.8 jklm
Deltamethrin	269.2 abcdefg	363.1 a	346.8 ab
Control			208.9 fghijk
Second generation			
HCH	229.1 bcdefghi	275.4 abc	263.0 abcde
Fenitrothion	186.2 hijk	177.8 ijkl	245.5 abcdefg
Fenthion	263.0 abcde	218.8 bcdefghij	166.0 klm
Methyl parathion	190.6 ghijk	234.4 abcdefgh	251.2 abcdef
Quinalphos	213.8 cdefghijk	186.2 hijk	229.1 bcdefghi
Dimethoate	195.0 fghijk	120.2 n	141.3 lmn
Monocrotophos	177.8 ijkl	263.0 abcde	144.5 lmn
Phosphamidon	199.5 fghijk	229.0 bcdefghi	186.2 hijk
Phorate	186.2 hijk	169.8 jklm	204.2 efghijk
BPMC	190.6 ghijk	208.9 defghijk	208.9 defghijk
Carbaryl	208.9 defghijk	199.5 fghijk	138.0 mn
Carbofuran	213.8 cdefghijk	269.2 abcd	239.9 abcdefgh
Deltamethrin	177.8 ijkl	281.8 ab	302.0 a
Control			213.8 cdefghijk

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% (DMRT)

At the field doses of the insecticides (L_2, vide Table 1) also deltamethrin treated plants had the highest progeny production of N. lugens and it was on par with fenitrothion, 0.05%, the mean nymphal populations being 363.1 and 338.8 respectively. These were significantly higher than the population in control. Field doses of methyl parathion, quinalphos, dimethoate, BPMC, carbaryl, HCH, fenthion and phorate came on par with the above two treatments but they were also on par with control, the mean number of insects in the treatments ranging from 263 to 288.4 only. Rest of the treatments also were on par with control.

The lowest doses of insecticides tried (L_1, vide Table 1) did not increase the progeny production significantly above that of control. Minimum number of nymphs (114.8) was observed on plants treated with carbofuran 0.5 kg ai/ha and the treatment came on par with BPMC 0.025% and phorate 0.5 kg ai/ha, (138 and 147.5, respectively). These numbers were significantly lower than the population in control.

N. lugens reared to the adult stage on plants treated with deltamethrin (0.004%) produced a significantly higher number of insects in the second generation (302) when compared to the population on untreated plants (213.8). HCH 0.25%, methyl parathion 0.1%, fenitrothion 0.1% and carbofuran 1 kg ai/ha came on par with deltamethrin. But the above treatments were on par with control also. Progeny production of N. lugens was significantly reduced when the parents were reared on plants treated with carbaryl 0.25%, dimethoate 0.1% and monocrotophos 0.1%, mean nymphal populations in the treatments being 138, 141.3 and 144.5 respectively. Significant differences were lacking among the above treatments.

At the field dose also, deltamethrin induced resurgence in the second generation (231.8) which came on par with HCH 0.2%, carbofuran 0.75 kg ai/ha, monocrotophos 0.05%, methyl parathion, 0.05%, phosphamidon 0.05% and fenthion 0.05%. These treatments came on par with control also. Significant reduction in progeny, when compared to control, was observed on plants treated with dimethoate 0.05%. The least number of nymphs (120.2) was noted in that treatment.

At the lower levels all the insecticides tested came on par with control and the mean number of nymphs ranged from 177.8 to 263.

3.1.2. Progeny production on plants treated at P.I. stage

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 2.

At the higher doses of the insecticides maximum resurgence was observed on plants treated with methyl parathion 0.1% (288.8) and it was on par with quinalphos 0.1%, fenthion 0.1%

Table 2. Progeny production of *N. lugens* on rice plants (var. T(N) 1) treated with different insecticides at the panicle initiation stage

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	131.8 mn	169.8 hijklm	158.5 klm
Fenitrothion	151.4 lmn	166.0 ijklm	213.8 bcdefghi
Fenthion	218.8 bcdefgh	263.0 abc	245.5 abcd
Methyl parathion	213.8 bcdefghi	275.4 ab	288.8 a
Quinalphos	208.9 cdefghij	190.6 defghijkl	263.0 abc
Dimethoate	182.0 efghijkl	223.4 abcdefg	199.5 defghijk
Monocrotophos	173.8 ghijkl	151.4 lmn	204.2 cdefghijk
Phosphamidon	123.0 n	158.5 klm	186.2 efghijkl
Phorate	190.6 defghijkl	182.0 efghijkl	131.8 mn
BPMC	169.8 hijklm	204.2 cdefghijk	162.2 jklm
Carbaryl	234.4 abcde	229.1 abcdef	213.8 bcdefghi
Carbofuran	195.0 defghijkl	162.2 jklm	151.4 lmn
Deltamethrin	194.9 defghijkl	213.8 bcdefghi	234.4 abcde
Control			177.8 fghijkl
Second generation			
HCH	138.0 ij	173.8 bcdefghij	223.9 abc
Fenitrothion	181.9 abcdefghi	173.8 bcdefghij	190.6 abcdefghi
Fenthion	195.0 abcdefg	199.5 abcdef	147.5 fghij
Methyl parathion	208.9 abcde	239.9 a	195.0 abcdefg
Quinalphos	173.8 bcdefghij	141.3 hij	154.9 efghij
Dimethoate	154.9 efghij	128.8 j	177.8 abcdefghi
Monocrotophos	229.1 ab	182.0 abcdefghi	158.5 defghij
Phosphamidon	141.3 hij	186.2 abcdefghi	144.5 ghij
Phorate	166.0 cdefghij	182.0 abcdefghi	144.5 ghij
BPMC	144.5 ghij	162.2 defghij	195.0 abcdefg
Carbaryl	162.2 defghij	182.0 abcdefghi	169.8 bcdefghij
Carbofuran	239.9 a	213.8 abcd	154.9 efghij
Deltamethrin	169.8 bcdefghij	151.4 fghij	181.2 abcdefghi
Control			181.9 abcdefghi

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

and deltamethrin 0.004%, the number of progeny in the treatments being 263, 245.5 and 234.4 respectively. The population in the control was 177.8 only. The lowest nymphal count (131.8) was recorded on plants treated with phorate 1 kg ai/ha and it was on par with carbofuran 1 kg ai/ha, HCH 0.25% and control.

At the field dose of 0.05% methyl parathion showed maximum resurgence and it was closely followed by fenthion 0.05%, the numbers of nymphs in the treatments being 275.4 and 263 respectively. They were on par with carbaryl 0.2%, dimethoate 0.05% and deltamethrin 0.002% and these three treatments came on par with control also.

At the lower doses carbaryl 0.15% caused significant increase in progeny (234.4) when compared with control. Fenthion 0.025%, methyl parathion 0.025%, quinalphos 0.025%, carbofuran 0.5 kg ai/ha, deltamethrin 0.001%, phorate 0.5 kg ai/ha and dimethoate 0.025% came on par with carbaryl, but they were also on par with control. The nymphal population in the above treatments ranged from 182 to 218.8. Progeny production, compared to control, was seen significantly reduced on plants treated with phosphamidon 0.025% and HCH 0.15%, the mean numbers of nymphs on them being 123 and 131.8 respectively. The difference between the two was not statistically significant. Fenitrothion 0.025% also came on par with the above treatments, but it was on par with control also.

At the higher doses none of the treatments differed significantly from control with reference to progeny production of N. lugens in the second generation. The mean nymphal count in the treatments ranged from 144.5 to 223.9 only while in control it was 181.9.

At the field dose also the progeny productions in different treatments except the plants treated with dimethoate were on par with that of control. The number of nymphs observed in plants treated with dimethoate was significantly lower than that of control.

At the lower doses also all the insecticides were on par with control and the nymphal population in the treatments ranged from 138 to 239.9 and in control the count of nymphs was 181.9.

3.1.3. Progeny production on plants treated at booting stage

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 3.

When the higher doses of the insecticides were applied, maximum resurgence was observed on plants treated with methyl parathion 0.1% and it was closely followed by fenthion 0.1%,

Table 3. Progeny production of N. lugens on rice plants (var. T(N) 1) treated with different insecticides at the booting stage

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	190.6 abcdefgh	128.8 k	223.9 ab
Fenitrothion	158.5 efghijk	141.3 ijk	213.8 abcd
Fenthion	204.2 abcdef	169.8 bcdefghijk	229.1 a
Methyl parathion	147.9 hijk	134.9 jk	234.4 a
Quinalphos	186.2 abcdefghi	151.4 ghijk	199.5 abcdefg
Dimethoate	177.8 abcdefghi	186.2 abcdefghi	213.8 abcd
Monocrotophos	199.5 abcdefg	162.2 defghijk	218.8 abc
Phosphamidon	181.2 abcdefghi	162.2 defghijk	204.2 abcdef
Phorate	213.8 abcd	204.2 abcdef	162.2 defghijk
BPMC	169.8 bcdefghijk	154.9 fghijk	186.2 abcdefghi
Carbaryl	190.1 abcdefgh	166.0 cdefghijk	208.9 abcde
Carbofuran	147.4 hijk	195.0 abcdefgh	134.9 jk
Deltamethrin	158.5 efghijk	154.9 fghijk	195.0 abcdefgh
Control			169.8 abcdefghijk
Second generation			
HCH	147.9 cdefghijk	204.2 abcd	218.8 ab
Fenitrothion	128.8 hijk	162.2 bcdefghijk	123.0 jk
Fenthion	144.5 defghijk	125.9 ijk	177.8 abcdefghi
Methyl parathion	165.9 bcdefghijk	173.8 abcdefghij	123.0 jk
Quinalphos	144.5 defghijk	154.9 bcdefghijk	239.9 a
Dimethoate	208.9 abc	154.9 bcdefghijk	169.8 abcdefghij
Monocrotophos	134.9 fghijk	166.0 bcdefghijk	190.6 abcdef
Phosphamidon	151.4 cdefghijk	117.5 k	131.8 ghijk
Phorate	151.4 cdefghijk	158.5 bcdefghijk	218.8 ab
BPMC	173.8 abcdefghij	186.2 abcdefg	147.9 cdefghijk
Carbaryl	128.8 hijk	195.0 abcde	141.3 efghijk
Carbofuran	162.2 bcdefghijk	154.9 bcdefghijk	117.5 k
Deltamethrin	134.9 fghijk	181.9 abcdefgh	154.9 bcdefghijk
Control			173.8 abcdefghij

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

the numbers of nymphs in the treatments being 234.4 and 229.1 respectively. The above treatments were on par with HCH 0.25%, monocrotophos 0.1%, fenitrothion 0.1%, dimethoate 0.1%, carbaryl 0.25%, phosphamidon 0.1%, quinalphos 0.1%, deltamethrin 0.004% and BPMC 0.1%, but the latter treatments were on par with control also.

At the field doses and at the lower doses tested, the mean progeny production in the different treatments were in the ranges of 128.8 to 204.2 and 147.4 to 213.8 respectively. The treatments did not vary significantly from control.

In the second generation, resurgence was not observed in any of the treatments. Progeny production was significantly lower on plants treated with carbofuran 1 kg ai/ha when compared with that of control (117.5 and 173.8 respectively). Methyl parathion 0.1%, fenitrothion 0.1%, phosphamidon 0.1%, carbaryl 0.25%, BPMC 0.1% and deltamethrin 0.004% came on par with carbofuran, but they were on par with control also.

The progeny production on plants treated with phosphamidon 0.05% was significantly lower than that of control, the mean numbers of nymphs produced being 117.5 and 173.8 respectively. Fenthion 0.05%, quinalphos 0.05%, dimethoate 0.05%, carbofuran 0.75 kg ai/ha, phorate 0.75 kg ai/ha, fenitrothion 0.05% and monocrotophos 0.05% came on par and also on par with control.

At the lower doses all the insecticides tested came on par with control and the mean number of nymphs in the different treatments ranged from 128.8 to 208.9.

3.1.4. Progeny production of nymphs on plants treated at tillering and P.I. stages

When the treatments were done twice, once at the tillering and then at P.I. stages of the plants, deltamethrin 0.004% ranked first in inducing resurgence of *N. lugens*, the mean number of progeny being 295.1 as against 162.2 in control. Fenitrothion 0.1%, fenthion 0.1% and methyl parathion 0.1% also came on par with deltamethrin, the number of nymphs produced on plants treated with these insecticides being 245.5, 245.5 and 234.4 respectively. Rest of the treatments at the higher doses were all on par with control (vide Table 4).

At the field doses tested, the mean numbers of nymphs were significantly higher on plants treated with deltamethrin 0.002%, fenitrothion 0.05% and methyl parathion 0.05% and they were on par among themselves. The mean numbers of nymphs produced in the above treatments were 295.1, 275.4 and 251.2 respectively as against 162.2 in control. Carbaryl 0.2% came on par with the above treatments but it was on par with control also. Rest of the treatments did not vary significantly from control.

Table 4. Progeny production of N. lugens on rice plants (var. T(N) 1) treated with different insecticides at the tillering and panicle initiation stages

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	147.9 hijk	190.6 cdefghi	199.5 bcdefghi
Fenitrothion	204.2 bcdefghi	275.4 ab	245.5 abcd
Fenthion	169.8 efghij	186.2 cdefghij	245.5 abcd
Methyl parathion	229.1 abcdef	251.2 abc	234.4 abcde
Quinalphos	173.8 defghij	199.5 bcdefghi	166.0 efghijk
Dimethoate	199.5 bcdefghi	173.8 defghijk	158.5 ghijk
Monocrotophos	218.8 abcdefg	195.9 bcdefghi	199.5 bcdefghi
Phosphamidon	158.5 ghijk	144.5 ijk	154.9 ghijk
Phorate	182.0 cdefghij	144.5 ijk	195.0 bcdefghi
BPMC	162.2 fghijk	131.8 jk	177.8 cdefghij
Carbaryl	186.2 cdefghij	218.8 abcdefg	208.9 bcdefgh
Carbofuran	208.9 bcdefgh	120.2 k	181.9 cdefghij
Deltamethrin	195.0 bcdefghi	295.1 a	295.1 a
Control			162.2 fghijk
Second generation			
HCH	186.2 bcdefgh	234.4 abcd	218.8 abcdef
Fenitrothion	190.6 bcdefgh	234.4 abcd	204.2 abcdefg
Fenthion	239.9 abc	162.2 fghi	154.9 ghij
Methyl parathion	223.9 abcde	169.8 efghi	154.9 ghij
Quinalphos	195.0 abcdefgh	151.3 ghij	245.5 ab
Dimethoate	120.2 jk	204.2 abcdef	158.5 ghij
Monocrotophos	173.8 defghi	112.2 k	195.0 abcdefgh
Phosphamidon	154.9 ghij	131.8 ijk	199.5 abcdefg
Phorate	138.0 ijk	162.2 fghi	229.1 abcde
BPMC	144.5 hijk	234.4 abcd	195.0 abcdefgh
Carbaryl	204.2 abcdefg	239.9 abc	195.0 abcdefgh
Carbofuran	134.9 ijk	177.8 cdefghi	190.6 bcdefgh
Deltamethrin	186.2 bcdefgh	169.8 efghi	263.0 a
Control			190.6 bcdefgh

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

At the lower doses all the treatments were on par with control and the mean numbers of nymphs in the different treatments ranged from 147.9 to 229.1 only.

With reference to the number of nymphs produced in the second generation by *N. lugens* reared on treated plants deltamethrin 0.004% was the only insecticide which showed significant resurgence (263 compared to 190.6 in control). Carbaryl 0.25%, BPMC 0.1%, monocrotophos 0.1%, phosphamidon 0.1%, fenitrothion 0.1%, HCH 0.25%, phorate 1 kg ai/ha and quinalphos 0.1% came on par with deltamethrin but they were on par with control also.

At the field doses resurgence was not noticed in any of the treatments in second generation. But significant reduction was observed in the number of nymphs produced on plants treated with monocrotophos 0.05% and phosphamidon 0.05% the numbers being 112.2 and 131.8 respectively.

At the lower doses, dimethoate 0.025%, carbofuran 0.5 kg ai/ha and phorate 0.5 kg ai/ha caused significant reduction in the number of nymphs produced in the second generation (120.2, 134.9 and 138 respectively). Phosphamidon and BPMC came on par with the above treatments but they were on par with control also.

3.1.5. Progeny production on plants treated twice, once at tillering and then at booting stages

Results pertaining to the experiment and statistical analysis of the same are presented in Table 5.

Plants treated with fenitrothion 0.1% produced the highest population of nymphs in the first generation and it was closely followed by methyl parathion 0.1%, the mean nymph counts in the treatments being 239.9 and 234.4 respectively. Phosphamidon 0.05%, phorate 0.1 kg ai/ha, BPMC 0.05%, dimethoate 0.05%, deltamethrin 0.004%, HCH 0.25%, fenthion 0.05% and carbofuran 1 kg ai/ha came on par with the above two treatments; but they were on par with control also.

At the field dose maximum number of nymphs was seen on plants treated with fenitrothion 0.05% (229.1) and the number was significantly higher than that of control (169.8), HCH 0.2%, BPMC 0.05%, monocrotophos 0.05%, methyl parathion 0.05%, quinalphos 0.05% and fenthion 0.05% were on par with fenitrothion; but they were on par with control also. Carbofuran 0.75 kg ai/ha and dimethoate 0.05% caused significant inhibition on the progeny production (120 and 123 respectively) when compared with control. Phorate 0.75 kg ai/ha, carbaryl 0.2%, phosphamidon 0.05% and deltamethrin 0.002% came on par with the above two treatments and also with control.

Table 5. Progeny production of *N. lugens* on rice plants (var. T(N) 1) treated with different insecticides at the tillering and booting stages

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	138.0 jklm	173.8 cdefghi	195.0 abcdefgh
Fenitrothion	208.9 abcde	229.1 abc	239.9 a
Fenthion	169.8 defghijkl	199.5 abcdefg	204.2 abcdef
Methyl parathion	144.5 ijklm	194.9 abcdefgh	234.4 ab
Quinalphos	151.4 ghijklm	190.6 abcdefghi	131.8 klm
Dimethoate	134.9 jklm	123.0 m	190.6 abcdefghi
Monocrotophos	166.0 defghijkl	186.2 abcdefghi	158.5 efghijklm
Phosphamidon	190.6 abcdefghi	151.4 ghijklm	186.2 abcdefghi
Phorate	204.2 abcdef	138.0 jklm	177.8 bcdefghij
BPMC	166.0 defghijkl	173.8 cdefghijk	186.2 abcdefghi
Carbaryl	128.8 lm	147.9 hijklm	186.2 abcdefghi
Carbofuran	208.9 abcde	120.2 m	218.8 abcd
Deltamethrin	134.9 jklm	154.9 fghijklm	195.0 abcdefgh
Control			169.8 defghijkl
Second generation			
HCH	162.2 efghijklm	218.8 ab	120.2 n
Fenitrothion	141.3 jklm	169.8 cdefghijk	199.6 abcde
Fenthion	173.8 bcdefghij	144.5 ijklmn	195.0 abcdef
Methyl parathion	169.8 cdefghijk	141.3 jklmn	154.9 fghijklm
Quinalphos	182.0 abcdefghi	144.9 ijklmn	147.9 hijklmn
Dimethoate	186.2 abcdefgh	166.0 defghijkl	182.0 abcdefghi
Monocrotophos	177.8 abcdefghij	204.2 abcde	151.4 ghijklmn
Phosphamidon	128.8 mn	173.8 bcdefghij	134.9 klmn
Phorate	177.8 abcdefghij	208.9 abcd	181.3 abcdefghij
BPMC	169.8 cdefghijk	190.6 abcdefg	141.3 jklmn
Carbaryl	166.0 defghijkl	182.0 abcdefghi	151.4 ghijklmn
Carbofuran	131.8 lmn	195.0 abcdef	213.8 abc
Deltamethrin	173.8 bcdefghij	144.5 ijklmn	195.0 abcdef
Control			177.8 abcdefghij

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

At the lower doses none of the treatments differed from control with reference to progeny production and the mean populations of nymphs ranged from 128.8 to 208.9 only as against 169.8 in control.

There was no significant increase in the progeny production of N. lugens in the second generation in any of the treatments. The population of nymphs on plants treated with HCH 0.25% was significantly lower (120.2) when compared with control (177.8) and it was closely followed by the population on plants treated with phosphamidon 0.1%, BPMC 0.1%, monocrotophos 0.1% and carbaryl 0.25%. Quinalphos 0.1% came on par with HCH and phosphamidon and also with control.

At the field doses all the treatments were on par with control and the mean numbers of nymphs in different treatments ranged from 141.3 to 218.8 only as against 177.8 in control.

The lower dose of phosphamidon caused significant reduction in progeny of N. lugens in second generation (128.8) when compared to control (177.8) and carbofuran 0.5 kg ai/ha (131.8) came on par with phosphamidon. Fenitrothion 0.025% and HCH 0.15% also came on par with the two treatments but they were on par with control also.

3.1.6. Progeny production on plants treated, once at P.I. and then at booting stages

Data relating to the experiment and the results of statistical analysis of the same are presented in Table 6.

When insecticides were applied at P.I. and booting stages, the resurgence observed was highest on plants treated with fenthion 0.1% (281.8) while the population on untreated plants was 173.8 nymphs only. It was followed by quinalphos 0.1%, deltamethrin 0.004% and methyl parathion 0.1%, the numbers of nymphs in the treatments being 269.1, 263 and 245.5 respectively. The above treatments were on par and significantly different from control. HCH 0.25%, BPMC 0.1% and carbaryl 0.25% came on par with the above treatments but they were also on par with control.

At the field doses, maximum resurgence was observed on plants treated with methyl parathion 0.05% and deltamethrin 0.002%; the number of nymphs observed in both the treatments were the same (245.5) and significantly higher than that of control (173.8). Fenitrothion 0.05%, carbaryl 0.2%, monocrotophos 0.05%, fenthion 0.05%, quinalphos 0.05% and HCH 0.2% were on par with the above two treatments and also with control. The insect population was least on plants treated with carbofuran 0.75 kg ai/ha (123). Phosphamidon 0.05%,

Table 6. Progeny production of *N. lugens* on rice plants (var. T(N) 1) treated with different insecticides at the panicle initiation and booting stages

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	177.8 defghijk	195.0 bcdefghi	204.2 abcdefghi
Fenitrothion	208.9 abcdefg	223.9 abcdef	195.0 bcdefghi
Fenthion	223.9 abcdef	208.9 abcdefgh	281.8 a
Methyl parathion	218.8 abcdef	245.5 abcd	245.5 abcd
Quinalphos	182.0 cdefghij	208.9 abcdefgh	269.1 ab
Dimethoate	177.8 defghij	154.9 ghijk	151.4 hijk
Monocrotophos	234.4 abcde	213.8 abcdefg	199.5 bcdefghi
Phosphamidon	154.9 ghijk	134.9 jk	147.9 ijk
Phorate	162.2 fghijk	166.0 fghijk	147.9 ijk
BPMC	147.9 ijk	166.0 fghijk	204.2 abcdefghi
Carbaryl	281.8 a	223.9 abcdef	240.0 abcde
Carbofuran	195.0 bcdefghi	123.0 k	131.8 jk
Deltamethrin	199.5 bcdefghi	245.5 abcd	263.0 ab
Control			173.8 efghij
Second generation			
HCH	173.8 bcdefgh	208.9 abc	144.5 fghi
Fenitrothion	154.9 defghi	190.6 abcdef	177.8 bcdefgh
Fenthion	162.2 cdefghi	204.2 abcd	158.5 cdefghi
Methyl parathion	182.0 bcdefg	162.2 cdefghi	204.2 abcd
Quinalphos	169.8 cdefghi	169.8 cdefghi	158.5 cdefghi
Dimethoate	128.8 i	144.5 fghi	182.0 bcdefg
Monocrotophos	138.0 ghi	169.8 cdefghi	208.9 abc
Phosphamidon	186.2 abcdef	134.9 hi	134.9 hi
Phorate	144.5 fghi	195.0 abcde	229.1 ab
BPMC	177.8 bcdefgh	151.4 efghi	204.2 abcd
Carbaryl	151.4 efghi	138.0 ghi	208.9 abc
Carbofuran	169.8 cdefghi	199.5 abcde	154.9 defghi
Deltamethrin	208.9 abc	245.5 a	281.8 a
Control			204.2 abcd

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

dimethoate 0.05%, phorate 0.75 kg ai/ha and BPMC 0.05% were on par with carbofuran and also with control.

At the lower doses tried, carbaryl 0.15% was the only insecticide found inducing resurgence of N. lugens with a mean number of 281.8 nymphs per plant. Fenitrothion 0.025%, methyl parathion 0.025%, fenthion 0.025% and monocrotophos 0.025% came on par with carbaryl and also with control.

Resurgence was not seen induced by any of the insecticides in the second generation of N. lugens. Progeny production was significantly low in the second generation when the insects were reared on plants treated with phosphamidon 0.1% and HCH 0.25%, the mean numbers of nymphs observed being 134.9 and 144.5 respectively as against the mean number of 204.2 in control. Carbofuran 1 kg ai/ha, quinalphos 0.1%, fenthion 0.1%, fenitrothion 0.1% and deltamethrin 0.004% came on par with the above two insecticides and with control.

Among the field doses of different insecticides tried least number of nymphs was recorded on plants treated with phosphamidon 0.05% and it was followed by carbaryl 0.2%, dimethoate 0.05% and BPMC 0.05% (134.9, 138.0, 144.5 and 151.4 respectively) the number in the four treatments being on par and significantly lower than that of control. Methyl parathion 0.05%, monocrotophos 0.05% and quinalphos 0.05%

also came on par with the above insecticides but they were on par with control also.

At the lower doses tested, dimethoate 0.025%, monocrotophos 0.025% phorate 0.5 kg ai/ha and carbaryl 0.15% showed significant suppression in progeny production in second generation, the numbers of nymphs observed in the treatments being 128.8, 138, 144.5 and 151.4 respectively as against 204.2 in control. Remaining treatments were on par with control.

3.1.7. Progeny production on plants treated thrice, once at tillering, once at P.I. and then at booting stage

Data relating to the experiment and the results of statistical analysis of the same are presented in Table 7.

The mean number of nymphs observed was highest on plants treated with deltamethrin 0.004% (288.4) and it was followed by methyl parathion 0.1%, carbaryl 0.25%, fenitrothion 0.1%, fenthion 0.1% and quinalphos 0.1%, the mean populations in these treatments being 275.4, 269.2, 251.2, 245.5 and 234.4 respectively. All the six treatments were on par and significantly different from control (177.8). The lowest number of nymphs was observed on plants treated with phorate at 1 kg ai/ha (125.9 nymphs) and it was significantly lower than that of control. Carbofuran 1 kg ai/ha, phosphamidon 0.1% and BPMC 0.1% came on par with phorate and also with control.

Table 7. Progeny production of *N. lugens* on rice plants (var. T(N) 1) treated with different insecticides at the tillering, panicle initiation and booting stages

Treatments	Mean number of nymphs observed on plants treated with insecticides at different concentrations / doses		
	L_1	L_2	L_3
First generation			
HCH	144.5 mn	165.9 klmn	208.9 cdefghijk
Fenitrothion	245.5 abcdefgh	281.8 ab	251.2 abcdefg
Fenthion	186.8 hijklm	240.0 abcdefghi	245.5 abcdefgh
Methyl parathion	257.0 abcdef	263.0 abcde	275.4 abc
Quinalphos	186.2 hijklm	208.9 cdefghijk	234.4 abcdefghi
Dimethoate	204.2 defghijk	195.0 fghijkl	173.8 klm
Monocrotophos	186.2 hijklm	190.6 ghijklm	186.2 hijklm
Phosphamidon	199.5 efghijk	169.8 klm	162.2 klmn
Phorate	186.2 hijklm	169.8 klm	125.9 n
BPMC	182.0 ijklm	147.9 lmn	162.2 klmn
Carbaryl	234.4 abcdefghij	213.8 bcdefghijk	269.2 abcd
Carbofuran	195.0 fghijklm	162.2 klmn	147.9 lmn
Deltamethrin	239.9 abcdefghi	295.1 a	288.4 a
Control			177.8 jklm
Second generation			
HCH	141.3 hijk	131.8 jk	169.8 cdefghi
Fenitrothion	141.3 hijk	182.0 abcdefg	165.0 defghi
Fenthion	223.9 a	147.9 fghijk	134.9 ijk
Methyl parathion	204.2 abcd	151.4 fghijk	173.8 bcdefgh
Quinalphos	144.5 ghijk	199.5 abcde	158.5 efghij
Dimethoate	218.8 ab	154.9 fghijk	123.0 k
Monocrotophos	158.5 efghij	151.4 fghijk	131.8 jk
Phosphamidon	141.3 hijk	131.8 jk	169.8 cdefghi
Phorate	147.9 fghijk	154.9 fghijk	204.2 abcd
BPMC	134.9 ijk	162.2 defghij	144.5 ghijk
Carbaryl	186.2 abcdef	162.2 defghij	177.8 abcdefgh
Carbofuran	162.2 defghij	173.8 bcdefgh	144.5 ghijk
Deltamethrin	213.8 abc	154.9 fghijk	162.2 defghij
Control			186.2 abcdef

	L_1	L_2	L_3
HCH and carbaryl	0.15%	0.2%	0.25%
Carbofuran and phorate	0.5 kg ai/ha	0.75 kg ai/ha	1.0 kg ai/ha
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Means under L_1, L_2 and L_3 in a generation followed by a common letter are not significantly different at 5% level (DMRT)

At the field doses tested also deltamethrin 0.002% caused maximum build up of insect population and it was on par with fenitrothion 0.05%, methyl parathion 0.05% and fenthion 0.05%, the mean number of nymphs observed being 295.1, 281.8, 263 and 240 respectively. These were significantly higher than the number observed in control. Remaining treatments were on par with control.

At the lower doses, maximum resurgence was observed on plants treated with methyl parathion 0.025% (257 nymphs). It was closely followed by fenitrothion 0.025% and deltamethrin 0.001% (245.5 and 239.9 respectively). Significant differences were not observed among the three treatments. Carbaryl 0.15%, dimethoate 0.025%, phosphamidon 0.025% and carbofuran 0.5 kg ai/ha came on par with the above treatments; but they were on par with control also.

Significant resurgence was not noted in the second generation when the parents reared on plants treated with the different doses of insecticides were exposed to the same lot of plants, the number of nymphs produced ranged from 123 to 204.2 as against 186.2 in control. Significant reduction in the numbers of nymphs produced in the second generation was observed on plants treated with dimethoate 0.1%, monocrotophos 0.1%, fenthion 0.1%, BPMC 0.1% and carbofuran 1 kg ai/ha (123, 131.8, 134.9, 144.5 and 144.5 respectively).

Fig. 1. Resurgence of N. *lugens* induced by insecticidal sprays at different growth stages of rice

	L_1	L_2	L_3
Carbaryl	0.15%	0.2%	0.25%
Deltamethrin	0.001%	0.002%	0.004%
Other treatments	0.025%	0.05%	0.1%

Coloured histograms indicate first generation progeny

* Significant increase (5% level)

Colourless histograms indicate second generation progeny

\+ Significant increase (5% level)

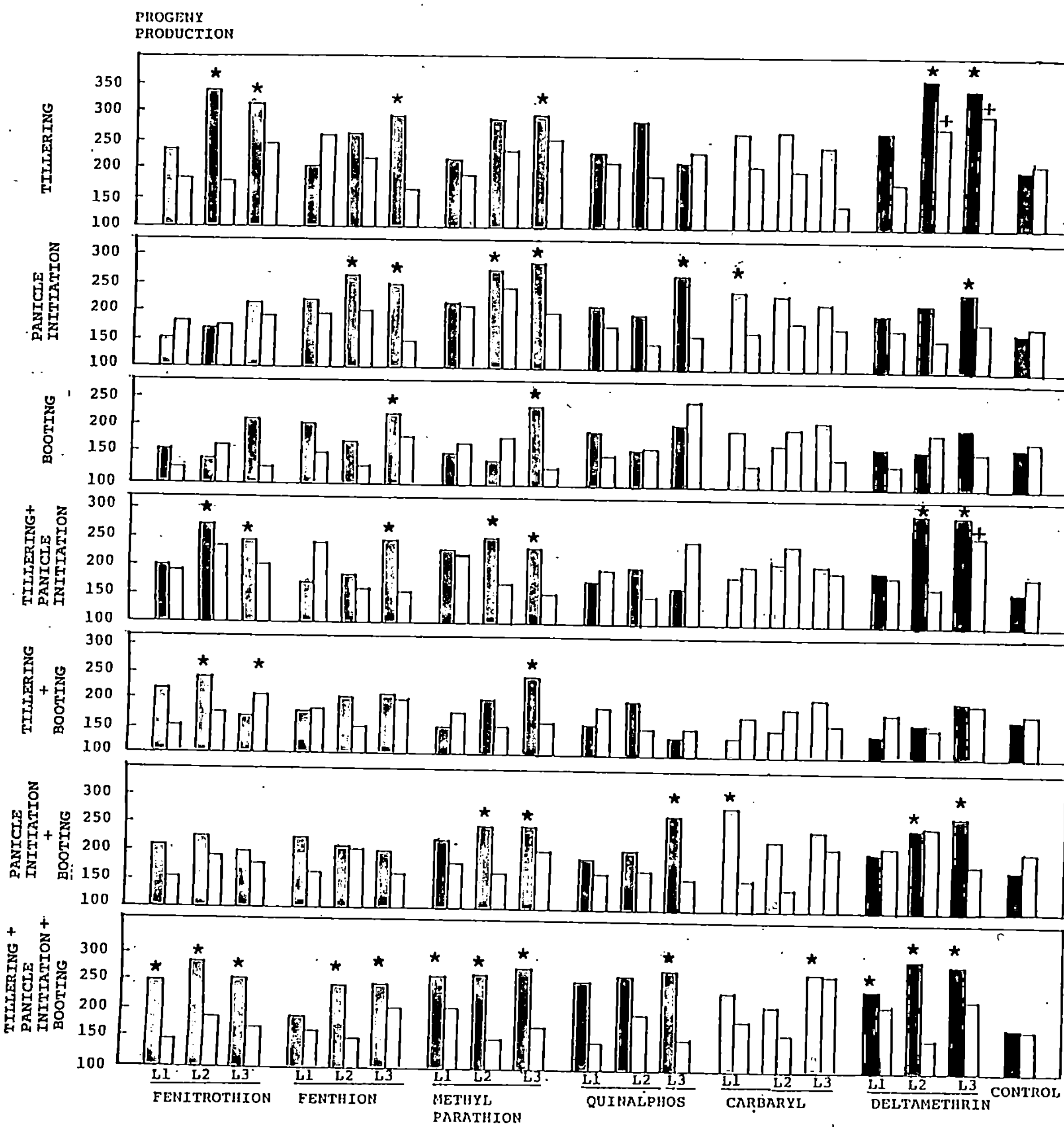

PROGENY PRODUCTION
TILLERING
PANICLE INITIATION
BOOTING
TILLERING+ PANICLE INITIATION
TILLERING + BOOTING
PANICLE INITIATION + BOOTING
TILLERING + PANICLE INITIATION + BOOTING
100
150
200
250
300
350
L1
L2
L3
FENITROTHION
FENTHION
METHYL PARATHION
QUINALPHOS
CARBARYL
DELTAMETHRIN
CONTROL

Fig.1

Fig. 2. Inhibitory effect on the progeny production of *N. lugens* caused by insecticidal sprays at different growth stages of rice

	L_1	L_2	L_3
HCH	0.15%	0.2%	0.25%
Phorate and carbofuran (kg ai/ha)	0.5	0.75	1.0
Others	0.025%	0.05%	0.1%

Coloured histograms indicate first generation progeny

* Significant reduction (5% level)

Colourless histograms indicate second generation progeny

\+ Significant reduction (5% level)

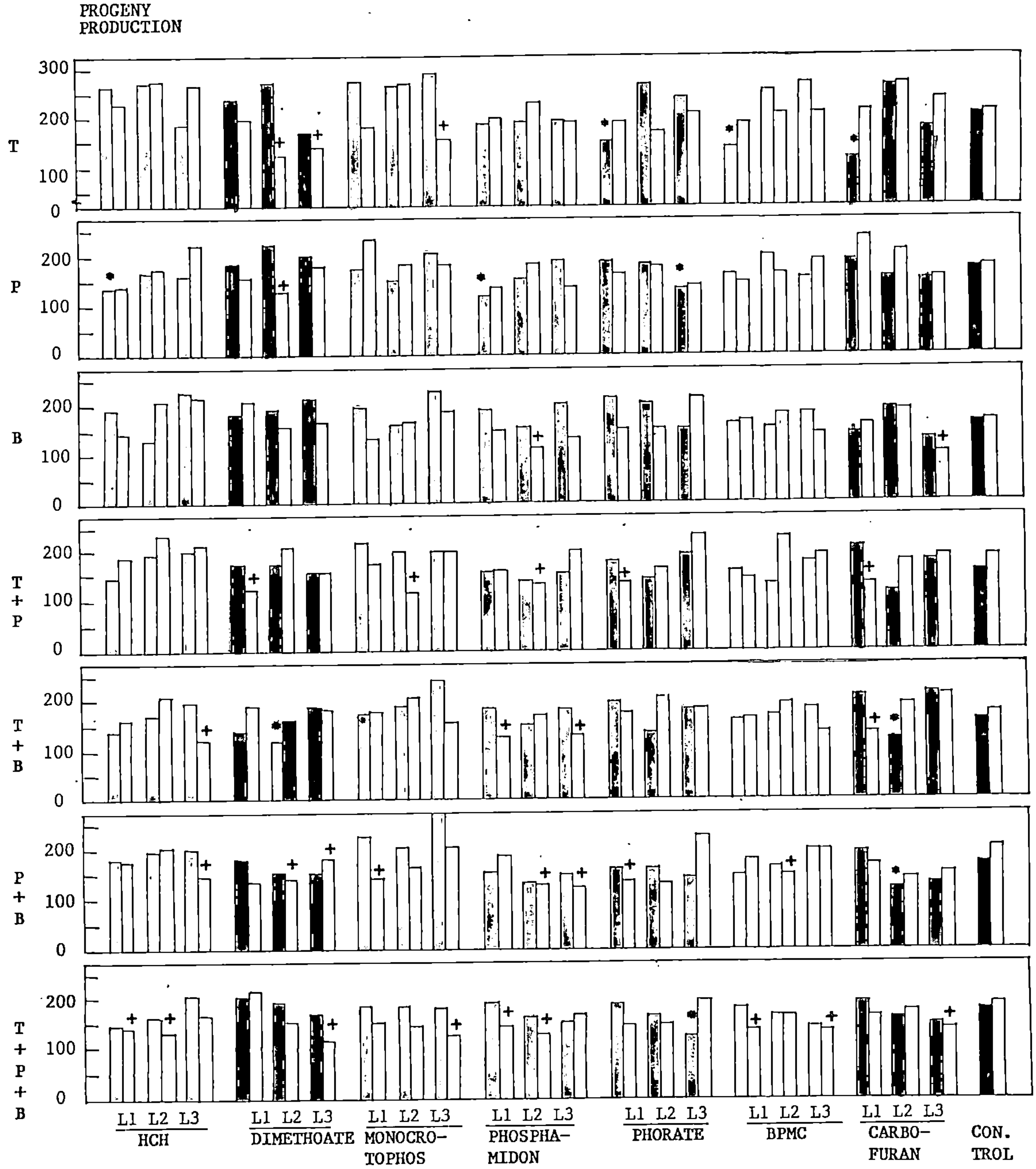

PROGENY
PRODUCTION
300
200
100
0
T
P
B
T + P
T + B
P + B
T + P + B
L1 L2 L3
HCH
DIMETHOATE
MONOCRO-
TOPHOS
PHOSPHA-
MIDON
PHORATE
BPMC
CARBO-
FURAN
CON.
TROL

Fig.2

At the field doses, phosphamidon 0.05% and HCH 0.2% caused significant reduction in the mean numbers of nymphs produced, 131.8 in both the treatments. Fenthion 0.05%, methyl parathion 0.05%, monocrotophos 0.05%, dimethoate 0.05%, phorate 0.75 kg ai/ha, deltamethrin 0.002%, BPMC 0.05% and carbaryl 0.2% came on par with phosphamidon and also with control.

At the lower doses of the insecticides also, progeny production on treated plants was significantly reduced. The number of nymphs on plants treated with BPMC 0.025% was the least (134.9). HCH 0.15%, fenitrothion 0.025%, phosphamidon 0.025% and quinalphos 0.025% also caused significant reduction in population and these treatments were on par. Phorate 0.5 kg ai/ha, monocrotophos 0.025% and carbofuran 0.5 kg ai/ha came on par with BPMC; but they were on par with control also.

The stimulatory/suppressing plant mediated effects of various insecticides, on the progeny production of *N. lugens* when applied at different levels at the different growth stages of rice have been summarised in Figs. 1 and 2.

3.2. Influence of the growth stages of rice plants on the resurgence effect of different insecticides to *N.lugens*

Data relating to the experiment and results of the statistical analysis of the same have been presented in Table 8.

Table 8. Influence of growth stages of rice plants on the resurgence induced by different insecticides in *N. lugens*

Growth stages of the crop	Per cent increase in progeny production over control on plants treated with								
	Fenitrothion			Fenthion			Methyl parathion		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Tillering	11.51 a	63.12 a	50.41 a	-3.65 b	26.46 c	41.33 a	4.40 a	37.49 c	42.76 cd
PI	-14.07 b	-5.39 b	18.17 c	21.86 a	48.34 a	39.90 a	20.26 c	53.42 ab	61.86 a
Booting	-9.08 b	-18.33 c	23.84 bc	20.01 a	-0.02 f	29.27 bc	-14.03 e	-21.63 e	35.71 d
Tillering and PI	26.89 a	36.03 a	17.85 c	36.65 a	30.40 b	21.98 c	32.99 b	61.67 a	48.86 bc
Tillering and booting	23.21 a	35.69 a	-5.86 d	1.15 b	17.90 d	22.06 c	-13.65 e	16.71 d	39.24 cd
PI and booting	17.42 a	59.28 a	41.42 ab	-3.48 b	6.30 e	41.11 a	32.04 b	45.19 bc	32.61 d
Tillering, PI and booting	35.67 a	56.87 a	39.59 ab	3.98 b	34.03 b	36.81 a	44.04 a	47.12 b	55.18 ab

Growth stages of the crop	Quinalphos			Carbaryl			Deltamethrin		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Tillering	11.11 ab	38.21 a	1.99 d	26.93 c	28.25 bc	19.69 b	30.25 a	76.77 a	66.73 a
PI	16.67 a	8.32 c	48.29 ab	33.15 bc	28.57 bc	19.64 b	10.50 ab	20.64 b	32.01 b
Booting	9.79 bc	-10.01 e	17.58 c	11.47 d	-1.83 d	23.62 b	-6.15 b	-9.22 c	13.45 c
Tillering and PI	10.89 ab	27.49 b	64.70 a	74.48 a	60.51 a	45.59 a	23.14 a	50.63 a	62.28 a
Tillering and booting	-9.98 e	11.96 c	-20.66 e	-24.25 e	-13.10 e	11.38 c	-21.99 c	-28.63 d	16.07 c
PI and booting	-1.12 d	13.99 c	21.76 c	7.40 d	25.71 c	19.32 b	12.20 ab	68.06 a	68.52 a
Tillering, PI and booting	4.53 c	15.09 c	30.09 bc	31.80 bc	18.43 c	49.04 a	32.37 a	62.43 a	59.07 a

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

Fenitrothion, at all the three levels, gave the maximum resurgence inducement at the tillering stage. At the lowest and middle doses, all treatments combining the different growth stages showed resurgence on par with that of the tillering stage. At the highest dose treatment at panicle initiation + booting stages as well as the treatment at tillering + panicle initiation + booting stages showed resurgence on par with that of the tillering stage.

Fenthion, at all the three levels, showed high level of progeny production on plants treated at panicle initiation stage. At the highest dose the tillering stage also came on par with panicle initiation stage. At the lowest level the population observed on plants treated at booting as well as at tillering + panicle initiation stages came on par with population on plants treated at panicle initiation stage. The panicle initiation + booting as well as tillering + panicle initiation + booting also came on par with panicle initiation stage while the increase in population in the remaining treatments were significantly lower.

In the case of methyl parathion higher build up of the population was noted at the panicle initiation stage at all the three levels of the insecticides used. In general this was followed by the tillering and booting stages. At the lowest and highest levels, the highest per cent increases in progeny production were seen in plants treated at tillering +

panicle initiation + booting stages and in the middle dose in tillering + panicle initiation stages.

Quinalphos gave the highest increase in progeny production in the panicle initiation stage in the lowest and highest doses and in the tillering stage in the middle dose. Among the combinations the application of the insecticide in tillering and panicle initiation stages gave greater increase in population than the rest. At all the three levels, the tillering and panicle initiation stages were on par in inducing the increase in progeny production.

At the highest dose of carbaryl the booting stage also came on par with tillering and panicle initiation stages. The highest per cent increase in progeny production was observed on plants treated at tillering + panicle initiation stages. At the highest dose treatment at tillering + panicle initiation + booting stages also came on par with tillering + panicle initiation stage combinations.

In the case of deltamethrin, the highest increase was recorded on plants treated at tillering stage at all the three doses used. The panicle initiation stage also came on par with the tillering stage at the lowest dose of the insecticide and at the other two doses the panicle initiation stage came just below the tillering stage in ranking. Booting stage showed significantly lower level of increase in progeny production than the tillering stagesat the lowest dose and lower than the tillering and panicle initiation stage at the middle and highest doses of the insecticide tried. The increase in progeny production in all the combinations except tillering + booting stage were on par with the increase on plants treated at tillering stage.

3.3. <u>Persistence of resurgence effect induced by insecticides on rice plants treated at tillering, panicle initiation and booting stages</u>

The data relating to the experiment and the results of the statistical analysis of the data are presented in Table 9 and Fig. 3. The highest progeny production was found on plants treated with deltamethrin (282.8) when the insects were exposed on plants at 10 DAT and the population on plants treated with fenthion (255.8) also came on par with it. The latter was on par with fenitrothion (240.8) also. The above three treatments were followed by methyl parathion and quinalphos. The populations on plants treated with HCH and carbaryl came on par with that of control.

The progeny productions on plants treated with deltamethrin, fenitrothion and fenthion at 15 days after treatment (DAT) were on par and the latter two were on par with methyl parathion also. Quinalphos and carbaryl were less stimulating. HCH alone came on par with control.

Table 9. Persistence of resurgence effect of different insecticides on rice plants treated at tillering, panicle initiation and booting stages

Treatments	Concentration (%)	Mean number of nymphs observed at			
		10 DAT	15 DAT	20 DAT	25 DAT
HCH	0.25	174.5 e	165.6 e	193.9 de	200.7 abc
Fenitrothion	0.1	240.8 a	257.9 ab	236.9 ab	197.5 abc
Fenthion	0.1	255.8 ab	248.9 ab	223.7 abc	192.7 abc
Methyl parathion	0.1	217.7 cd	243.0 b	203.6 cd	214.7 ab
Quinalphos	0.1	208.7 d	222.9 c	230.9 ab	203.5 abc
Carbaryl	0.25	183.7 e	198.9 d	215.9 bc	173.4 c
Deltamethrin	0.004	282.8 a	270.9 a	241.8 a	225.5 a
Control (water spray)		172.3 e	172.7 e	181.7 e	187.4 bc

DAT Days after treatment

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

Fig. 3. Persistence of plant mediated resurgence induced in *N. lugens* by different insecticides

Treatments

Carbaryl & HCH	0.25 per cent suspension
Deltamethrin	0.004 per cent emulsion
Other treatments	0.1 per cent emulsion

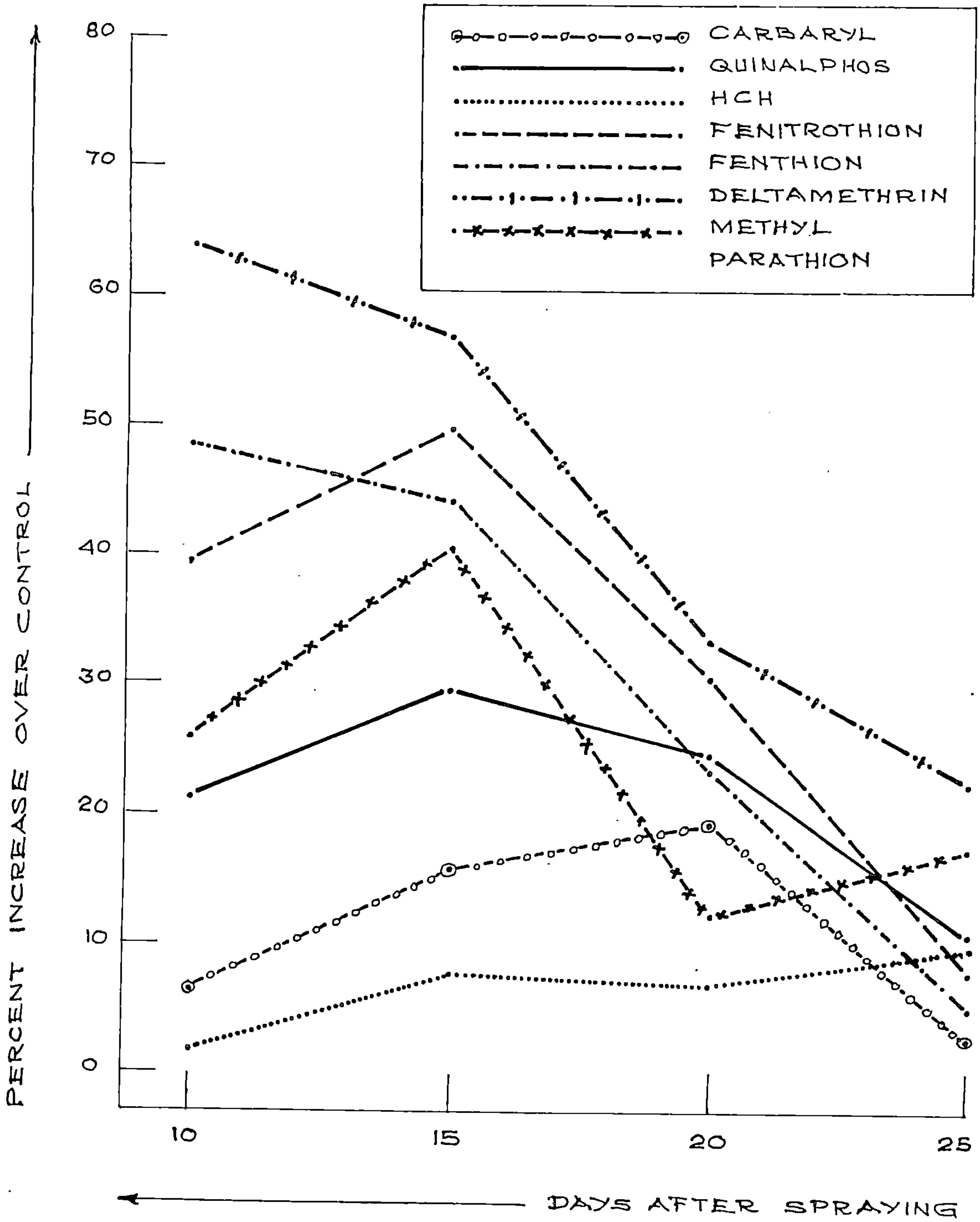

CARBARYL
QUINALPHOS
HCH
FENITROTHION
FENTHION
DELTAMETHRIN
METHYL PARATHION
PERCENT INCREASE OVER CONTROL
80
70
60
50
40
30
20
10
0
10
15
20
25
DAYS AFTER SPRAYING

FIG. 3

The progeny production on plants exposed to N. lugens for egg laying at 20 DAT showed parity in the case of deltamethrin, quinalphos, fenitrothion, and fenthion. Fenthion came on par with carbaryl and methyl parathion. The population on HCH treated plants alone came on par with control.

At 25 DAT, the progeny produced on plants treated with deltamethrin (225.5) alone was significantly higher than that of control. Methyl parathion (214.7), quinalphos (203.5), HCH (200.7), fenitrothion (197.5) and fenthion (192.7) came on par with deltamethrin and also on par with control. Progeny production on carbaryl treated plants came on par with the progeny production in control.

As is shown clearly in Fig. 3 the resurgence induced by the various treatments persisted up to 15 days after treatment without significant change. When exposed on plants at 20 DAT the increase in progeny productions over controls were considerably less, and at 25 DAT the resurgence inducement was seen completely lost except in deltamethrin.

3.4. Resurgence effect of different insecticides in N. lugens exposed on rice plants sprayed at tillering, panicle initiation and booting stages

Repeated application of the insecticides at different growth stages of the crop was giving higher resurgence and hence by adopting this schedule of spraying all the commonly available insecticides, excluding those covered in para 3.3, were screened for resurgence and the data obtained and the results of statistical analysis of the same are presented in Table 10. The numbers of the nymphs of N. lugens in seven treatments were significantly higher than that of control. Highest number of nymphs (283.2) was observed on plants treated with cypermethrin 0.02% and it was followed by methyl demeton 0.1% (276.4), fenvalerate 0.04% (245.4) and permethrin 0.02% (237.2). The differences among the above treatments were not statistically significant. Malathion 0.2%, FMC 35001 0.1% and flucythrinate 0.004% also gave rise to significantly higher numbers of nymphs (231, 244.9 and 223.9 respectively) when compared with control (184.6). The rest of the treatments were on par with control and the mean numbers of nymphs in the treatments ranged from 155.3 to 217.

3.5. Effect of different granular insecticides on the progeny production of N. lugens on rice plants treated at tillering and panicle initiation stages

The data relating to this experiment and the results of statistical analysis are presented in Table 11. The mean progeny productions in the different treatments varied significantly. The highest progeny production was in plants treated with diazinon 1.0% (286.8) and it came on par with carbofuran 1.0 kg ai/ha and cartap 1.0 kg ai/ha (237.8 and 211.8 respectively),

Table 10. Progeny production of N. lugens on rice plants treated with different insecticides at tillering, panicle initiation and booting stages

Treatments	Concentrations	Mean number of nymphs observed
Endosulfan	0.14%	166.8 fg
Malathion	0.2%	231.0 bc
Formothion	0.1%	162.6 fg
Phosalone	0.14%	155.3 g
Methyl demeton	0.1%	276.4 ab
DDVP	0.1%	217.0 cde
Chlorpyriphos	0.1%	189.0 def
Methamidophos	0.1%	191.5 def
FMC 35001	0.1%	244.9 cd
Carbaryl + DDVP	0.25 + 0.1%	212.7 cde
HCH + DDVP	0.25 + 0.1%	175.4 fg
Fenvalerate	0.04%	245.4 abc
Permethrin	0.02%	237.2 abc
Cypermethrin	0.02%	283.2 a
Flucythrinate	0.004%	223.9 cd
Control (water spray)		184.6 efg

Means followed by a common letter are not significantly different at 5% level (DMRT)

Table 11. Progeny production of N. lugens on rice plants treated with granular insecticides at tillering and panicle initiation stages

Treatments	Dose kg ai/ha	Mean number of nymphs observed
Diazinon	1.0	286.8 a
Phorate	1.0	205.7 bc
Quinalphos	1.0	187.7 cd
Aldicarb	1.0	138.6 e
Carbofuran	1.0	237.8 ab
Carbaryl + lindane (sevidol)	1.0	174.7 d
Cartap	1.0	211.8 abc
Control	-	176.7 d

Means followed by a common letter are not significantly different at 5% level (DMRT) there being no significant differences among the three treatments. Phorate 1.0 kg ai/ha ranked next with a mean progeny production of 205.7. The progeny production on phorate treated plants was significantly lower than that of diazinon treated plants but was on par with plants treated with carbofuran and cartap and the population in all the four treatments were significantly higher than that of control. Quinalphos 1.0 kg ai/ha and sevidol 1.0 kg ai/ha were on par with control while the number (138.6) on aldicarb treated plants was significantly lower than that of control.

3.6. Progeny production of N. lugens on rice plants treated with fungicides and herbicides

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 12. None of the fungicides tested had any resurgence effect on N. lugens. Maximum number of insects was observed on plants treated with zineb 0.3% (202.5) and it was followed by mancozeb 0.3% (190.8), ediphenphos 0.1% (183.8), carbendazim 0.1% (171.8), carboxin 0.1% (162.7) and kitazin 0.1% (157.7). All the treatments were on par with control (178.7). Significant reduction in progeny was observed on plants treated with captafol (143.7).

When N. lugens was exposed to plants treated with various herbicides the populations of nymphs ranged from 153.1 to 219.3

Table 12. Effect of fungicides and herbicides, sprayed on rice plants, on the progeny production of *N. lugens*

Fungicides	Concen-trations (%)	Mean number of nymphs observed	Herbicides	Dose kg ai/ha	Mean number of nymphs observed
Zineb	0.3	202.5 a	2,4-D sodium salt	1.0	215.3 a
Mancozeb	0.3	190.8 ab	2,4-D ester	1.0	211.3 a
Captafol	0.3	143.7 e	Pendimethalin	1.0	219.3 a
Ediphenphos	0.1	183.8 abc	Fluchloralin	1.0	175.2 abc
Kitazin	0.1	157.7 de	Butachlor	1.0	164.1 bc
Carbendazim	0.1	171.8 bcd	Propanil	1.0	145.0 c
Carboxin	0.1	162.7 cde	Thiobencarb	2.0	153.1 bc
Control (water spary)		178.7 abcd	Control (water spary)		188.2 ab

Fungicides were sprayed at tillering, panicle initiation and booting stages and herbicides at the tillering stage only

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

only and the treatments were on par and also with control (188.2). Significant reduction in progeny was observed on plants treated with propanil 1 kg ai/ha (145).

3.7. Resurgence induced by fenitrothion on different varieties of rice

The progeny produced on different rice varieties treated with insecticide and on corresponding untreated control plants are presented in Table 13. The results of the analysis of the data are also shown in the Table.

The varieties in which the progeny productions were significantly higher than those of the corresponding controls were Mushoorie (increase over control 80.9 per cent), C 1727 (78.84), Asha (77.25), T(N)-1 (73.41), Ptb 33 (66.14), Bhadra (58.19), Bharati (56.62), IR 36 (53.71), Triveni (52.80) and Jaya (48.17). The nymphal populations in the remaining eight varieties were on par with those of the corresponding control plants (the increase ranged from -14.55 to 34.07). The above two groups included resistant and susceptible varieties.

3.8. Mechanism of resurgence of *N. lugens*

From the results of the experiment 3.1, six resurgence inducing insecticides *viz.* fenitrothion, fenthion, methyl parathion, quinalphos, carbaryl and deltamethrin and a non-inducing insecticide (HCH) were chosen for detailed studies on the mechanism of resurgence inducement.

Table 13. Progeny production of N. lugens exposed on different rice varieties treated with fenitrothion at tillering, panicle initiation and booting stages and on control plants

Varieties	Mean number of nymphs produced on plants		Increase in number over control	Relative susceptibility reported
	untreated	treated		
Mushoorie	107.77 (4.68)	188.67 (5.24)	80.9*	S
C 1727	115.58 (4.75)	194.42 (5.27)	78.84*	-
Asha	139.77 (4.94)	217.02 (5.38)	77.25*	MR
T(N)-1	181.27 (5.20)	254.68 (5.54)	73.41*	S
Ptb 33	104.58 (4.65)	170.72 (5.14)	66.14*	R
Bhadra	134.29 (4.90)	192.48 (5.26)	58.19*	MR
Bharathi	126.47 (4.84)	183.09 (5.21)	56.62*	MR
IR 36	123.97 (4.82)	177.68 (5.18)	53.71*	MR
Triveni	117.92 (4.77)	170.72 (5.14)	52.8*	MR
Jaya	127.74 (4.85)	175.91 (5.14)	48.17*	S
IR 20	196.37 (5.28)	230.44 (5.44)	34.07	S
Ptb 4	126.47 (4.84)	151.41 (5.02)	24.94	-
Jyothi	174.16 (5.16)	196.37 (5.28)	22.21	MR
Pavizham	148.41 (5.00)	149.90 (5.01)	1.49	MR
Ptb 20	125.21 (4.83)	145.47 (4.98)	20.26	-
Karthika	135.64 (4.91)	134.29 (4.9)	-1.35	MR
Annapoorna	151.41 (5.02)	137.01 (4.92)	-14.40	S
Rohini	249.64 (5.52)	235.09 (5.46)	-14.55	S

* Significant at 5% level

C.D. for comparing treatments with corresponding control = 0.19

S - Susceptible MR - Moderately resistant R - Resistant

Figures in parentheses are transformed values ($\log_e x$)

3.8.1. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with different insecticides at the tillering stage

The data on the stimulatory effect of different insecticides applied on rice at tillering stage and the statistical analysis of the same are presented in Table 14. Though the number of tillers ranged from 8 to 9.3 per plant the variations were not statistically significant. The numbers of leaves (range 28.3 to 32.0) also did not vary significantly. Mean height of plants treated with deltamethrin (66 cm) was highest and it was on par with methyl parathion, fenitrothion, HCH and control. The remaining treatments also came on par with the above treatments except deltamethrin. With references to the leaf area indices HCH treated plants alone came on par with control (1.88 and 2.13 respectively). The indices in all other treatments (2.51 to 2.94) were on par and significantly higher than the index in control. The variations observed in the population of nymphs were significantly correlated with the variations in plant height ($r = 0.67$) and leaf area indices ($r = 0.72$).

3.8.2. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with insecticides at the panicle initiation stage

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 15.

Table 14. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with different insecticides at the tillering stage

Treatments	Concentration (%)	Mean No. of tillers (x_1)	Mean No. of leaves (x_2)	Mean height of plants (x_3)	Leaf area index (x_4)	Mean number of nymphs observed (y)
HCH	0.25	8.0 a	28.3 a	61.7 ab	1.88 b	189
Fenitrothion	0.1	7.7 a	29.7 a	64.3 ab	2.82 a	314
Fenthion	0.1	9.0 a	30.3 a	61.3 b	2.62 a	295
Methyl parathion	0.1	8.3 a	31.0 a	65.3 ab	2.51 a	298
Quinalphos	0.1	8.7 a	28.7 a	61.3 b	2.79 a	213
Carbaryl	0.25	9.3 a	29.3 a	61.0 b	2.71 a	250
Deltamethrin	0.004	8.7 a	31.3 a	66.0 a	2.94 a	348
Control		8.0 a	32.0 a	62.7 ab	2.13 b	210
Correlation coefficient between x and y		NS	NS	0.67*	0.72*	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

Table 15. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with different insecticides at the panicle initiation stage

Treatments	Concentration (%)	Mean No. of tillers (x_1)	Mean No. of leaves (x_2)	Mean height of plants (x_3)	Leaf area index (x_4)	Mean number of nymphs observed (y)
HCH	0.25	8.7 a	33.3 a	71.0 c	3.18 c	159
Fenitrothion	0.1	9.3 a	35.0 a	76.0 ab	3.83 ab	212
Fenthion	0.1	9.7 a	34.3 a	72.3 bc	3.25 bc	249
Methyl parathion	0.1	10.3 a	34.7 a	68.3 c	4.15 a	288
Quinalphos	0.1	9.7 a	36.7 a	75.7 ab	3.66 abc	264
Carbaryl	0.25	10.0 a	35.7 a	68.7 c	3.33 bc	212
Deltamethrin	0.004	8.7 a	36.0 a	77.3 a	3.25 bc	235
Control		10.0 a	34.7 a	71.0 c	3.61 abc	178
Correlation coefficient between x and y		NS	NS	0.05	0.51*	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

The mean number of tillers (8.7 to 10.3 per plant) and numbers of leaves (33.3 to 36.7) did not show significant variations among the different treatments. Height of plants treated with deltamethrin (77.3 cm), fenitrothion (76 cm) and quinalphos (75.7 cm) were on par and significantly higher than that of control. The remaining treatments were on par with control. The maximum leaf area index (4.15) observed was that of the plants treated with methyl parathion and it came on par with the indices of the plants treated with fenitrothion, quinalphos and control also (3.61 to 3.83). In the remaining treatments leaf area indices (3.18 to 3.33) were on par and significantly lower. Variations in the populations of the nymphs were positively correlated to the leaf area indices (r = 0.51) but not to the varying heights of plants in different treatments.

3.8.3. Population build up of *N. lugens* in relation to the variations in the growth of plants sprayed with insecticides at the booting stage

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 16. The numbers of tillers (9 to 10.7) and numbers of leaves (39.0 to 43.7) did not show statistically significant variations. Height of plants treated with methyl parathion (92.3 cm), deltamethrin (91.3) and fenitrothion (91.0) were on par and significantly higher than the heights of plants in remaining

Table 16. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with different insecticides at the booting stage

Treatments	Concentration (%)	Mean No. of tillers (x_1)	Mean No. of leaves (x_2)	Mean height of plants (x_3)	Leaf area index (x_4)	Mean number of nymphs observed (y)
HCH	0.25	10.0 a	42.7 a	85.3 b	6.21 c	222
Fenitrothion	0.1	10.7 a	41.0 a	91.0 a	6.91 bc	213
Fenthion	0.1	10.3 a	40.7 a	85.0 b	6.03 c	221
Methyl parathion	0.1	9.7 a	43.7 a	92.3 a	8.17 abc	250
Quinalphos	0.1	9.3 a	42.3 a	83.0 b	8.68 ab	201
Carbaryl	0.25	9.0 a	39.0 a	82.0 b	6.48 c	212
Deltamethrin	0.004	10.7 a	43.3 a	91.3 a	8.79 ab	192
Control		10.3 a	41.3 a	81.4 b	6.52 bc	171
Correlation coefficient between x and y		NS	NS	0.49*	-0.02	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

treatments including control. Leaf area indices of plants treated with deltamethrin (8.79), quinalphos (8.68) and methyl parathion (8.17) were on par and the indices in former two treatments were significantly higher than those of the plants treated with fenthion, HCH and carbaryl (6.03 to 6.48). Leaf area indices in the latter group came on par with methyl parathion, fenitrothion and control. Variations in nymphal populations were found significantly correlated with the heights of the plants (r = 0.49) in different treatments.

3.8.4. Effect of spraying different insecticides at the tillering, panicle initiation and booting stages of rice on the growth of the plants and the population of *N. lugens* reared on the same

The results of the above experiment and the statistical analysis of the data are presented in Table 17. Number of tillers in plants treated with fenitrothion, deltamethrin, quinalphos and methyl parathion (11 to 11.7) were higher than in the numbers in remaining treatments including control. Numbers of leaves in methyl parathion, deltamethrin and quinalphos sprayed plants (47.7 to 49.3) were higher than those of the remaining treatments and control. Plant height was also significantly higher in the different treatments (86.7 to 89), except fenthion (78.7) and carbaryl (77.3), when compared with that of control (79.7). The leaf area indices of the plants treated with deltamethrin

Table 17. Population build up of *N. lugens* in relation to the variations in the growth of rice plants sprayed with different insecticides at the tillering, panicle initiation and booting stages

Treatments	Concentration (%)	Mean No. of tillers (x_1)	Mean No. of leaves (x_2)	Mean height of plants (x_3)	Leaf area index (x_4)	Mean number of nymphs observed (y)
HCH	0.25	8.7 b	41.0 b	88.0 a	8.15 abc	207
Fenitrothion	0.1	11.7 a	41.7 b	87.0 a	7.10 c	251
Fenthion	0.1	9.3 b	39.7 b	78.7 b	6.92 c	249
Methyl parathion	0.1	11.0 a	47.7 a	89.0 a	8.97 ab	279
Quinalphos	0.1	11.3 a	49.3 a	86.7 a	8.31 abc	234
Carbaryl	0.25	10.7 ab	40.3 b	77.3 b	7.08 c	268
Deltamethrin	0.004	11.3 a	48.0 a	86.7 a	9.75 a	284
Control		9.3 b	42.0 b	79.7 b	7.58 bc	180
Correlation coefficient between x and y		0.11	0.23	0.17	0.35	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

(9.75) was the highest and it was on par with the indices of plants treated with methyl parathion (8.97), quinalphos (8.31) and HCH (8.13). Deltamethrin was the only treatment which showed significantly higher leaf area index in treated plants, than in control plants. The correlations between the variations in population and plant height and leaf area indices were statistically insignificant.

3.8.5. <u>The effect of spraying different insecticides at the tillering stage of rice, on the nutrient content of the plants and the correlation between the variations in nutrient content and progeny production of *N. lugens* exposed on treated plants</u>

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 18. The nitrogen content of the leaf sheaths showed significant variations. Nitrogen content (11.42 per cent higher than that of corresponding control) in plants treated with fenitrothion was maximum and it was significantly higher than the content in all other treatments. It was followed by the plants treated with deltamethrin (8.59 per cent) and fenthion (6.4 per cent) and the differences among the three treatments were statistically significant. Quinalphos and methyl parathion were less stimulating and on par (3.89 and 2.57per cent). The nitrogen content in plants treated with carbaryl and HCH were less than the nitrogen

Table 18. The effect of spraying different insecticides at tillering stage of rice plants on the nutrient content of the leaf sheath (on dry weight basis) and the correlations between each of the factors and the progeny production of *N. lugens* on the treated plants

Insecticides	Concentration (%)	Mean per cent increase over corresponding controls in									
		N (x_1)	P (x_2)	K (x_3)	Ca (x_4)	Mg (x_5)	Zn (x_6)	Mn (x_7)	Cu (x_8)	Fe (x_9)	Number of nymphs (y)
HCH	0.25	-6.42 f	-3.71 c	5.15 abc	8.42 a	6.78 a	-12.53 a	-9.02 a	8.5 ab	1.32 a	-9.6 c
Fenitrothion	0.1	11.42 a	9.87 a	7.70 abc	-1.93 a	7.65 a	-16.20 a	-4.89 a	12.8 a	0.53 a	50.4 ab
Fenthion	0.1	6.40 c	3.54 b	10.70 a	3.39 a	-6.11 a	-2.10 a	-8.51 a	3.31 abc	2.86 a	41.4 b
Methyl parathion	0.1	2.57 d	5.87 ab	1.47 c	8.20 a	12.70 a	-10.90 a	-1.42 a	-7.03 c	1.61 a	42.8 b
Quinalphos	0.1	3.89 d	2.99 b	5.88 abc	-1.19 a	-5.94 a	-18.60 a	2.12 a	1.63 abc	-1.95 b	2.0 d
Carbaryl	0.25	-2.56 e	4.93 ab	2.57 bc	5.80 a	10.53 a	-3.13 a	2.44 a	-4.44 c	2.39 a	19.6 c
Deltamethrin	0.004	8.59 b	9.37 a	8.59 ab	5.74 a	15.37 a	-9.55 a	-11.10 a	-1.99 bc	1.23 a	67.0 a
Correlation coefficient between x and y		0.79*	0.78*	0.19	0.01	0.25	0.05	-0.26	-0.10	0.28	--

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

content of control plants. The variations in the nitrogen content of the treated plants was significantly correlated ($r = 0.79$) with the variations in progeny production of N. lugens in different treatments.

The mean per cent increases of phosphorus content of the plants treated with fenitrothion (9.87), deltamethrin (9.37), methyl parathion (5.87) and carbaryl (4.93) were on par. The increases in phosphorus content in plants sprayed with fenthion (3.54) and quinalphos (2.99) came on par with those of methyl parathion and carbaryl treated plants while HCH treated plants showed a reduction in P content. The variations in phosphorus content was positively correlated with the variations in progeny production ($r = 0.78$) in different treatments.

The per cent increase in the potash content of plants treated with fenthion (10.7) was the highest and it came on par with those of deltamethrin (8.59), fenitrothion (7.70), quinalphos (5.88) and HCH (5.15) treated plants. The per cent increase in potash content in plants sprayed with carbaryl and methyl parathion treated plants were 2.57 and 1.47 respectively. The variations in the content of potash was not significantly correlated with the progeny productions in various treatments.

The variations in the mean per cent increases in the content of calcium (-1.93 to 8.42), magnesium (-6.11 to 15.37), zinc (-18.6 to -2.10), manganese (-11.10 to 2.44), copper

(-7.03 to 12.8) and iron (-1.95 to 2.86) compared to the content in corresponding controls did not show statistical significance. None of these factors showed significant correlation with the progeny production of N. lugens in different treatments.

3.8.6. Effect of spraying different insecticides, at the panicle initiation stage of rice, on the nutrient content of the plants and the correlation between the variations in nutrient contents and progeny production of N. lugens exposed on treated plants

The results of the experiment and the results of statistical analysis of the data are presented in Table 19. The nitrogen content showed significant variations in the different treatments. Highest increase in nitrogen content was observed in plants treated with fenthion (21.28 per cent) and all the remaining treatments except deltamethrin and HCH (-0.39 to 17.25) came on par with fenthion. The per cent increase in nitrogen content of deltamethrin and HCH treated plants (-11.28 and -15.41) were significantly lower than that of control plants. The variations in the nitrogen content of the treated plants was positively correlated ($r = 0.49$) with the variations in the progeny production of N. lugens observed in different treatments.

Table 19. The effect of spraying different insecticides at panicle initiation stage of rice plants on the nutrient content of the leaf sheath (on dry weight basis) and the correlations between each of the factors and the progeny production of *N. lugens* on the treated plants

cticides	Concen-tration (%)	Mean per cent increase over corresponding controls in									
		N (x_1)	P (x_2)	K (x_3)	Ca (x_4)	Mg (x_5)	Zn (x_6)	Mn (x_7)	Cu (x_8)	Fe (x_9)	Number of nymphs (y)
	0.25	-15.41 c	-4.01 a	-3.05 a	-9.98 a	-9.09 a	-10.75 a	10.33 a	7.46 a	0.22 a	-10.9 e
rothion	0.1	17.25 ab	10.61 a	4.58 a	-2.76 a	-10.23 a	0.22 cd	10.35 a	7.68 a	-0.44 a	18.9 d
ion	0.1	21.28 a	4.48 a	7.02 a	-5.84 a	6.80 a	-1.55 d	4.08 bcd	-4.88 a	-1.85 a	39.9 b
yl parathion	0.1	15.11 ab	6.32 a	10.10 a	-3.62 a	-3.27 a	6.65 bc	8.00 ab	-2.86 a	1.19 a	61.9 a
lphos	0.1	7.19 abc	3.22 a	6.41 a	-0.75 a	-5.58 a	1.29 cd	1.86 cd	2.65 a	-0.43 a	48.3 b
ryl	0.25	-0.39 abc	5.28 a	0.82 a	-4.62 a	1.58 a	13.71 ab	6.15 bc	2.95 a	-0.36 a	19.1 d
methrin	0.004	-11.28 bc	-6.09 a	-2.28 a	-2.57 a	-16.24 a	15.38 a	-1.12 d	-2.38 a	-0.39 a	31.8 c
lation coefficient en x and y		0.49*	1.19	0.46*	0.16	0.16	0.38	-0.38	-0.36	0.04	--

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

The mean per cent increases in the content of phosphorus (-6.09 to 10.61), potassium (-3.05 to 10.1), calcium (-9.98 to -0.75), magnesium (-16.24 to 6.8), copper (-4.88 to 7.68) and iron (-1.85 to 1.19) did not show significant variations. None of the factors showed significant influence on progeny production of N. lugens in different treatments except in the case of potassium content where a significant correlation (r = 0.46) was observed.

The content of zinc and manganese varied significantly among the different treatments. The per cent increase in zinc content was maximum (15.38) in deltamethrin sprayed plants which was followed by carbaryl (13.71). The zinc content in plants sprayed with methyl parathion, quinalphos, fenitrothion and fenthion were on par (-1.55 to 6.65). The content of zinc in HCH treated plants showed a significant reduction (10.75) when compared to the remaining treatments. The manganese levels in fenitrothion, HCH and methyl parathion treated plants were on par (8.0 to 10.35 per cent increase) and the former two treatments had higher increase than the other insecticide treated plants (-1.12 to 5.15 per cent). However the variations in both the nutrients were not significantly correlated with the variations in progeny production of N. lugens in the different treatments.

3.8.7. Effect of spraying different insecticides at the booting stage of rice, on the nutrient content of the plants and the correlation between the variations in the nutrient contents and progeny production of *N. lugens* exposed on treated plants

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 20. Mean per cent increase in nitrogen content was maximum in plants sprayed with fenitrothion (33.3) and the extent of increase in methyl parathion (29.5) and deltamethrin (28.4) treated plants also came on par with the former. The nitrogen content in plants treated with fenthion (16.6 per cent increase), quinalphos (13.9), HCH (4.01) and carbaryl (0.62) came next in the ranking. The correlation between nitrogen content and progeny production of *N. lugens* was not statistically significant.

Phosphorus content in treated plants showed significant increase in the case of methyl parathion (2.8 per cent) only while those of the remaining treatments (-11.6 to -3.37) were on par or lower than the content in control plants. The variations in phosphorus content was not significantly correlated with the progeny production in various treatments.

The per cent increase in the potash content of plants treated with methyl parathion (5.04) was the maximum and it came on par with fenitrothion (4.68). The per cent increase

Table 20 The effect of spraying different insecticides at booting stage of rice plants on the nutrient content of the leaf sheath (on dry weight basis) and the correlations between each of the factors and the progeny production of N. lugens on the treated plants

cticides	Concen- tration (%)	Mean per cent increase over corresponding controls in									
		N (x_1)	P (x_2)	K (x_3)	Ca (x_4)	Mg (x_5)	Zn (x_6)	Mn (x_7)	Cu (x_8)	Fe (x_9)	Number of nymphs (y)
	0.25	4.01 de	-10.22 b	0.20 b	-11.30 a	8.33 ab	3.87 a	-6.61 bc	-14.90 cd	-5.38 a	29.7 ab
trothion	0.1	33.30 a	-11.60 b	4.68 a	-10.30 a	17.70 a	-3.96 a	-5.11 abc	-18.10 cd	-5.36 a	24.4 bc
hion	0.1	16.60 bc	-5.12 ab	-6.12 e	-12.90 a	4.26 ab	3.38 a	-10.60 bc	-12.90 bcd	0.24 a	29.3 ab
yl parathion	0.1	29.50 a	2.80 a	5.04 a	-8.91 a	19.10 a	4.37 a	-2.86 ab	-2.96 abc	-2.22 a	35.7 a
alphos	0.1	13.90 cd	-9.35 b	-1.44 c	-4.40 a	1.26 b	-1.54 a	2.96 a	-20.10 d	-8.24 a	17.6 cd
aryl	0.25	0.62 e	-3.65 ab	-4.68 d	-1.85 a	0.23 b	-3.98 a	-12.30 c	0.51 a	-6.90 a	23.7 bc
amethrin	0.004	28.40 ab	-3.37 ab	-8.99 f	-14.50 a	7.42 ab	2.04 a	-7.43 bc	-8.04 abc	-3.94 a	12.5 d
elation coefficient een x and y		-0.07	0.29	0.55*	-0.01	0.26	0.35	-0.12	0.09	0.16	--

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

in the remaining treatments were less than that of control plants and the treatments showed significant differences and they were in the following descending order quinalphos (-1.44), carbaryl (-4.68), fenthion (-6.12) and deltamethrin (-8.99). The variations in the potash content of treated plants were significantly correlated (r = 0.55) with the variation in progeny production in N. lugens in different treatments.

The mean per cent increase in the content of calcium (-14.5 to -1.85), zinc (-3.98 to 4.37) and iron (-8.24 to 0.24) did not vary significantly. The content of magnesium showed highest increase in plants sprayed with methyl parathion (19.1 per cent) and it came on par with fenitrothion (17.7 per cent), HCH (8.33 per cent), deltamethrin (7.42 per cent) and fenthion (4.26 per cent). The increase in the magnesium content in the remaining treatments were marginal.

Manganese content in plants sprayed with quinalphos (per cent increase over control 2.96), methyl parathion (-2.86) and fenitrothion (-5.11), were on par. The content in the remaining treatments (-12.3 to -6.61) were on par.

The content of copper decreased in plants treated with the different insecticides except in the case of carbaryl (per cent increase over control 0.51). The copper content in methyl parathion (-2.96) and deltamethrin (-8.04) sprayed plants also came on par with that of carbaryl. The level of copper in the remaining treatments (-20.1 to -12.9) were on par. In general the minor nutrient content (Ca, Mg, Zn, Mn, Cu or Fe) of the treated plants did not exert significant influence on the progeny production of N. lugens.

3.8.8. The effect of spraying different insecticides, at the tillering, panicle initiation and booting stages of rice, on the nutrient content of the plants and the correlation between the variations in the nutrient content and progeny production of N. lugens exposed on treated plants

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 21. The nitrogen content showed highest increase in plants sprayed with methyl parathion (58.8 per cent over control) and it was significantly higher than the content in all other treatments. This was followed by fenthion (48.8), deltamethrin (39.7) and fenitrothion (33.9) in descending order with significant differences among the treatments. The per cent increase of nitrogen content in quinalphos (14.1) and carbaryl (8.99) sprayed plants were next in the rank and the effect of HCH (4.29) was least. The variations in the nitrogen content of the treated plants was significantly correlated (r = 0.57) with the variations in progeny production of N. lugens.

The content of phosphorus in all the treated plants were lower than that of control plants. Mean per cent change in the phosphorus levels in plants sprayed with methyl parathion (-2.15 per cent over control), carbaryl (-5.7) and fenthion (-9.58) were on par. The content observed in the remaining treatments (-15.2 to -12.1) also came on par with fenthion. The correlation coefficient between the variations in phosphorus content and progeny production of N. lugens of the treated plants was significant and positive (r = 0.49).

The content of potash showed maximum increase in fenthion sprayed plants (9.09 per cent over control) and it was significantly higher than the rest of the treatments. The per cent increase of potash observed in plants sprayed with deltamethrin and fenitrothion were on par and came next in rank. HCH and methyl parathion sprayed plants had potash levels less than that of control. Correlation between this factor and progeny production of N. lugens was statistically insignificant.

The per cent increases in the content of calcium (-34.8 to 11.5), magnesium (-16.9 to -0.9) and zinc (-10.7 to 32.6) did not show statistically significant variations.

Per cent increase in the manganese content was highest in carbaryl sprayed plants (23.3) and it came on par with methyl parathion (20.0) and HCH (17.1); fenitrothion (15.8) also came on par with methyl parathion and HCH. Increase in the manganese content in the remaining treatments were only marginal.

Table 21. The effect of spraying different insecticides at tillering, panicle initiation and booting stages of rice plants on the nutrient content of the leaf sheath (on dry weight basis) and the correlations between each of the factors and the progeny production of N. lugens on the treated plants

ecticides	Concen-tration (%)	Mean per cent increase over corresponding controls in									
		N (x_1)	P (x_2)	K (x_3)	Ca (x_4)	Mg (x_5)	Zn (x_6)	Mn (x_7)	Cu (x_8)	Fe (x_9)	Number of nymphs (y)
	0.25	4.29 e	-15.20 c	-0.68 d	3.70 a	-6.37 a	22.10 a	17.10 ab	2.85 bc	10.90 a	15.2 e
itrothion	0.1	33.90 c	-12.10 bc	5.05 b	1.85 a	-6.82 a	-2.02 a	15.80 b	-11.40 d	-1.66 b	39.8 bcd
thion	0.1	48.80 b	-9.58 abc	9.09 a	9.77 a	-16.90 a	17.80 a	-5.71 d	23.60 a	13.30 a	37.1 cd
hyl parathion	0.1	58.80 a	-2.15 a	-5.39 e	-4.73 a	-0.90 a	8.25 a	20.00 ab	18.50 a	4.46 ab	55.6 ab
nalphos	0.1	14.10 d	-12.80 bc	2.24 c	-34.80 a	-1.83 a	32.60 a	2.80 c	-7.97 cd	8.56 ab	30.5 d
baryl	0.25	8.99 d	-5.70 ab	3.25 c	11.50 a	-4.66 a	-10.70 a	23.30 a	9.77 ab	5.54 ab	49.4 abc
tamethrin	0.004	39.70 c	-15.20 c	5.72 b	9.06 a	-2.68 a	14.10 a	4.16 c	12.70 ab	2.94 ab	59.3 a
relation coefficient ween x and y		0.57*	0.49*	-0.01	0.08	0.19	-0.03	0.09	0.25	-0.43	--

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

Highest increase in copper content was recorded in plants sprayed with fenthion (23.6 per cent over control) and it came on par with methyl parathion (18.5), deltamethrin (12.7) and carbaryl (9.77). The copper content in plants treated with fenitrothion and quinalphos were less than the level in control plants.

The per cent increase in iron content of rice plants was maximum in plants sprayed with fenthion (13.3) and all the remaining treatments (2.94 to 10.9) came on par with fenthion except fenitrothion (-1.66). The variations in Ca, Mg, Zn, Mn, Cu and Fe were not significantly correlated with progeny production of *N. lugens* on treated plants.

3.8.9. Effect of spraying different insecticides, at the tillering stage of rice, on the feeding index of *N. lugens*, on the biochemical constituents of the plants and on the progeny production of the insect

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 22. The feeding indices of *N. lugens* showed highly significant variations in different treatments. The highest mean per cent increase in feeding index was compared to that in control observed on plants treated with deltamethrin (37.6) and it was significantly higher than the feeding in all other treatments. The per cent

Table 22. Effect of spraying different insecticides at the tillering stage of rice on the feeding index of *N. lugens* and on the biochemical constituents of the plants and the correlation of the variations in the content of each of the above factors with the progeny production of the insect in different treatments

Treatments	Concentration (%)	Mean per cent increase over corresponding controls in				
		Feeding index (x_1)	Free amino acids (x_2)	Free sugars (x_3)	Carbohydrate/nitrogen ratio (x_4)	Number of nymphs (y)
HCH	0.25	-4.6 f	-2.5 e	2.2 a	8.5 a	-9.6 a
Fenitrothion	0.1	27.4 b	19.3 bc	-28.4 e	-36.3 e	50.4 ab
Fenthion	0.1	30.9 b	16.7 c	-34.3 f	-38.4 e	41.4 b
Methyl parathion	0.1	13.7 c	21.7 ab	-14.5 c	-16.4 c	42.8 b
Quinalphos	0.1	7.7 d	7.3 d	-3.1 b	-6.9 b	2.0 d
Carbaryl	0.25	2.1 e	3.9 d	-26.1 de	-24.4 d	19.6 c
Deltamethrin	0.004	37.6 a	23.5 a	-22.4 d	-28.9 d	67.0 a
Correlation coefficient between x and y		0.89*	0.89*	-0.71*	-0.8*	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

increase on plants treated with fenthion (30.9) and fenitrothion (27.4) were on par and significantly lower than that of deltamethrin. The per cent increases in the feeding indices observed on plants treated with methyl parathion, quinalphos and carbaryl were low (13.7, 7.7 and 2.1 respectively). The feeding index of N. lugens on plants treated with HCH was lower than that of control (per cent increase -4.6). The data on the increase in feeding indices in different treatments were significantly correlated with the different levels of progeny production of N. lugens observed in the treatments (r = 0.89).

The mean per cent increases of the free amino acid content (compared to corresponding control) in the leaf sheaths of plants treated with deltamethrin (23.5) and methyl parathion (21.7) were on par. The latter was on par with the increase in fenitrothion treated plants (19.3). Fenthion (16.7) was on par with fenitrothion also. The mean percentage increases in plants treated with quinalphos (7.3), carbaryl (3.9) and HCH (-2.5) were very low. The variations in the free amino acid content of plants treated with different insecticides were seen positively correlated with the variations in the progeny production of N. lugens in different treatments (r = 0.89).

The only treatment in which the content of free sugars showed an increase over the content in corresponding control was HCH (2.2 per cent). The maximum reduction of sugars was observed in plants treated with fenthion (34.3 per cent) and it was significantly higher than all other treatments. The free sugar content increase in fenitrothion (-28.4), carbaryl treated plants (-26.1) were on par and the latter was on par with deltamethrin treated plants also (-22.4). The deductions in the sugar contents of methyl parathion and quinalphos treatments were very low (14.5 and 3.1 respectively). The percentage decreases in the content of free sugars in different treatments were highly correlated to the varying population levels of N. lugens reared in the treatments.

The per cent increase in carbohydrate nitrogen ratios in plants treated with fenthion (-38.4) and fenitrothion (-36.3) were on par and significantly lower than in rest of the treatments. The above treatments were followed by deltamethrin (-28.9) and carbaryl (-24.4) which were on par. Methyl parathion and quinalphos had the least effect on C/N value. The decrease in the carbohydrate nitrogen ratios in different treatments were significantly correlated with the increase in the varying progeny production in the treatments.

3.8.10. Effect of spraying different insecticides, at panicle initiation stage of rice on the feeding indices of N. lugens, on the biochemical constituents of the plants and on the progeny production of the insect

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 23. The mean per cent increase in feeding index of N. lugens was maximum in quinalphos (27.2) treated plants. It was on par with methyl parathion sprayed plants (22.1) and was closely followed by deltamethrin (20.3) treated plants, the differences between the latter two treatments being statistically insignificant. Fenthion (17.3) came on par with deltamethrin and fenitrothion (15.6) on par with fenthion. The per cent increases in the feeding indices observed on plants treated with carbaryl and HCH were relatively low (9.9 and 6.1). The variations in feeding indices were positively correlated (r = 0.82) with the variations in the numbers of N. lugens produced in different treatments.

Increases in free amino acid content of plants sprayed with fenitrothion (28.6), methyl parathion (22.7) and deltamethrin (21.9) were on par. Quinalphos (15.4) came on par with methyl parathion. Per cent increases in the amino acid content of HCH (11.3), fenthion (9.6) and carbaryl (3.4) treated plants were on par and less than the increase in plants treated with methyl parathion. The

Table 23. Effect of spraying different insecticides at the panicle initiation stage of rice on the feeding index of N. lugens and on the biochemical constituents of the plants and the correlation of the variations in the content of each of the above factors with the progeny production of the insect in different treatments

Treatments	Concentration (%)	Mean per cent increase over corresponding controls in: Feeding index (x_1)	Free amino acids (x_2)	Free sugars (x_3)	Carbohydrate/nitrogen ratio (x_4)	Number of nymphs (y)
HCH	0.25	6.1 e	11.3 cd	-4.9 b	12.6 a	-10.9 c
Fenitrothion	0.1	15.6 d	28.6 a	-4.9 b	-18.7 d	18.9 d
Fenthion	0.1	17.3 cd	9.6 cd	-10.2 c	-25.9 e	39.9 b
Methyl parathion	0.1	22.1 ab	22.7 ab	-21.6 e	-31.7 e	61.9 a
Quinalphos	0.1	27.2 a	15.4 bc	-2.2 ab	-8.7 c	48.3 b
Carbaryl	0.25	9.9 e	3.4 d	1.2 a	1.3 b	19.1 d
Deltamethrin	0.004	20.3 bc	21.9 ab	-17.2 d	-28.0 e	31.8 c
Correlation coefficient between x and y		0.82*	0.24*	-0.51*	-0.76*	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

* Significant at 5% level

correlation between amino acid content and progeny production of N. lugens was significant (r = 0.24).

Free sugar content showed reduction over corresponding controls except in carbaryl treated plants which had an increase of 1.2 per cent. Maximum reduction in sugar content was observed in plants sprayed with methyl parathion and it was significantly higher than the reductions in remaining treatments. Deltamethrin and fenthion followed this treatment with mean reductions of 17.2 and 10.2 per cent, over corresponding controls. The changes in the free sugar content was significantly and negatively correlated (r = -0.51) with the variations in progeny production of N. lugens.

Carbohydrate / nitrogen ratio also showed reduction in the different treatments except in KOH sprayed plants (12.6 per cent over control). Greatest reduction in the ratio was observed in plants sprayed with methyl parathion (31.7 per cent) and it was on par with deltamethrin (28.0 per cent) and fenthion (25.9 per cent). Fenitrothion ranked next (18.7 per cent) and the reduction in other treatments were relatively less. The variations observed in the carbohydrate / nitrogen ratio and progeny production of N. lugens in the different treatments were negatively correlated (r = 0.76).

3.8.11. Effect of spraying different insecticides, at the booting stage of rice, on the feeding index of *N. lugens*, on the biochemical constituents of the plants and on the progeny production of the insect

The results of this experiment and the results of statistical analysis are presented in Table 24. Per cent increase in feeding index was highest in plants sprayed with methyl parathion (23.0) and it was significantly higher than the feeding indices in remaining treatments. It was followed by deltamethrin (18.2) and fenitrothion (16.4) and the difference between the two treatments was statistically insignificant. Increases in feeding indices were lesser in rest of the treatments (3.8 to 9.6 per cent) and the data were not correlated with the data on progeny production of *N. lugens*.

Free amino acid content increased to the highest level in plants sprayed with deltamethrin (24.9 per cent and it came on par with the content in methyl parathion (20.8 per cent) and fenitrothion (18.7 per cent) treated plants. Fenthion and HCH stood next in ranking and the increases in the treatments were negligible.

Free sugar content of plants showed significant increase over control (6.2 to 18.9 per cent) except in HCH and deltamethrin treated plants (-3.8 per cent in both). The increase observed in plants sprayed with fenitrothion and quinalphos were on par (18.9 and 17.0) and these were followed by methyl parathion and fenthion.

Except in carbaryl (5.1) and quinalphos (2.7) sprayed plants, carbohydrate/nitrogen ratio in all treatments showed significant reduction over the ratio in control plants. Maximum reduction in the ratio was observed in plants sprayed with deltamethrin (21.1 per cent) and it was followed by methyl parathion (15.1), the difference between the two treatments being statistically significant. The rest of the treatments were on par (-7.3 to -8.9 per cent increase).

Variations in any of the biochemical constituents in rice plants treated at booting stage was not significantly correlated with the variations observed in progeny production of *N. lugens*.

3.8.12. Effect of spraying different insecticides at tillering, panicle initiation and booting stages, on the feeding index of *N. lugens*, on the biochemical constituents of the plants and on the progeny production of the insect

The data relating to the experiment and the results of statistical analysis are presented in Table 25. Feeding index of *N. lugens* varied significantly on the treated plants and the per cent increase of the indices in deltamethrin (37.8)

Table 24. Effect of spraying different insecticides at the booting stage of rice on the feeding index of *N. lugens* and on the biochemical constituents of the plants and the correlation of the variations in the content of each of the above factors with the progeny production of the insect in different treatments

Treatments	Concentration (%)	Mean per cent increase over corresponding controls in				
		Feeding index (x_1)	Free amino acids (x_2)	Free sugars (x_3)	Carbohydrate/nitrogen ratio (x_4)	Number of nymphs (y)
HCH	0.25	3.8 f	10.4 c	-3.8 d	-7.8 b	29.7 ab
Fenitrothion	0.1	16.4 bc	18.7 ab	18.9 a	-8.9 b	24.4 bc
Fenthion	0.1	12.9 cd	12.6 bc	8.2 bc	-7.3 b	29.3 ab
Methyl parathion	0.1	23.0 a	20.8 a	10.0 b	-15.1 c	35.7 a
Quinalphos	0.1	9.6 de	-2.9 d	17.0 a	2.7 a	17.6 cd
Carbaryl	0.25	5.3 ef	5.4 c	6.2 c	5.1 a	23.7 bc
Deltamethrin	0.004	18.2 b	24.9 a	-3.8 d	-21.1 d	12.5 d
Correlation coefficient between x and y		0.10	0.08	0.11	0.03	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

and fenitrothion (33.3) treated plants were on par and higher than in the remaining treatments. Fenthion and methyl parathion (25.3 and 23.4) ranked next and the difference between the two treatments was statistically insignificant. These were followed by quinalphos (17.4) and carbaryl (10.5) and there was significant difference between the two treatments. The correlation coefficient between the variations in feeding indices and the variations in progeny production was significant and positive (r = 0.60).

Per cent increase in free amino acid content observed in the different treatments, except in quinalphos and HCH treated plants, were on par (11.4 to 20.9) and significantly correlated with the variations in progeny production (r = 0.5).

Per cent increase in the free sugar content in plants treated with fenthion (21.6) and methyl parathion (19.6) were on par and they were followed by deltamethrin, carbaryl and quinalphos (2.1 to 6.6) the differences among the latter also were insignificant. Sugar content in fenitrothion and HCH treated plants were less than in control plants. Correlation between free sugar content and progeny production of N. lugens was significant and positive (r = 0.61).

The carbohydrate/nitrogen ratio of treated plants showed reduction over that of control plants and the per cent reductions in methyl parathion (31.1), fenitrothion (29.8) and deltamethrin (23.5) treated plants were on par and higher than in the remaining treatments (-2.2 to -18.1). The correlation between the reduction in the ratio and progeny production was not significant.

3.8.13. Effect of treating the different growth stages (tillering, panicle initiation or booting and at all the three stages) of rice with the different resurgence inducing insecticides on the progeny production of *N. lugens* reared on the plants in relation with the feeding rate of the insect and total nitrogen, free sugar and free amino acid content of the plants

Data relating to the above aspects are presented in Fig. 4. As indicated in the figure the per cent increase in the population of *N. lugens* on treated plants, compared to the population on the control plants in respective growth stages, were positively correlated with the feeding indices and free amino acid content of the plants. The free sugar content showed a negative correlation with the nymphal population on plants treated with fenitrothion, fenthion, methyl parathion and deltamethrin. The variations in the free sugar content of plants treated with quinalphos and carbaryl were very low. Though the total nitrogen showed an increase over

Table 25. Effect of spraying different insecticides at the tillering, panicle initiation and booting stages of rice on the feeding index of <u>N. lugens</u> and on the biochemical constituents of the plants and the correlation of the variations in the content of each of the above factors with the progeny production of the insect in different treatments

Treatments	Concentration (%)	Mean per cent increase over corresponding controls in				
		Feeding index (x_1)	Free amino acids (x_2)	Free sugars (x_3)	Carbohydrate/nitrogen ratio (x_4)	Number of nymphs (y)
HCH	0.25	4.5 e	-12.2 c	-10.8 c	-6.3 ab	15.2 e
Fenitrothion	0.1	33.3 a	16.0 ab	-6.3 c	-29.8 cd	39.8 bcd
Fenthion	0.1	25.3 b	14.0 ab	21.6 a	-18.1 bc	37.1 cd
Methyl parathion	0.1	23.4 b	12.0 ab	19.6 a	-31.1 d	55.6 ab
Quinalphos	0.1	17.4 c	3.4 b	2.1 b	-10.7 ab	30.5 d
Carbaryl	0.25	10.5 d	11.4 ab	6.6 b	-2.2 a	49.4 abc
Deltamethrin	0.004	37.8 a	20.9 a	6.6 b	-23.5 cd	59.3 a
Correlation coefficient between x and y		0.60*	0.50*	0.61*	-0.26	-

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

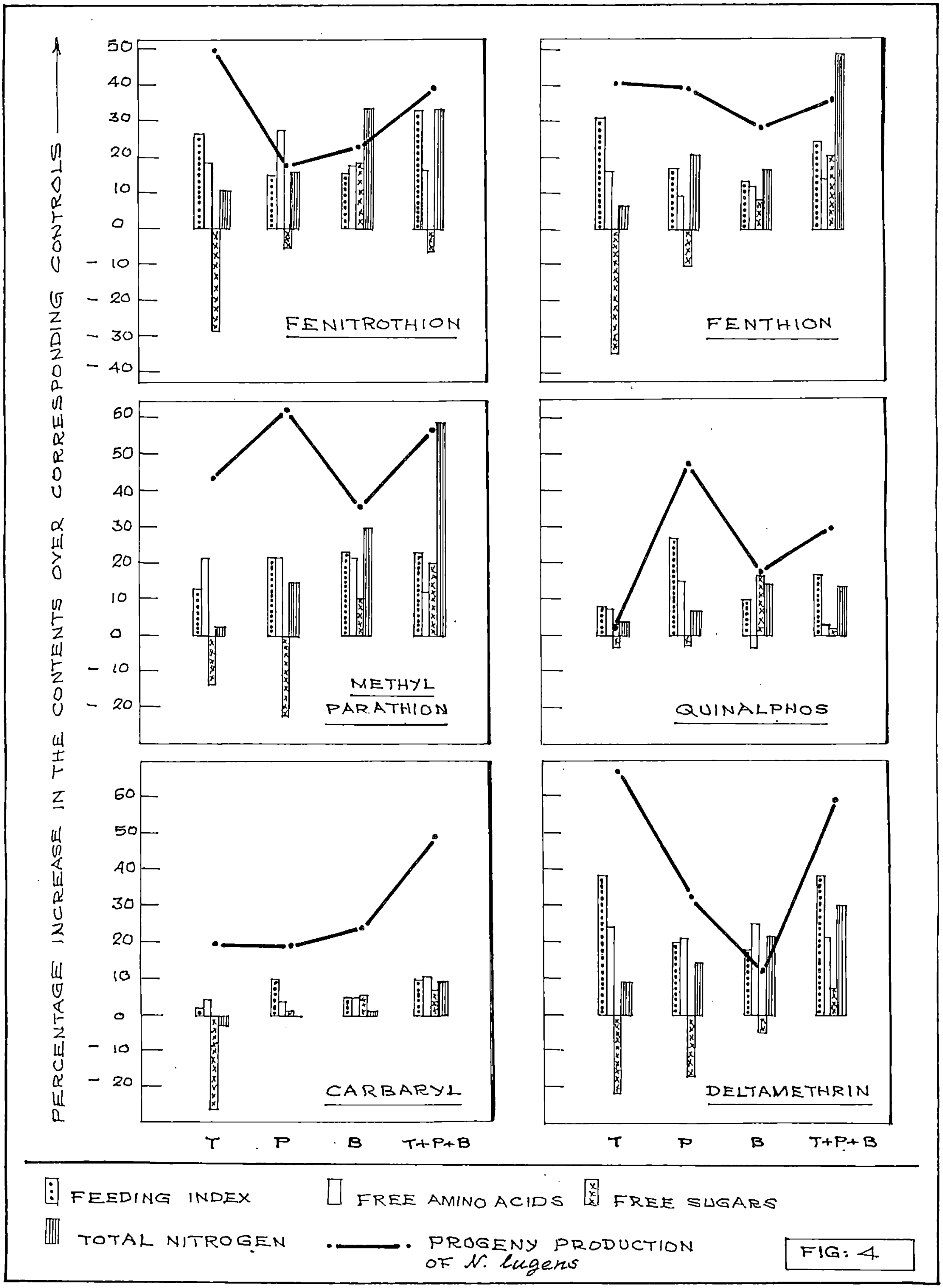
* Significant at 5% level

Fig. 4. Association between the varying resurging populations of N. *lugens* observed at different growth stages of rice treated with different insecticides and the varying contents of free amino acids, free sugars and total nitrogen of the plants and feeding index of the insect

T Tillering

P Panicle initiation

B Booting



PERCENTAGE INCREASE IN THE CONTENTS OVER CORRESPONDING CONTROLS
50
40
30
20
10
0
- 10
- 20
- 30
- 40
FENITROTHION
FENTHION
60
50
40
30
20
10
0
- 10
- 20
METHYL PARATHION
QUINALPHOS
60
50
40
30
20
10
0
- 10
- 20
CARBARYL
DELTAMETHRIN
T
P
B
T+P+B
T
P
B
T+P+B
FEEDING INDEX
FREE AMINO ACIDS
FREE SUGARS
TOTAL NITROGEN
PROGENY PRODUCTION OF N. lugens

FIG: 4

control in all the stages of the crop the variation was not related to the variation in the insect populations.

3.8.14. Correlation between the resurgence inducing factors in rice plants treated with different insecticides and the progeny production of N. lugens

The correlation coefficients between the progeny production and resurgence inducing factors are presented in Table 26. At tillering stage the total nitrogen content and free amino acids of the plants and the feeding index of the insects showed highly significant and positive correlation with progeny production (coefficients 0.783, 0.891 and 0.886 respectively) while the free sugars showed a significant negative correlation (-0.717). At panicle initiation also the same trend was observed but the correlation between free amino acid content and progeny production though positive was not statistically significant. The correlations between resurgence inducing factors and the populations observed at the booting stage of the crop were not significant (the coefficients varied from 0.046 to 0.107). When the treatments were repeated at tillering, panicle initiation and booting stages all the four factors inducing resurgence showed highly positive and significant correlation with the variation in the insect populations, (coefficients ranged from 0.506 to 0.614).

3.8.15. Path coefficient analysis

The results of path coefficient analysis are also presented in Table 26. The nature of the causal mechanisms assumed in path analysis of the plant mediated effects on resurgence is represented schematically in Fig. 5 also.

The residual effects at the tillering (0.33) and panicle initiation (0.39) stages showed that the major cause for resurgence could be attributed to the total nitrogen, free sugars and amino acid content of the plants and feeding index of the insect. But only 4 per cent of resurgence observed at the booting stage could be attributed to the above factors (residual 0.96). When the insecticides were repeatedly applied at tillering, panicle initiation and booting stages 39 per cent of resurgence was attributable to the above factors.

Among the four factors inducing resurgence at tillering stage free amino acid content had the highest direct effect (positive) on resurgence and it was followed by the effect shown by the feeding indices. The associations between these factors and resurgence also were positive and significant. The association between total nitrogen content and resurgence was highly significant and positive while the direct effect of the factor was relatively low and negative. The positive association appeared to be due to the indirect influence

Table 26. Correlation between the varying progeny production of *N. lugens* on rice plants treated with insecticides (fenitrothion, fenthion, methyl parathion, quinalphos, carbaryl and deltamethrin) at each growth stage and the factors inducing resurgence, and the direct and indirect effects of the different factors on resurgence assessed through path coefficient analysis

Stage of the crop		Correlation coefficient between progeny production (y) and resurgence inducing factors (x_1 to x_4)	Direct and indirect effects of				Residual effect
			Total nitrogen (x_1)	Total sugars (x_2)	Free amino acids (x_3)	Feeding index (x_4)	
Tillering	(x_1)	0.783*	-0.161	0.132	0.454	0.358	0.33
	(x_2)	-0.717*	0.094	-0.225	-0.309	-0.277	
	(x_3)	0.891*	-0.132	0.126	0.552	0.345	
	(x_4)	0.886*	-0.142	0.153	0.468	0.407	
Panicle initiation	(x_1)	0.665*	0.326	0.092	-0.085	0.332	0.39
	(x_2)	-0.505*	-0.118	-0.252	0.157	-0.292	
	(x_3)	0.244	0.093	0.132	-0.299	0.318	
	(x_4)	0.823*	0.155	0.105	-0.136	0.699	
Booting	(x_1)	0.046	-0.639	0.227	0.334	0.124	0.96
	(x_2)	0.107	-0.281	0.517	-0.165	0.036	
	(x_3)	0.077	-0.397	-0.159	0.537	0.096	
	(x_4)	0.104	-0.499	0.118	0.326	0.159	
Tillering + Panicle initiation + Booting	(x_1)	0.560*	-0.519	0.518	0.154	0.407	0.61
	(x_2)	0.614*	-0.370	0.726	0.077	0.181	
	(x_3)	0.506*	-0.351	0.246	0.227	0.384	
	(x_4)	0.602	-0.358	0.223	0.148	0.589	

* Significant at 5 per cent level

Underlined figures are direct effects

Fig. 5. Path diagram representing the cause (total nitrogen, free sugars, free amino acids and feeding index)- effect (resurgence) relationship. (variability induced by the application of different insecticides at critical growth stage/s of the crop

N Total nitrogen S Free sugars

A Free amino acids F Feeding index

R Resurgence (per cent increase in progeny production of N. lugens)

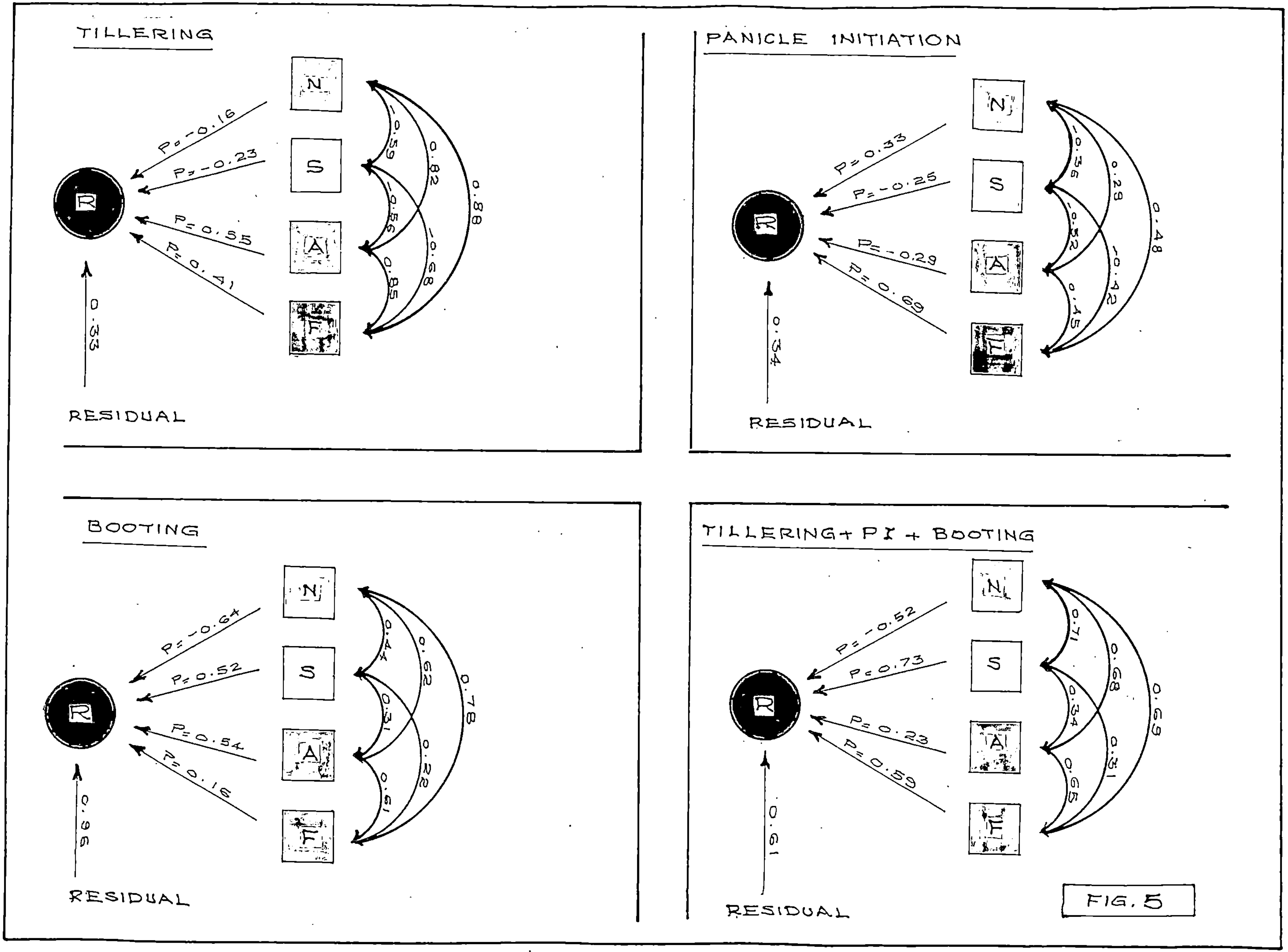

TILLERING
N
S
A
F
R
P= -0.16
P= -0.23
P= 0.55
P= 0.41
-0.59
0.82
0.88
-0.56
-0.68
0.85
0.33
RESIDUAL
PANICLE INITIATION
N
S
A
F
R
P= 0.33
P= -0.25
P= -0.29
P= 0.69
-0.36
0.29
0.48
-0.32
-0.42
0.45
0.34
RESIDUAL
BOOTING
N
S
A
F
R
P= -0.64
P= 0.52
P= 0.54
P= 0.16
0.44
0.62
0.78
0.31
0.22
0.61
0.96
RESIDUAL
TILLERING+ PI + BOOTING
N
S
A
F
R
P= -0.52
P= 0.73
P= 0.23
P= 0.59
0.71
0.68
0.69
0.34
0.31
0.65
0.61
RESIDUAL

FIG. 5

through the feeding rate of the insect and the amino acid content of the plant. In the direct and indirect effects shown by the free sugar content on resurgence as well as its association with resurgence, a highly significant negative relation was evident. The above factor also showed significant negative effect through the free amino acid content of the plant and the feeding index.

At the panicle initiation stage of the crop feeding indices showed the maximum positive effect on resurgence. It was followed by the total nitrogen content of the plant. The direct effect of free amino acid content was negative but it had exerted a high positive indirect effect through the feeding index. The association between this factor and resurgence was positive and highly significant. The direct effect and the indirect effect of the free sugar content of the plant on resurgence as well as the association of the free sugars with resurgence showed inverse relationship.

Since the residual effect observed in path analysis of the data relating to the treatments given at the booting stage was high (0.96) no reliable inferences could be drawn by its interpretation.

When the repeated application of the insecticides was done the free sugar content showed the highest positive effect on resurgence while it had a negative indirect effect through the total nitrogen content. The association between the factor and resurgence also was found to be highly positive and significant. Feeding index also had high and positive direct effect on resurgence. The direct effect of free amino acid also was positive. In their association with resurgence also the same positive relationship could be seen. Total nitrogen content of the plant had a negative direct effect on resurgence while it had a positive indirect influence through the free sugar content of the plant and the feeding index of the insect. Thus in the association between this factor and resurgence a significant positive relationship was evident.

3.8.16. Correlation between the resurgence inducing factors in rice plants, treated with each of the resurgence insecticides at different growth stages of the plant, and resurgence

The results of statistical analysis of the data are presented in Table 27. The variations induced by fenitrothion in the free sugar content and free amino acid content of the plant showed significant negative correlation with resurgence while the correlation between feeding index and resurgence was positive and significant. Though the total nitrogen content and growth stages of the plants were also negatively correlated with resurgence the correlation coefficients were not statistically significant. Variations induced by fenthion and

N. lugens on rice treated with each insecticide at different growth stages (T, P, B and T + P + B) and the factors inducing resurgence (x_1 to x_5) and the direct and indirect effects of the different factors on resurgence assessed through path coefficient analysis

Insecticide		Correlation coefficient between progeny production (y) and the resurgence inducing factors (x_1 to x_5)	Direct and indirect effects of: Total nitrogen (x_1)	Free sugars (x_2)	Free amino acids (x_3)	Feeding index (x_4)	Growth stage (x_5)	Residual effect
Fenitrothion	(x_1)	-0.269	-0.022	-0.299	0.261	0.012	-0.219	0.184
	(x_2)	-0.697*	-0.016	-0.426	0.039	-0.133	-0.151	
	(x_3)	-0.668*	-0.009	0.027	-0.634	-0.146	0.094	
	(x_4)	0.765*	-0.001	0.217	0.355	0.260	-0.066	
	(x_5)	-0.223	-0.019	-0.254	0.235	0.068	-0.253	
Fenthion	(x_1)	-0.055	0.982	3.726	-0.034	-0.003	-4.728	0.356
	(x_2)	-0.331	0.804	4.554	-0.065	-0.267	-5.357	
	(x_3)	-0.278	-0.127	-1.216	0.245	0.189	0.631	
	(x_4)	0.549	-0.005	-1.908	0.072	0.638	1.752	
	(x_5)	-0.395	0.849	4.459	-0.028	-0.204	-5.471	
Methyl parathion	(x_1)	0.196	0.958	-1.433	0.648	0.227	-0.209	0.349
	(x_2)	-0.201	0.834	-1.645	0.613	0.187	-0.190	
	(x_3)	-0.332	-0.758	1.233	-0.818	-0.138	0.149	
	(x_4)	0.302	0.538	-0.764	0.280	0.403	-0.155	
	(x_5)	0.119	0.923	-1.438	0.564	0.288	-0.218	
Quinalphos	(x_1)	0.107	0.105	0.083	0.037	-0.109	-0.009	0.235
	(x_2)	-0.110	0.053	0.163	0.062	-0.382	-0.006	
	(x_3)	0.375	-0.047	-0.123	-0.082	0.621	0.006	
	(x_4)	0.935*	-0.011	-0.059	-0.048	1.055	-0.002	
	(x_5)	0.349	0.078	0.077	0.035	0.172	-0.013	
Carbaryl	(x_1)	0.504	-0.151	-0.633	-0.106	0.171	1.223	0.305
	(x_2)	0.467	-0.074	-1.297	-0.066	0.392	1.506	
	(x_3)	0.587*	-0.070	-0.379	-0.227	0.165	1.098	
	(x_4)	0.605*	-0.045	-0.895	-0.065	0.577	1.033	
	(x_5)	0.772*	-0.104	-1.098	-0.140	0.335	1.779	
Deltamethrin	(x_1)	0.065	0.641	-0.768	0.024	0.173	-0.005	0.227
	(x_2)	-0.119	0.597	-0.826	0.026	0.089	-0.005	
	(x_3)	-0.290	-0.139	0.196	-0.109	-0.239	0.001	
	(x_4)	0.920*	0.131	-0.088	0.031	0.845	0.001	
	(x_5)	-0.213	0.598	-0.806	0.015	-0.014	0.006	

* Significant at 5 per cent level

T Tillering
P Panicle initiation
B Booting

methyl parathion in the different factors were not significantly correlated with the resurgence of the insect. In the case of quinalphos the variations induced on the feeding indices of the insect observed at different growth stages were seen positively correlated with a highly significant coefficient (0.935) with the varying levels of resurgence observed. In the case of carbaryl the variations induced in the progeny production was seen significantly and positively correlated with the free aminoacid content of the plant, feeding indices of the insect as well as the growth stages of the crop. In the case of deltamethrin a significant positive association was observed between the feeding index of the insect and resurgence.

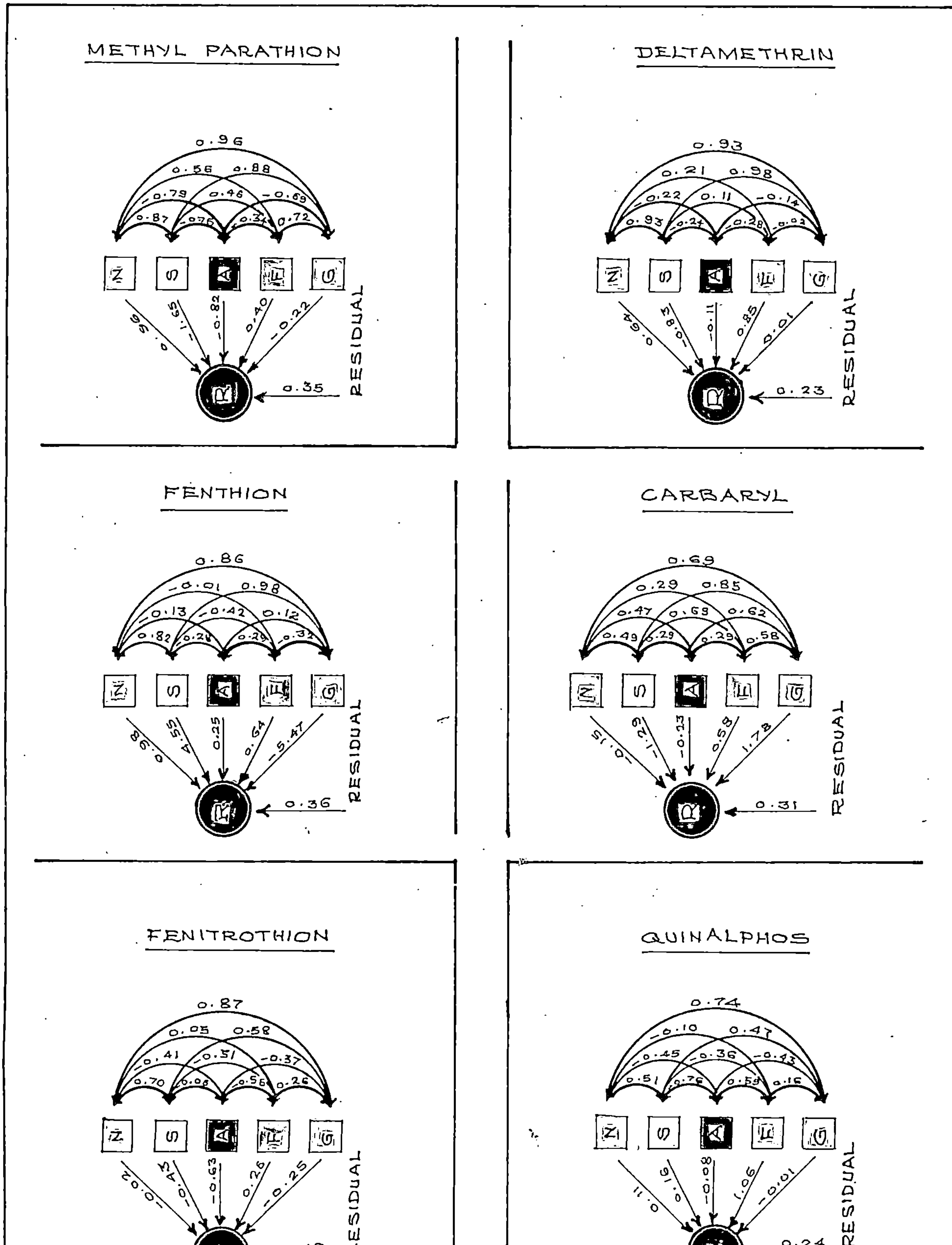
3.8.17. Path coefficient analysis

The results of analysis are presented in Table 27 and Fig. 6. The low residual effects seen in path coefficient analysis (0.184 to 0.356) indicated that the resurgence observed could largely be attributed to the different factors studied in the experiment.

When treated with fenitrothion at different growth stages of the crop the variability induced in the feeding index alone had a positive direct effect on resurgence. The direct effect of other factors was negative and they came in the following descending order: free amino acid, free sugars,

Fig. 6. Path diagram representing the cause (total nitrogen, free sugars, free amino acids and feeding index) - effect (resurgence) relationship. (variability induced by the application of each insecticide at critical growth stage/s of the crop

N	Total nitrogen	S	Free sugars
A	Free amino acids	F	Feeding index
G	Growth stage	R	Resurgence



METHYL PARATHION
0.96
0.56 0.88
-0.79 0.46 -0.69
0.87 0.76 0.34 0.72
Z S A F G
0.96 -1.65 -0.82 0.40 -0.22
R
0.35
RESIDUAL
DELTAMETHRIN
0.93
0.21 0.98
-0.22 0.11 -0.14
0.93 0.24 0.28 0.03
Z S A F G
0.64 -0.83 -0.11 0.85 0.01
R
0.23
RESIDUAL
FENTHION
0.86
-0.01 0.98
-0.13 -0.42 0.12
0.82 0.28 0.29 0.32
Z S A F G
0.98 4.55 0.25 0.64 -5.47
R
0.36
RESIDUAL
CARBARYL
0.69
0.29 0.85
0.47 0.63 0.62
0.49 0.29 0.29 0.58
Z S A F G
-0.15 -1.29 -0.23 0.58 1.78
R
0.31
RESIDUAL
FENITROTHION
0.87
0.05 0.58
-0.41 -0.31 -0.37
0.70 0.06 -0.56 0.26
Z S A F G
-0.02 -0.43 -0.63 0.26 -0.25
R
0.18
RESIDUAL
QUINALPHOS
0.74
-0.10 0.47
-0.45 -0.36 -0.43
0.51 0.76 0.58 0.16
Z S A F G
0.11 0.16 -0.08 1.06 -0.01
R
0.24
RESIDUAL

FIG. 6

growth stage, total nitrogen. The effect of different factors shown in path analysis on resurgence agreed with the association of different factors with resurgence.

In the case of fenthion direct effect of free sugars was the highest and positive and it was followed by total nitrogen content, feeding index and free amino acid content. The growth stage had a high negative effect on resurgence. Total nitrogen and free sugar content had high indirect negative effect through the growth stages and thus their association with resurgence became negative. Free amino acid content had positive direct effect on resurgence but it showed a negative association with resurgence through its highly negative indirect effect through the free sugar content of the plant.

Variations induced by methyl parathion in the total nitrogen content of the plant had highest positive effect on resurgence and it was followed by the feeding index. Other factors had negative effect and they came in the following descending order: free sugars, free amino acid, growth stage. The direct effects of the different factors except the growth stages were seen in their association with resurgence also. The direct effect of growth stage was negative while its indirect positive effect through total nitrogen and free amino acid content led to the positive association of the two factors with resurgence.

Quinalphos induced changes in feeding index had the highest positive and direct effect on resurgence and it was followed by free sugar content and total nitrogen content. The free aminoacid content and growth stages showed a negative direct effect on resurgence. Though the free sugar content in the plant had a direct positive effect its negative indirect effect through the feeding index rendered the association of the factor with resurgence negative. Similarly the negative direct effect of free amino acid content showed positive association with resurgence because of its positive indirect effect through feeding index. Negative direct effect of the growth stage was rendered positive in its association with resurgence due to its positive indirect effect through all the other factors.

When treated with carbaryl the effect of growth stages of the crop had the highest direct effect on resurgence and it was followed by the feeding index. The direct effects of the remaining factors were negative and they were in the following descending order: free sugars, free amino acids, total nitrogen. The direct negative effect of total nitrogen, free sugars and free amino acids were rendered positive in their association with resurgence by their positive indirect effect through the growth stages of the crop.

When treated with deltamethrin the variations induced on the feeding index of the insect showed the highest direct effect on resurgence and it was followed by the direct effects of total nitrogen content and the growth stage. The direct effect of free sugar on resurgence was negative and it was followed by the effect of free amino acid. The direct effect of different factors were indicated in their association with resurgence also except in the case of growth stage. The positive direct effect of the growth stage was rendered negative in its correlation with resurgence due to its positive indirect effects through total nitrogen and free amino acid content of the plants.

3.9. Effect of direct application of sublethal doses of different insecticides on the progeny production of *N. lugens*

The data relating to the experiment are presented in Table 28. At LC_{10} levels the highest progeny production was seen in the surviving insects treated with carbaryl (297.45) and the progeny production of insects exposed to deltamethrin also was on par with it (280.6) both being significantly higher than the population observed in control (197.86). At LC_{20} level the population produced by insects treated with deltamethrin (321.42) was the highest and it was significantly higher than the population in any of the remaining treatments. Progeny production of surviving insects treated with methyl parathion (285.9) and carbaryl (278.23) were on par and significantly higher than

Table 28. Effect of different insecticides directly applied on fifth instar nymphs of *N. lugens* on the progeny production of survivals

Insecticides	LC_{10}	LC_{20}	LC_{30}	LC_{40}	LC_{50}
HCH	184.21 c	183.41 de	176.59 e	168.21 d	180.42 f
Fenitrothion	206.34 bc	201.46 cd	185.87 de	202.67 cd	195.26 de
Fenthion	196.90 bc	196.21 de	183.79 de	186.21 bcd	202.11 cde
Methyl parathion	221.32 b	285.90 b	252.17 a	210.44 ab	215.82 cd
Quinalphos	213.25 bc	228.85 c	212.90 bcd	231.62 a	243.22 ab
Monocrotophos	192.39 bc	171.24 e	173.10 e	171.53 d	184.98 f
Carbaryl	297.45 a	278.23 b	237.49 a	228.27 a	227.23 bc
Deltamethrin	280.60 a	321.42 a	219.26 bc	217.18 ab	264.92 a
Control	197.86 bc	203.18 cd	192.31 cde	206.84 abc	211.25 cde

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

Sublethal concentrations (LC_{10} to LC_{50}) used in the experiment are given in the interleaf of Fig 7.

the population produced by insects in control (203.18). The progeny production of insects exposed to monocrotophos (171.24) was significantly lower than that of control. At LC_{30} levels methyl parathion (252.17) and carbaryl (237.49) produced significantly higher levels of progeny when compared to control (192.31). At LC_{40} levels none of the insecticides was found to induce higher reproduction in N. lugens, monocrotophos and HCH inhibited the reproductive rate when compared to control. At LC_{50} level insects treated with deltamethrin and quinalphos induced resurgence, the progeny produced by the treated insects being 264.92 and 243.22 respectively compared to 211.25 numbers in control. Carbaryl came on par with quinalphos (the progeny produced being 227.23) and also with control. Monocrotophos and HCH which resulted in the progeny productions of 184.98 and 180.42 respectively were found to inhibit the reproductive rate significantly.

The mean per cent increase of progeny production of N. lugens exposed to varying sublethal levels of resurgence inducing insecticides over the progeny production in corresponding controls are presented in Fig. 7. HCH at all levels tried inhibited the reproductive potential of N. lugens while fenitrothion and fenthion did not show significant effect on the reproduction of the insect. Methyl parathion, carbaryl and deltamethrin were found to cause significant resurgence at lower doses (LC_{10}, LC_{20} and LC_{30}) while quinalphos had

Fig. 7. Effect of direct application of sublethal doses of insecticides on the resurgence of *N. lugens*

	LC_{10}	LC_{20}	LC_{30}	LC_{40}	LC_{50}
HCH	0.081	0.114	0.172	0.246	0.312
Fenitrothion	0.011	0.029	0.052	0.072	0.093
Fenthion	0.015	0.027	0.039	0.056	0.074
Methyl parathion	0.022	0.034	0.045	0.061	0.083
Quinalphos	0.014	0.033	0.048	0.066	0.082
Monocrotophos	0.004	0.007	0.011	0.014	0.018
Carbaryl	0.075	0.110	0.145	0.183	0.228
Deltamethrin	0.0008	0.0012	0.0016	0.002	0.0025

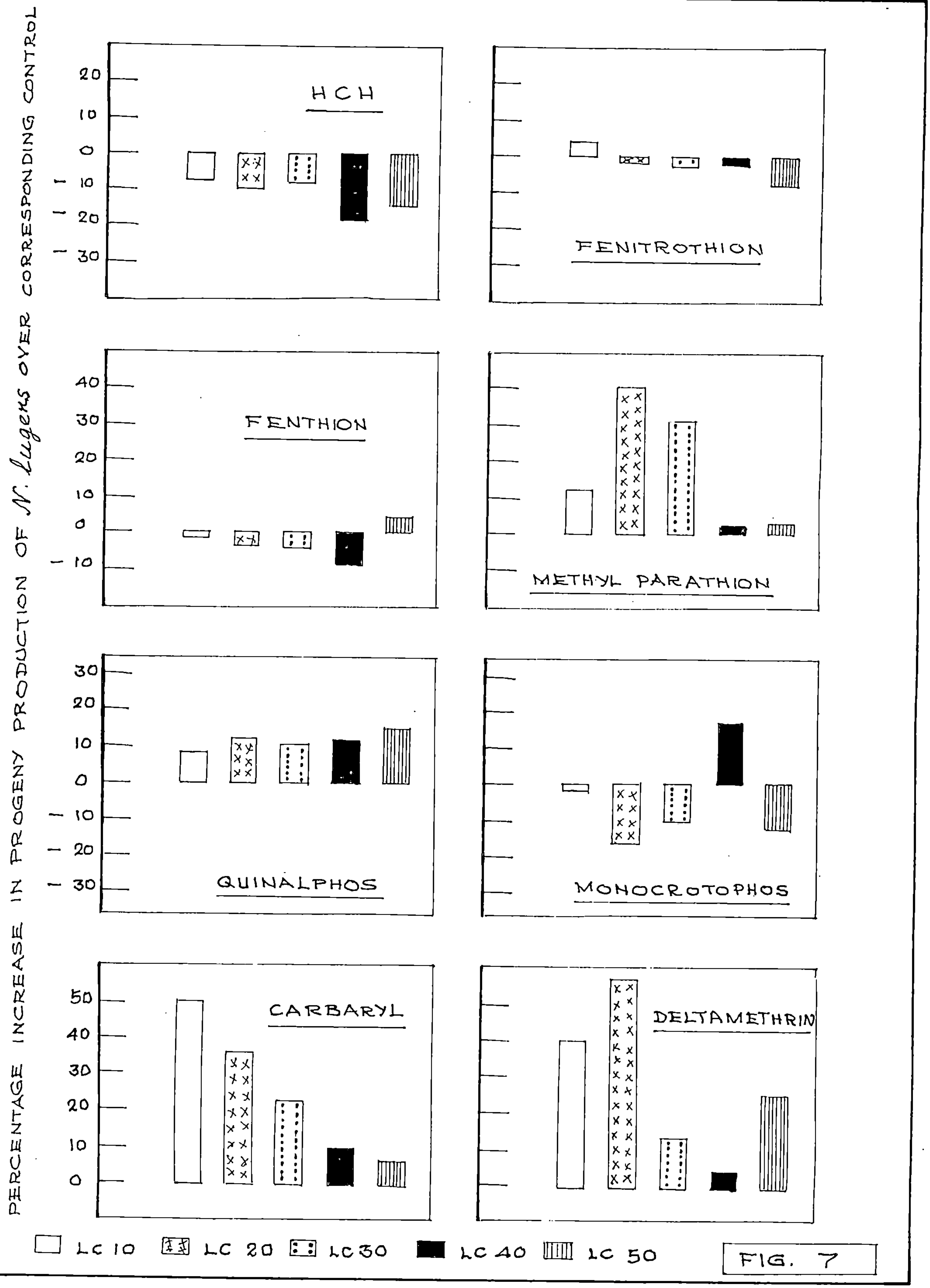

PERCENTAGE INCREASE IN PROGENY PRODUCTION OF N. lugens OVER CORRESPONDING CONTROL
HCH
FENITROTHION
FENTHION
METHYL PARATHION
QUINALPHOS
MONOCROTOPHOS
CARBARYL
DELTAMETHRIN
20
10
0
- 10
- 20
- 30
40
30
20
10
0
- 10
30
20
10
0
- 10
- 20
- 30
50
40
30
20
10
0
LC 10
LC 20
LC 30
LC 40
LC 50

FIG. 7

the effect at LC_{50} level only, though at the remaining levels also there was increase in progeny production. Deltamethrin caused significant resurgence at the lower and highest levels tried (LC_{10}, LC_{20} and LC_{50}) and at LC_{30} and LC_{40} levels the increase in progeny production was marginal.

3.10. Effect of insecticides on the field population of N. lugens

The results of the field experiment conducted at Alleppey along with the results of statistical analysis of the same are presented in Table 29. The population of N. lugens prior to the insecticidal treatment was heterogeneous. The population levels in different treatments before the second spraying (34 DAP) did not show statistically significant variations and hence it was inferred that no resurgence of N. lugens was caused by the application of any of the insecticides.

Population of N. lugens observed prior to the third spraying (49 DAP) showed statistically significant variations. The populations observed in plots treated with deltamethrin 0.024 kg ai/ha (235.2) and deltamethrin 0.012 kg ai/ha (252.7) were on par and significantly higher than the population in control (108.3). It was followed by the populations in plots treated with deltamethrin 0.006 kg ai/ha (179.8), methyl parathion 0.25 kg ai/ha (178.8), methyl parathion 0.5 kg ai/ha (158.8) and quinalphos 0.5 kg ai/ha (158.6). All other

Table 29. Resurgence of N. lugens in fields treated thrice with different insecticides as observed and as calculated giving weightage for variation in the pretreatment population counts and for varying levels of reductions caused by insecticidal effect of treatments (multiple covariance analysis)

nts ha)	Mean number of insects / 10 hills in treatments												
	Before first spraying (19 DAP)	After first spraying (22 DAP)	Per cent reduction	Before second spraying (resurgence) (34 DAP)	Calculated (resurgence)	After second spraying (37 DAP)	Per cent reduction	Before third spraying (resurgence) (49 DAP)	Calculated (resurgence)	After third spraying (52 DAP)	Per cent reduction	Last sampling (resurgence) (67 DAP)	Calculated (resurgence)
0.75	22.0 bcd	10.0 b	54.6	120.20 a (7.03)	123.90 d (12.70)	26.0 ab	78.4	100.70 fg (-7.02)	105.0 ef (68.5)	50.1 b	50.3	80.00 g (-31.90)	82.60 f (-13.20)
1.00	16.7 cd	5.7 b	65.9	113.90 a (1.42)	131.30 cd (19.50)	13.0 b	88.6	137.50 cde (26.90)	151.4 bcd (143.1)	42.2 b	69.3	82.40 g (-29.80)	88.70 f (-6.83)
1.25	18.8 bcd	6.0 b	68.1	136.60 a (21.60)	148.70 b (25.30)	8.3 b	93.9	89.30 g (-17.50)	106.7 ef (71.3)	36.6 b	51.0	54.60 h (-53.90)	62.20 g (-34.70)
0.125	27.7 ab	12.0 b	56.7	119.50 a (6.41)	109.50 e (0.36)	35.0 a	70.7	94.00 fg (-13.20)	92.0 f (47.7)	43.3 b	53.9	110.50 f (-5.88)	117.00 e (22.90)
0.25	37.3 a	11.6 b	68.9	124.00 a (10.40)	93.20 f (-15.20)	15.6 b	87.4	120.90 def (11.60)	134.1 cde (115.2)	28.7 c	76.3	116.20 f (-1.02)	130.90 e (37.50)
0.5	36.9 a	12.7 b	65.6	100.10 a (-10.90)	73.50 g (-33.10)	9.0 b	91.0	158.60 bc (46.40)	174.9 b (180.1)	32.0 c	79.8	174.90 e (48.90)	187.00 d (96.40)
n 0.125	13.6 d	10.3 b	24.3	108.70 (-3.21)	140.40 bc (27.80)	43.3 a	60.2	143.30 cd (30.50)	128.8 de (106.7)	44.7 b	68.4	111.90 f (4.68)	117.90 e (23.80)
0.25	13.9 d	6.7 b	51.8	136.60 a (21.60)	167.70 a (52.60)	31.0 a	77.3	178.80 b (65.10)	184.3 b (195.8)	38.4 b	78.4	202.70 d (72.70)	211.40 d (112.10)
0.5	28.7 ab	7.0 b	75.6	124.20 a (10.60)	109.50 e (0.36)	14.6 b	88.2	158.80 bcd (42.90)	169.7 bc (192.4)	82.3 a	46.8	254.40 c (116.70)	242.70 c (154.90)
0.006	25.9 abc	13.7 b	47.1	168.80 a (50.30)	162.90 a (48.20)	78.0 a	53.8	179.80 b (66.00)	163.3 bcd (162.1)	81.9 a	54.5	211.90 d (80.50)	209.80 d (120.40)
0.012	19.4 bcd	10.0 b	48.5	126.40 a (12.60)	139.90 bc (26.80)	38.4 a	69.6	252.70 a (133.30)	249.9 a (300.3)	94.7 a	62.5	313.30 b (166.90)	293.60 b (208.40)
0.024	25.2 abc	7.0 b	72.2	127.30 a (13.40)	120.60 de (9.70)	27.7 ab	78.2	235.20 a (117.20)	241.3 a (287.3)	103.3 a	56.1	356.40 a (203.60)	332.90 a (249.70)
	27.3 ab	33.3 a	-21.9	112.30 a	109.90 e	77.0 a	31.4	108.30 efg	62.3 g	108.6 a	--	117.40 f	95.20 f

Figures in parentheses are per cent increases over corresponding controls
Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

treatments except methyl parathion 0.125 kg ai/ha (143.3) were on par with control.

The resurgence effects of the treatments were observed in the last sampling also. The highest population was in plots sprayed with deltamethrin 0.024 kg ai/ha (356.4) and it was significantly higher than all other treatments. It was followed by the resurgence observed in plots treated with deltamethrin 0.012 kg ai/ha (313.3) and methyl parathion 0.5 kg ai/ha (254.4) and the data from the two treatments being significantly different. Populations in plots treated with deltamethrin 0.006 kg ai/ha (211.9) and methyl parathion 0.25 kg ai/ha (202.7) were on par and came next in rank. Among the remaining treatments quinalphos 0.5 kg ai/ha alone showed resurgence (174.9). The populations in plots sprayed with methyl parathion 0.125 kg ai/ha, quinalphos 0.25 and 0.125 kg ai/ha were on par with control while the numbers of N. lugens in plots treated with different doses of HCH were significantly lower than that of control.

When the data obtained before the second spraying (the effect of the first insecticidal application) were adjusted through multiple covariance analysis taking the heterogeneity in the preceding population at 19 DAP (parental) and per cent reductions in population caused by the insecticidal effect of the treatments (observed two days after first spraying) statistically significant variations were seen among the calculated values. The highest doses of methyl parathion and deltamethrin and the lowest dose of quinalphos came on par with control while the population in other treatments came significantly higher than that of control.

In the population observed before the third spraying (49 DAP) all treatments except the three doses of HCH and the lower two doses of quinalphos showed resurgence and in the resurgence inducing treatments the increases in population over control ranged from 30.5 to 117.2. In the calculated population all the treatments showed varying levels of resurgence and in the resurgence inducing treatments the increases in population over control ranged from 47.7 to 300.3 per cent.

In the last sampling at 67 DAP the three levels of deltamethrin and methyl parathion and quinalphos @ 0.5 kg ai/ha showed resurgence, the increases in population compared to control being in the range of 4.68 to 203.6 per cent. But in the adjusted column the three levels of deltamethrin, methyl parathion and quinalphos were found as resurgence inducing insecticides and the per cent increases of the populations in the treatments over corresponding controls ranged between 22.9 and 249.7.

3.11. Effect of different insecticides sprayed for the control of *N. lugens* on the population of *C. lividipennis* in field

The population of the predatory bugs collected at different intervals from the treated fields and the results of statistical analysis of the data are presented in Table 30. The population before the first spraying ranged from 5 to 14.4 and the variations were statistically insignificant. The mean populations before the second treatment ranged from 14.9 to 40.9 and there was heterogeneity in the data. Plots previously treated with HCH 1 kg ai/ha and methyl parathion 0.25 kg ai/ha showed significantly higher population than control. The mean populations before the third treatment ranged from 26.4 to 51.2. The least population was in plots previously treated with quinalphos 0.5 kg ai/ha and the maximum was in plot treated with HCH 1.25 kg ai/ha which came on par with all plots except those previously treated with HCH 0.75 kg ai/ha (28.9), quinalphos 0.125 kg ai/ha (30.9) or 0.5 kg ai/ha (26.4) and deltamethrin 0.006 kg ai/ha (33.3).

After the first spraying the population in treatments, (2.3 to 10.5) when compared to pretreatment population, did not show very conspicuous reduction. Except in plots treated with methyl parathion 0.5 kg ai/ha and deltamethrin 0.024 kg ai/ha the populations remained on par with control. After

Table 30. Effect of insecticides on the field population of *C. lividipennis*

Insecticide	Dose kg ai/ha	Mean number of bugs caught / five sweeps						
		First treatment		Second treatment		Third treatment		Last sampling (67 DAP)
		Before	After	Before	After	Before	After	
HCH	0.75	11.9 a	6.0 abc	28.9 abc	15.8 de	28.9 cd	32.4 cde	20.9 bc
	1.0	11.5 a	5.0 bc	33.8 a	31.3 abc	40.9 abcd	27.8 de	36.9 a
	1.25	7.3 a	3.4 bc	31.3 ab	22.4 cde	51.2 a	26.9 e	38.4 a
Quinalphos	0.125	11.5 a	4.8 bc	15.6 cd	11.0 e	30.9 cd	24.9 e	35.9 a
	0.25	6.5 a	2.9 bc	25.4 abcd	27.2 bcd	37.8 abcd	42.4 bcd	36.8 a
	0.5	14.4 a	4.0 bc	14.9 d	11.8 e	26.4 d	23.9 e	18.2 c
Methyl parathion	0.125	11.9 a	10.5 a	33.9 ab	40.9 ab	47.9 ab	23.3 e	28.9 abc
	0.25	4.8 a	4.0 bc	40.9 a	48.4 a	42.9 abc	35.9 cde	18.3 c
	0.5	8.3 a	2.5 c	35.7 ab	30.9 abcd	41.0 abcd	22.4 e	7.9 d
Deltamethrin	0.006	6.9 a	4.0 bc	35.8 ab	25.9 bcd	33.3 bcd	27.8 de	32.8 ab
	0.012	5.0 a	2.9 bc	27.7 abcd	29.2 abcd	38.8 abcd	53.2 b	20.4 bc
	0.024	8.8 a	2.3 c	28.9 abc	11.8 e	50.7 a	80.9 a	31.7 ab
Control		10.5 a	6.5 ab	20.5 bcd	32.9 abc	39.9 abcd	47.5 bc	30.8 abc

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

the second spraying the populations in plots treated with quinalphos 0.125 kg or 0.5 kg ai/ha and deltamethrin 0.024 kg ai/ha alone were below the level of control. After the third treatment the populations in plots treated with HCH 0.75 kg ai/ha, quinalphos 0.25 kg ai/ha, methyl parathion 0.25 kg ai/ha and deltamethrin 0.012 kg ai/ha came on par with control and the populations in plots treated with deltamethrin 0.024 kg ai/ha was significantly higher than that of control. In other treatments the populations were significantly lower than that of control. In the last sampling the mean number of bugs in plots treated with methyl parathion 0.5 kg ai/ha alone was significantly lower than that of the control. All other treatments came on par with control and the population in the treatments ranged from 18.2 to 38.4 / five sweeps. The variations in the resurgence of *N. lugens* observed at 15 days after the first treatment (34 DAP, vide Table 29) was negatively correlated (r = -0.37) with the variations in population of *C. lividipennis* observed immediately after the first treatment (Table 30), though the correlation coefficient was nonsignificant. Significant, positive relationship between the pest population in last sampling (67 DAP, Table 29) and predator population immediately after the third treatment (Table 30) was also observed.

3.12. Effect of different insecticides used for controlling H. lugens on the population of M. atrolineata in field

Mean numbers of bugs trapped before and after each treatment and the results of statistical analysis of the data are presented in Table 31. The populations prior to the first, second and third treatments were in the ranges of 7.8 to 16.9, 6 to 16.9 and 3.9 to 11.9 respectively. There was no heterogeneity in the population. The numbers of bugs after the first, second and third spraying got reduced to the ranges of 1.9 to 11.8, 2.9 to 8.8 and 1.5 to 8.9 respectively. Significant reduction in populations, when compared to control was observed in plots covered with HCH (1.25 kg ai/ha), methyl parathion (0.25 kg ai/ha) and deltamethrin (0.024 kg ai/ha) in the first spray. The data from the plots treated with different doses of the insecticides did not show statistically significant variations after the second and third sprays or in the last sampling done at 67 DAP. The variations in the resurging populations of H. lugens (at 34, 49 and 67 DAP, vide Table 29) were not correlated significantly with the variations observed in the population of bugs at each of the preceding occasions, (after first, second and third treatment respectively, vide Table 31).

Table 31. Effect of insecticides on the population of *N. atrolineata* in field

Insecticide	Dose kg ai/ha	Mean number of bugs trapped from 300 cm^2 area of water surface						
		First treatment		Second treatment		Third treatment		Last sampling (67 DAP)
		Before	After	Before	After	Before	After	
HCH	0.75	16.9 a	7.4 abc	15.0 a	2.9 a	3.9 a	6.9 ab	5.0 a
	1.0	14.8 a	3.5 bcd	11.4 a	5.0 a	7.3 a	5.9 ab	5.0 a
	1.25	11.9 a	2.9 cd	6.9 a	4.0 a	6.3 a	1.5 c	1.9 a
Quinalphos	0.125	10.5 a	8.4 ab	11.8 a	4.0 a	5.5 a	5.0 abc	9.5 a
	0.25	8.9 a	4.8 bcd	13.9 a	6.4 a	9.0 a	8.0 a	6.9 a
	0.5	15.3 a	7.0 abc	10.5 a	6.0 a	9.9 a	7.4 ab	4.5 a
Methyl parathion	0.125	13.9 a	11.8 a	16.9 a	3.5 a	8.9 a	2.9 bc	4.5 a
	0.25	7.8 a	1.9 d	8.8 a	5.0 a	6.9 a	5.0 abc	8.0 a
	0.5	12.0 a	7.9 ab	15.4 a	4.8 a	5.9 a	7.9 a	4.0 a
Deltamethrin	0.006	7.9 a	10.9 a	6.0 a	4.8 a	11.9 a	6.4 ab	5.0 a
	0.012	9.6 a	6.9 abc	12.8 a	6.4 a	8.8 a	4.0 abc	2.9 a
	0.024	8.8 a	2.9 cd	16.8 a	4.0 a	10.5 a	8.9 a	4.8 a
Control		9.9 a	8.0 ab	13.4 a	8.8 a	7.9 a	4.5 abc	5.9 a

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

3.13. Effect of different insecticides used for the control of N. lugens on the population of *Tetragnatha* sp.

Mean numbers of spiders observed in plots treated with various insecticides in the field and the results of statistical analysis of the data are presented in Table 32. Mean numbers before the first, second and third sprayings were in the range of 12.8 to 35.4, 10.4 to 23.4 and 17.5 to 41.9, respectively. The mean ranges after the first, second and third sprayings were 1.9 to 16.3, 6.9 to 34.4 and 8.8 to 36.3 respectively. Significant reduction in population due to treatments were seen in plots treated with the three doses of HCH and deltamethrin @ 0.024 kg ai/ha in all the three sprayings, when compared to the corresponding controls. In the last sampling populations of spider in plots treated with HCH @ 1 or 1.25 kg ai/ha, quinalphos 0.25 kg ai/ha and deltamethrin 0.006 or 0.024 kg ai/ha were less than that of the corresponding controls. The correlation between the data on resurgence of N. lugens observed and the populations of *Tetragnatha* at the preceeding occasions were not statistically significant. However, a negative relationship ($r = -0.2$) could be observed between the data obtained after the second treatment of insecticides.

Table 32. Effect of insecticides on the population of *Tetragnatha* sp.

Insecticide	Dose kg ai/ha	Mean numbers of spiders / five sweeps						
		First treatment		Second treatment		Third treatment		Last sampling (67 DAP)
		Before	After	Before	After	Before	After	
HCH	0.75	22.9 bcde	4.4 cd	20.0 ab	6.9 f	22.9 bcde	15.9 cd	10.5 abc
	1.0	12.8 e	5.9 cd	13.9 ab	16.3 cde	12.8 e	10.9 d	7.9 bc
	1.25	16.4 de	1.9 d	16.9 ab	13.5 ef	16.4 de	8.8 d	6.0 c
Quinalphos	0.125	41.9 a	10.5 abc	19.8 ab	31.0 a	41.9 a	32.0 ab	10.9 abc
	0.25	33.4 ab	14.9 ab	19.9 ab	24.2 abcd	33.4 ab	27.9 ab	6.5 c
	0.5	29.9 abc	16.3 a	22.7 a	16.9 cde	29.9 abc	22.4 bc	16.0 a
Methyl parathion	0.125	25.9 bcd	8.9 abc	10.4 b	34.4 a	25.9 bcd	36.3 a	8.9 abc
	0.25	19.5 cde	14.9 ab	16.8 ab	28.1 ab	19.5 cde	32.9 ab	10.8 abc
	0.5	35.4 ab	12.8 ab	21.7 a	25.3 abcd	35.4 ab	31.0 ab	12.7 abc
Deltamethrin	0.006	27.7 abcd	14.3 ab	21.9 a	17.5 bcde	27.7 abcd	27.0 ab	6.9 c
	0.012	28.8 abcd	9.9 abc	23.4 a	15.9 de	28.8 abcd	31.0 ab	16.9 a
	0.024	17.5 cde	7.9 bc	22.9 a	12.0 ef	17.5 cde	13.0 d	7.0 c
Control		34.2 ab	14.9 ab	15.9 ab	27.0 abc	34.2 ab	29.9 ab	15.8 ab

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

3.14. Effect of insecticides used for the control of *N. lugens* on the population of *L. pseudoannulata*

The population of *L. pseudoannulata* observed at different intervals during the experiment and the results of statistical analysis of the data are presented in Table 33. The results showed that the spider had a heterogeneous distribution and the data prior to each of the three sprayings showed heterogeneity. The populations before the first, second and third sprayings were in the range of 0 to 4, 0 to 4 and 1.5 to 5.9 respectively. The ranges of the populations after the three treatments were 0 to 2.5, 0 to 5.5 and 0 to 7.9 respectively. After the first spraying plots sprayed with methyl parathion 0.125 kg ai/ha had population significantly higher than that of control. After the second treatment plots treated with methyl parathion 0.125 or 0.25 kg ai/ha had significantly higher number of the spiders than the control and all other treatments were on par with control. After the third treatment plots treated with deltamethrin 0.012 kg ai/ha had the population significantly higher than that of control. In the last sampling the population ranged from 0 to 2 numbers only and the data did not show significant variations.

Table 33. Effect of insecticides on the population of *L. pseudoannulata* in field

Insecticide	Dose kg ai/ha	Mean number of spiders caught / five sweeps						
		First treatment		Second treatment		Third treatment		Last sampling (67 DAP)
		Before	After	Before	After	Before	After	
HCH	0.75	2.9 ab	0.0 b	1.9 abc	1.0 cd	5.0 a	4.0 ab	2.0 a
	1.0	2.0 abc	0.0 b	0.0 d	1.9 bc	2.9 ab	0.0 c	1.0 a
	1.25	1.9 abc	0.0 b	4.0 a	1.5 cd	1.9 b	1.0 bc	0.0 a
Quinalphos	0.125	0.5 cd	1.0 ab	4.0 a	0.5 cd	5.9 a	3.5 ab	1.9 a
	0.25	0.0 d	1.0 ab	0.5 cd	1.0 cd	5.0 ab	3.0 b	0.9 a
	0.5	1.0 bcd	0.0 b	1.0 bcd	0.5 cd	1.6 b	2.0 bc	1.0 a
Methyl parathion	0.125	4.0 a	2.5 a	2.5 abc	5.5 a	2.9 ab	2.5 bc	1.9 a
	0.25	2.9 ab	0.9 ab	2.9 ab	4.0 ab	1.5 b	0.0 c	2.0 a
	0.5	0.0 d	0.0 b	2.0 abc	1.5 cd	2.0 ab	4.0 ab	1.0 a
Deltamethrin	0.006	1.0 bcd	0.0 b	2.9 ab	1.9 bc	3.9 ab	1.0 bc	0.0 a
	0.012	0.0 d	1.0 ab	2.0 abc	0.0 d	2.9 ab	7.9 a	1.0 a
	0.024	4.0 a	0.9 ab	4.0 a	1.0 cd	4.0 ab	2.9 b	0.5 a
Control		1.0 bcd	0.0 b	1.5 abcd	1.5 cd	3.6 ab	1.5 bc	1.0 a

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

DISCUSSION

DISCUSSION

Screening of insecticides used in the rice ecosystem for their resurgence inducing effect on *N. lugens*

A series of green house studies were carried out with a view to screening the insecticides, commonly used for the control of paddy pests in Kerala, for their resurgence inducement in brown plant hopper, *N. lugens*. The screening method recommended by IRRI (Heinrichs *et al*., 1981) consisting of the exposure of gravid females of the insect on rice plants, treated thrice consecutively at 20, 30 and 40 DAP with field doses of the insecticides at 15 days after treatment and the assessment of the progeny production was adopted in the present investigation. The desirability of using field dosages of insecticides in such screening has not been established conclusively. Methyl parathion, cypermethrin (Chelliah and Heinrichs, 1978), aldicarb, mephosfolan (Chelliah and Heinrichs, 1979 a), FMC 35001 (Heinrichs *et al*., 1982 b) and fenvalerate (Balaji *et al*., 1987) were found to induce significantly higher levels of resurgence in *N. lugens* at lower dosages. Heinrichs *et al*. (1982 b) reported that deltamethrin and methyl parathion caused more resurgence of *N. lugens* at higher doses. Similarly phorate-induced resurgences in *A. gossypii* on bhendi (Regupathy, 1971) and in *N. lugens* on rice (Chelliah and Heinrichs, 1979 a) were more at higher doses. Diazinon and deltamethrin have been reported to induce resurgence equally at lower and higher doses in N. lugens (Chelliah, 1979; Heinrichs et al., 1982 b; Balaji et al., 1987). With a view to avoiding chances for missing the detection of resurgence inducing insecticides, due to the inappropriate dosage used, all the insecticides were tried at their field doses and also at the higher and lower levels.

The need for consecutive applications of insecticides for inducing resurgence in insects also has not been convincingly established. Chelliah (1979) found that one, two or three sprayings of deltamethrin were on par in inducing resurgence of N. lugens. In the case of methyl parathion two or three sprayings were found to be on par while three sprayings gave significantly higher resurgence than when sprayed once. Heinrichs et al. (1982 a) observed that a single spraying of deltamethrin in field failed to induce resurgence of N. lugens while the second and third successive sprayings caused a progressive increase in population and very high resurgence. Raman (1981) observed that two sprayings done at 20 and 30 DAP was more resurging than three sprayings done at 10, 20 and 30 DAP, thus implying that the stage of the crop also was a factor influencing resurgence. Subsequently Heinrichs et al. (1982 a) found that the application of deltamethrin and methyl parathion twice at 50 and 65 DAP were more resurgence inducing than the treatments given at 20 and 35 or 35 and 50 DAP. When the insecticides were applied once at 20, 35, 50 or 60 days after planting there was no significant variation in the levels of resurgence observed. Kenmore and Mochida (1984) observed that spraying the crop at 42nd and 49th days after planting induced greater resurgence than the sprayings done at other stages of the crop. In view of the contradicting findings available on the effect of the number of sprayings and growth stages of the crop on the inducement of resurgence, the spraying the crop once at each of the three critical growth stages of the crop (tillering, panicle initiation and booting), twice (at tillering and panicle initiation, tillering and booting, panicle initiation and booting stages) and thrice (at tillering, panicle initiation and booting stages) were included as treatments in the present investigation.

The results presented in para 3.1.1 to 3.1.7 and shown comprehensively in Figs. 1 and 2 revealed that fenitrothion, fenthion, methyl parathion, quinalphos, carbaryl and deltamethrin induced resurgence in N. lugens while HCH, dimethoate, monocrotophos, phosphamidon, phorate, BPMC and carbofuran did not show any resurgence inducing property. The insecticides in the latter group even showed a significant suppression of the pest build up in some treatments.

Among the insecticides identified as resurgence inducing ones, fenitrothion, fenthion (Chelliah and Heinrichs, 1979), methyl parathion (Chelliah and Heinrichs, 1979 and 1980; Reissig *et al*., 1982 b; Heinrichs *et al*., 1982 a and 1982 b; Raman and Uthamasamy, 1983), quinalphos (Varadharajan *et al*., 1977; Chandy, 1979; Reissig *et al*., 1982 b; Raman and Uthamasamy, 1983) and deltamethrin (IRRI, 1978, 1979; Chelliah *et al*., 1980; Reissig *et al*., 1982 b; Heinrichs *et al*., 1982 and 1982 b; Raman and Uthamasamy, 1983; Balaji *et al*., 1987) have already been reported to cause resurgence in *N. lugens*. But Raman (1981) and Reissig *et al*. (1982 b) observed that the population found in fenthion treated rice field was not significantly higher than that of corresponding controls. Carbaryl was not identified earlier as an insecticide capable of inducing resurgence in *N. lugens* though it was known to cause the resurgence in *T. urticae* (Bartlett, 1968), *S. littoralis* (Abo-Elghar *et al*., 1972), *D. vergifera* (Ball and Su, 1979) and *A. gossypii* (Gajendran, 1984; Thimmiah and Kadapa, 1987).

The insecticides identified as non-resurgence inducing ones were known to be so in earlier green house studies also. But monocrotophos (Reissig *et al*., 1982 b), phorate (Chelliah, 1979) and carbofuran (Heinrichs *et al*., 1982 b) were observed to induce resurgence in *N. lugens* in field experiments.

However, the insecticides identified as non-resurgence inducing ones in N. lugens were reported to induce the resurgence of other insect pests. Such resurgences were observed in C. suppressalis treated with HCH (IRRI, 1969), in Z. maculifrons (Mani and Jayaraj, 1976) and F. externa (Mc Clure, 1977) treated with dimethoate, S. littoralis (El-lakwah and Abdel Salam, 1974), Z. maculifrons (Mani and Jayaraj, 1976), D. cingulatus (Gajendran, 1984) and P. latus (David, 1987) treated with monocrotophos, Z. maculifrons (Mani and Jayaraj, 1976), T. urticae (Bartlett, 1968), A. gossypii (Rengarajan, 1987) and P. latus (David, 1987) treated with phosphamidon and N. virescens (Velusamy, 1987), and A. gossypii (Regupathy, 1971; Regupathy and Jayaraj, 1973 a) treated with phorate. It appears that prior to the recommendations of an insecticide for use in an agroecosystem it would be desirable to screen the same against all the important pests available in the niche to avoid the resurgence of the target pest and the emergence of secondary pests through resurgence.

Carbaryl caused resurgence of N. lugens at the lower dose of 0.15 per cent only with one and two spraying while with three sprayings it caused significant increase in population at the highest dose of 0.25 per cent.

The levels of resurgence caused by insecticides in different treatments (varying doses and crop stages) (Table 1 to 7) did not show significant variations. Based on the numbers of treatments in which each insecticide caused resurgence, the resurgence inducing insecticides could be ranked in the following descending order: methyl parathion (resurgence in 12 out of 18 treatments), deltamethrin (10/18), fenitrothion (9/18), fenthion (7/18), quinalphos and carbaryl (3/18 each).

The insects grown on plants treated with deltamethrin 0.002 and 0.004% emulsions at the tillering stage of the crop showed the carry over of resurgence effect in the second generation. Gajendran (1984) observed that there was no carry over effect for resurgence while Balaji et al. (1987) observed that the resurgence induced by deltamethrin in N. lugens persisted in the second generation also. In the present investigation the inhibition of the reproductive potential manifested by HCH, dimethoate, monocrotophos, phosphamidon, phorate, BPMC and carbofuran were found to persist in a number of the treatments in the second generation also, out of 273 treatments in the experiment only three treatments under deltamethrin showed resurgence effect in the second generation. Further the insects bred on plants, treated thrice with deltamethrin, which should normally have reached the maximum resurging stimulus did not carry the effect to the succeeding generation. In the light of the known mechanisms of resurgence inducement also it is hard to conceive a method through which such inheritance can occur. Hence the observation has to be treated as an anomaly in the data.

Out of 44 treatments which showed resurgence in the present investigations five were at the lower doses of the pesticides, 14 were at the middle and 25 were at the higher levels. All insecticides which showed resurgence at lower levels (except carbaryl) manifested the property at higher levels also but not vice versa. Even with carbaryl which showed surgence at lower level when three sprayings were given, the higher dose was more resurging. It can hence be concluded that in green house screening of insecticides, the detection of resurgence inducement will be surer at higher doses than at lower doses.

Out of 54 treatments in which the six resurgence inducing insecticides were applied once at each of the three critical growth stages of the crop, 15 treatments showed resurgence. Among similar treatments with two successive sprayings also 15/54 treatments manifested resurgence. Out of 18 treatments in which the insecticides were applied thrice in succession 13 showed resurgence. Thus three sprayings were found to be more reliable than one or two sprayings detecting resurgence. But two sprayings done at tillering and panicle initiation stages, tillering and booting stages or at panicle initiation and booting stages did not show similar trends in resurgence inducement. While fenitrothion and fenthion showed higher resurgence on plants treated at tillering and panicle initiation stages quinalphos and carbaryl showed more resurgence on plants treated at panicle initiation and booting stages and methyl parathion and deltamethrin showed resurgence in both the above combinations of plant stages. The results indicated that the influence of growth stages of the host plants was more important in bringing out the resurging properties of insecticides than the number of applications given. The results also showed that the crop growth stage favourable for resurgence inducement varied with the insecticides involved. Some of the insecticides showed higher resurgence effect at tillering stage while panicle initiation stage was more favourable for others. In general the booting stage of the host plants was the least favourable. Thus the three sprayings done consecutively at tillering, panicle initiation and booting stages of the crop may be considered as ideal for the detection of the resurgence effect of the insecticides in green house screening.

The result also showed that levels of resurgence induced by one, two and three sprayings of the insecticides did not cause significant variations among the treatments. Hence repeated application of an insecticide may not be required under field conditions for inducing resurgence of a pest. The dosage of the insecticides used and the critical growth stages of the crop are likely to influence the incidence of resurgence in field.

The observations from the first series of the experiments led to the identification of six insecticides causing resurgence in N. lugens. It was also established that for better detection of resurgence effect of insecticides in screening experiments they should best be tried at levels higher than their field doses and should be applied consecutively at the tillering, panicle initiation and booting stages of the crop prior to the release of insects for assessing progeny production.

Persistence of resurgence effect induced by insecticides on rice plants

The results presented in para 3.3 and Fig. 3 showed that the resurgence inducing factors in/on treated plants remained without significant reduction at 10 and 15 days after treatment. At 20 days after treatment also the resurgence effect persisted but it was considerably less. At 25 days after treatment the resurgence inducing effect persisted in/on plants treated with deltamethrin only. The insecticide induced resurgence was thus found to persist from 15 to 25 days after treatment depending on the nature of insecticides used. This aspect was studied for the first time. The results showed that the repeated application of insecticides did not have any cumulative effect on resurgence. The results also endorsed earlier observations that even if an insecticide causing resurgence had been used inadvertently, the population build up could be controlled by using an effective insecticide later (Chelliah, 1979).

Screening of insecticides for their potency to induce resurgence on *N. lugens*

The results presented in para 3.4 showed that malathion, methyl demeton, FMC 35001, fenvalerate, permethrin, cypermethrin and flucythrinate may cause resurgence of *N. lugens* while endosulfan, phosalone, DDVP, chlorpyriphos, methamidophos, carbaryl-DDVP mixture and HCH-DDVP mixture could be used for the control of the pest without any hazard of resurgence. Malathion had not been reported to induce resurgence of any insect so far though it was reported to cause resurgence in citrus red mite *Panonychus citri* (McGregor)(Jones and Parella,1984). Methyl demeton was reported to induce resurgence in *P. latus* on chillies (David, 1987) but not in *N. lugens*. FMC 35001 (Heinrichs *et al*., 1982 b), fenvalerate (Reissig *et al*., 1982 b; Raman and Uthamasamy, 1983), cypermethrin and permethrin (Raman and Uthamasamy, 1983) were already reported to induce the resurgence in *N. lugens* on rice. The insecticides screened out as non-resurging ones were grouped as such by earlier workers also (Chelliah and Heinrichs, 1979 b; Heinrichs *et al*., 1982 b; Reissig *et al*., 1982 b; Raman and Uthamasamy, 1983).

Granular insecticides resurging the population of *N. lugens* on rice

Results presented in para 3.5 showed that the progeny production of *N. lugens* on plants exposed, 30 days after the treatment with different granular insecticides, were significantly higher than those of control plants in the case of diazinon, phorate, carbofuran and cartap while quinalphos, aldicarb and sevidol granules did not show any resurgence effect. Phorate and carbaryl had not shown resurgence in the first screening trial (para 3.1) at the dosage levels of 0.5, 0.75 and 1.0 kg ai/ha. In that experiment *N. lugens* was released on treated plants at 15 days after treatment. The residues of insecticide during the period could have had significant toxicity to the insect which prevented the manifestations of its resurgence effect. The resurgence induced by diazinon, cartap and aldicarb in *N. lugens* was reported earlier also (Chelliah and Heinrichs, 1979 a). Varadharajan (1977) found that quinalphos granules favourably influenced the population build up of *N. lugens* while in the present investigation the population on plants treated with quinalphos came on par with that of control. As observed in the present studies Reissig *et al.* (1982 b) found that sevidol did not induce resurgence in *N. lugens*. The study further revealed that slow release formulations of insecticides caused resurgence after a long lapse of time only following the treatment, than in the case of spray formulations. Hence in screening trials sufficient lapse of time after the treatment with granular formulations should be ensured prior to the exposure of the plants to the test insects for the assessment of progeny production.

Effect of fungicides and herbicides on the population build up of *N. lugens*

Results presented in para 3.6 showed that the fungicides and weedicides commonly used in the paddy ecosystem, at their recommended dosages and frequencies of applications, did not induce resurgence in *N. lugens*. Many fungicides had been reported to have insecticidal property and Ferbam was known to induce resurgence in *A. gossypii* (Bartlett, 1968).

Agreeing with the present findings none of the fungicides used for paddy pest control had been detected to induce resurgence in *N. lugens* so far.

Earlier reports on resurgence of *N. lugens* caused by weedicides are also lacking. Evidences have accumulated in recent years to show that the chemical changes in the host plants play an important role in inducing resurgence of insects (Chelliah and Heinrichs, 1980 and Heinrichs and Mochida, 1984). Since weedicides are known to affect the physiology and growth of target plants they may influence growth of rice plants also when applied in field for weed control. These changes might in turn affect the reproductive potential of insects inhabiting the niche. 2,4-D was found to induce resurgence of aphids and borers in corn (Oka and Pimentel, 1974). In this context the weedicides commonly used in Kerala were screened for their resurgence inducement in *N. lugens*. However none of weedicides tested had significant effect on the reproductive potential of the pest.

The effect of different varieties of rice on the resurgence induced by fenitrothion in *N. lugens*

The results presented in para 3.7 have positively established that the varieties of rice will significantly influence the nature and extent of resurgence caused by insecticides. Fenitrothion screened out as a highly resurgence inducing insecticide using T(N)-1 variety of rice failed to show any resurgence effect in _N. lugens_ when the insect was reared on rice varieties, IR 20, Ptb 4, Jyothi, Pavizham, Ptb 20, Karthika, Annapoorna and Rohini, treated with the insecticide. The progeny productions of _N. lugens_ were significantly higher than in respective controls on the varieties Mushoorie, C-1727, Asha, T(N)-1, Ptb 33, Bhadra, Bharati, IR 36, Triveni and Jaya. It was further observed that both the groups included varieties noted as moderately resistant and susceptible ones. Ptb 33 which was the only known BPH resistant variety included in the experiment appeared in the group showing resurgence of the pest.

The results thus contradicted the earlier findings that the degree of resurgence induced in _N. lugens_ by insecticides was inversely related to the levels of resistance in the varieties of rice used for the experiment (Chelliah, 1979; Aquino and Heinrichs, 1979; Buenaflor et al., 1981; Reissig _et al._, 1982 b; Heinrichs and Mochida, 1984; Salim and Heinrichs, 1987). But the present findings agreed with the earlier reports of Raman (1981) and Mathew and Das (1987) that there was no specific relation between the levels of resistance of rice varieties used and the degree of resurgence observed in _N. lugens_. The number of varieties included in the earlier studies ranged from two to three only and the dearth of variability in the resistance mechanisms would have caused the apparent negative relationship between host resistance and resurgence of insect. The present study involving a wide range of rice varieties showed that the varieties of host plants would influence the inducement of resurgence. There was no significant association between the levels of resistance in the varieties involved and the levels of resurgence observed in the insects tested. While screening insecticides for pest control in an agroecosystem it will be desirable to include all varieties of the host plant, popular in the locality, in the experiment for dependable results.

Resurgence inducement through phytotonic effects on plants

Plant growth stimulation due to insecticide application has been attributed as a cause for resurgence inducement in *N. lugens*. Chelliah and Heinrichs (1978), Heinrichs and Mochida (1984) and Raman and Uthamasamy (1984) observed that the increase in plant height, number of tillers and number of leaves caused by resurgence inducing insecticides would result in the lush growth of the plants in field and it may attract more winged migratory adults of the insect and cause resurging populations. The favourable microclimate created by more luxuriant growth of the crop may also be conducive to the sheltering, feeding and multiplication of the insects.

In the light of these findings the impact of the resurgence inducing insecticides, identified in the present investigations, on the growth of the plant was studied in detail. The results presented in para 3.8.1 to 3.8.4 showed that the number of tillers and leaves were significantly higher on plants treated thrice with methyl parathion, quinalphos and deltamethrin when the insecticides were sprayed at tillering, panicle initiation and booting stages. Data relating to a single application of the insecticides did not show significant variations relating to the number of tillers and leaves though resurgence was noted in these treatments too. The above insecticides caused significantly higher plant height also when treated at panicle initiation and booting stages or at all the three critical growth stages of the crop. The leaf area indices of plants treated with all the resurgence inducing insecticides were significantly higher than that of control when the treatment was done at tillering stage of the crop but at panicle initiation and booting stages the treatments did not show significant variations from corresponding controls.

Significant correlations between the varying plant heights and insect populations were seen at tillering and booting stages of the crop and between leaf area indices and pest populations at tillering and panicle initiation stages.

But the low magnitude of variations induced by the insecticides on different growth parameters and the inconsistent nature of the observed variations in different experiments indicated that phytotonic effect of the insecticides may not influence the resurgence of N. lugens significantly in field. Chelliah and Heinrichs (1980) observed that though the number of insects attracted to plants treated with resurgence inducing insecticides were significantly higher than the number of insects alighting in control, the phenomenon was not directly related to the levels of resurgence observed.

The effect of resurgence inducing insecticides in the nutrient content and biochemical constituents of rice plants and on the feeding indices of N. lugens and their influence on resurgence inducement

Data presented in para 3.8.5 to 3.8.8 showed that there were significant variations in the nutrient content of the leaf sheath of rice plants, sprayed with the resurgence inducing and noninducing insecticides at different growth stages of the crop. The nutrients showing such significant variations in content were nitrogen, phosphorus, potash, manganese, copper and zinc. Among these nitrogen alone showed consistent variations in the different experiments. Similar influence of insecticides in the nutrient content of treated plants was reported earlier also. Occurrence of higher NPK content and higher mite population following the application of DDT and HCH was reported by Redriguez _et al._ (1957) and Saini and Cutcomp (1966). Enhancement of nitrogen content in rice following the application of systemic insecticides and consequent resurgence of _Z. maculifrons_ was reported by Mani and Jayaraj (1976). Increase in the micronutrient content following the application of resurgence inducing insecticides was reported in corn and beans (Cole _et al._, 1968). But Chelliah (1979) and Raman (1981) observed that the major and minor nutrients in rice were not significantly altered by the application of resurgence inducing insecticides.

Results presented in para 3.8.9 to 3.8.12 revealed that the free amino acid content and free sugar content of the leaf sheaths as well as the carbohydrate/nitrogen ratio showed statistically significant variations when the plants were treated with resurgence inducing insecticides at different growth stages of the crop. Buenaflor et al. (1981) observed that deltamethrin caused a significant increase in total and free amino nitrogen in rice while a nonresurging insecticide failed to cause such a change. He further observed that the treatments did not increase the starch or sugar content of the plant.

The feeding indices of N. lugens released on plants treated with resurgence inducing insecticides also showed highly significant variations in all the experiments. Similar effects on the feeding rate of N. lugens exposed on rice treated with resurgence inducing insecticides, were observed earlier also (Chelliah and Heinrichs, 1980; Raman and Uthamasamy, 1983). Deltamethrin and methyl parathion were found to induce higher feeding in A. gossypii on cotton (Gajendran, 1984).

Since significant and consistent increase in the content of total nitrogen, free sugars and free amino acid, in the plants treated with resurgence inducing insecticides and the feeding indices of N. lugens exposed on the plants were observed, the data relating to these factors obtained from different experiments were correlated with the resurging populations of the insect in corresponding treatments. The data obtained from the experiment in which the insecticidal application was done at tillering stage of the crop showed significant positive correlation between the total nitrogen content/free amino acid content/feeding index and resurgence while the sugar content had a significant negative correlation with resurgence. The same association between the different factors and resurgence was observed when the treatments were done at panicle initiation stage of the crop also but for the lack of statistical significance for the correlation between the free amino acid content and resurgence. At booting stage the association between the four factors studied and resurgence did not show statistical significance. This stage of the crop had been identified as the most unfavourable one for the inducement of resurgence in N. lugens. When three sprayings were done one each at tillering, panicle initiation and booting stages all the factors showed highly significant positive association with resurgence. The correlation between the free sugar content showed an influence opposite to that observed in tillering and panicle initiation stages on resurgence.

Positive association of the amino acid content of the plants and populations of plant and leaf hoppers had been reported earlier (Sogawa, 1971; Cheng and Pathak, 1972). The favourable influence of phorate on the population build up of A. gossypii on cotton (Regupathy and Jayaraj, 1973; Sithananthan et al., 1973), Tetranychus sp. on brinjal (Uthamasamy et al., 1976) through the enhancement of amino nitrogen content of the plant was known. Higher numbers of amino acids were observed in the ovarian tissues of N. lugens breeding on insecticide treated rice plants (Kempraj, 1982).

As observed in the present studies a negative relationship between the carbohydrate content and insecticide induced resurgence had been reported in the case of A. gossypii infesting cotton (Sithanantham *et al*., 1973) and *Z. maculifrons* on rice (Mani and Jayaraj, 1976). A positive relationship between the carbohydrate content and resurgence was observed in spider mites on apple (Saini and Cutkomp, 1966), *A. gossypii* on bhendi (Regupathy and Jayaraj, 1973 a, b) and *Tetranychus* sp. on brinjal (Uthamasamy *et al*., 1976). As observed in the present investigations, a negative relationship between resurgence and carbohydrate/nitrogen ratio in the host plants was reported in *N. lugens* (Buenaflor *et al*., 1981), *A. gossypii* (Sithanantham *et al*., 1973) and *Z. maculifrons* (Mani and Jayaraj, 1976).

The path coefficient analysis showed that at tillering and panicle initiation stages more than sixty per cent of the resurgence observed could be attributed to plant mediated factors. The resurgence observed during the booting stages could be explained to an extent of four per cent only through the different factors covered in the study. When three consecutive sprayings were given, about 40 per cent of the resurgence could be explained through the four factors studied. The earlier experiments also showed that the occurrence of resurgence of *N. lugens* was more in tillering and panicle initiation stages than at booting stage. The changes induced by these successive sprayings failed to give a cumulative influence on resurgence. This also endorsed the earlier finding that resurging effect induced by insecticides will only be of a temporary nature and normally do not persist for more than 20 days after treatment. It was also seen from the path coefficient analysis that the associations between the varying factors and resurgence were not the direct effect of the concerned factor on resurgence but it was the net result of the direct effect of the factor and its indirect effects exerted through the other factors involved in resurgence. For example, at tillering stage, the positive and significant association of total nitrogen content with resurgence was actually caused by a negative direct effect of the factor modified by its highly positive indirect effect exerted through free amino acid content and feeding index. A similar phenomenon was observed in the association between the free amino acid content and resurgence at panicle initiation stage. With regard to the remaining factors the positive or negative influence seen in their association with resurgence were reflected in the direct effect of these factor/s on resurgence too, though the effect was always supplemented by the indirect effects through other factors. Since the identified resurgence inducing factors are all related to the nutrition of the insect and since they are all involved in the different metabolic path ways in the insect they are likely to exert an interacting influence on resurgence. Obviously in simple correlation analysis where the association of each factor is considered independently for its association with resurgence the mechanism by which different factors contributing to resurgence will not be exposed fully. For this purpose the path analysis will provide a better tool. The simple correlation analysis of the data showed that the total nitrogen content, free amino acid contents and feeding index had a positive association with resurgence while the total sugar content had a significant negative association when the resurgence inducing insecticides were applied at (a) tillering, (b) P I and (c) booting stages. But the path analysis revealed that the direct and indirect influence of the above factors were showing wide variations at the different growth stages of the crop and the mechanism, as summarised in Fig. 5, was a very complicated one with a lot of interactions among the factors.

Since each insecticide had been sprayed at tillering, panicle initiation, booting and tillering + panicle initiation + booting stages of the crop in the above experiment varying levels of increase/decrease were caused in the total content of nitrogen, free sugar, free amino acid at the above growth stages of rice. The feeding indices of N. lugens in different treatments also had similar variations. This variability could be correlated with the increase/decrease by the progeny production of N. lugens in the corresponding treatments. These could be done by a regrouping of the data obtained from the experiments and the results were presented in para 3.8.16 and 3.8.17.

Simple correlation analysis of the data showed that the association of the resurgence inducing factors and resurgence were not significant in the majority of cases (Table 27). But the path coefficient analysis showed that the plant mediated resurgence caused by all the insecticides could be attributed to the combined effect of the four factors covered in the study. The residuals ranged from 0.18 to 0.35 only. The associations between each factor and resurgence as well as the direct and indirect effects exerted by the factor on resurgence showed wide variations among the various insecticides tested in the experiments. Path analysis of the data thus revealed that the mechanism of resurgence inducement was significantly influenced by the chemical nature of the insecticide involved. No previous studies are available on the nutritional factors causing resurgence in N. lugens or the cause effect analysis of the same. The results of the experiments may be summarised as follows: The application of resurgence inducing insecticides on rice results in significant changes in nutritional status of the plant and on the feeding rate of N. lugens on treated plants.

Each of the factors through its direct effect and very complicated indirect effects through the remaining factors account for the resurgence caused by the insecticide. The mechanism of resurgence inducement through the above factors were seen significantly influenced by the growth stages of the crop and the chemical nature of the insecticides involved. Path coefficient analysis may be suggested as a better method for analysing the cause effect relationship in resurgence.

Effect of sublethal doses of resurgence inducing insecticides applied directly on N. lugens

The results presented in para 3.9 and Fig. 7 showed that among the five insecticides identified in the experiment as resurgence inducing ones, methyl parathion, deltamethrin and carbaryl caused significantly higher progeny production when sprayed directly at sublethal doses while the direct effect of quinalphos was comparatively less. Fenitrothion and fenthion which caused significant resurgence through the plant showed only marginal increase in progeny production through direct application. HCH and monocrotophos which were identified as nonresurging insecticides in the screening experiments, showed a suppressing effect on the progeny production except at the LC_{40} level of the latter. While LC_{10} was the most resurging dose of carbaryl, highest stimulation in methyl parathion and deltamethrin were observed at

LC_{20} level showed less resurgence than the survivals in lots treated with the insecticide at LC_{50} level. In methyl parathion and carbaryl the higher doses were less resurgence inducing.

The results thus showed that the direct inducement of resurgence caused by different insecticides in N. lugens and the dose effect of the insecticides on resurgence varied considerably, among the insecticides tested.

Chelliah et al. (1980) observed that deltamethrin at LD_5 and LD_{50} levels and methyl parathion at LD_{25} levels caused resurging effect in N. lugens. As observed in the present investigations monocrotophos showed an inhibitory effect in A. gossypii (Gajendran, 1984). The stimulatory effect of carbaryl had been reported in S. littoralis (Abo-Elghar et al., 1972), T. urticae (Dittrich et al., 1974), D. vergifera (Ball and Su, 1979) and A. gossypii (Gajendran, 1984). The data showed that all insecticides which caused plant mediated resurgence of N. lugens did not have direct stimulatory effect on the insect, and the dosage and intensity of resurgence inducement were variably related. The direct inducement of resurgence by insecticides in insects have been attributed to their interaction with the biochemical pathways or with the endocrine system resulting in hormoligosis (Roan and Hopkins, 1961; Raman, 1981; Gajendran, 1984). In this background the variability observed in the cause effect relationship of insecticide induced resurgence is a phenomenon that can normally be anticipated. Species response to this effect also is likely to vary since even structurally related insecticides show wide differences in their interactions with the physiological processes of the treated insects. Hence the direct resurging effect of a pesticide also will have to be assessed against all major and minor pests in an agroecosystem along with green house screening, to ensure the avoidance of the resurgence in the target species and the possible flare up of secondary pests under the field situations.

Field experiment

The objectives of the field experiment were the confirmation of the results obtained from laboratory and green house studies and also to assess the role of natural enemies of N. lugens in causing the resurgence of the pest. The results presented in para 3.10 showed that in the last sampling lower dose of methyl parathion and field dose and lower doses of quinalphos failed to show resurgence while in the resurging population at 49 DAP methyl parathion at the lower dose also had caused resurgence. Thus quinalphos detected as resurgence inducing insecticide failed to show resurgence of N. lugens under field condition. As was pointed out in the results (vide para 3.10) the end population counted for the assessment of the resurgence effect of the insecticides would have emerged from the residual population of the pest in field after each insecticidal treatment. This residual population would obviously be affected by the heterogeneity in the pretreatment population and the extent of reduction in that population caused by the insecticidal application. A statistical correlation was made for those variabilities in the data which could have been influenced by the inherent properties of insecticide, methods of application and also on other microclimatic factors. Through the above statistical procedure it would be possible to make an estimate of the maximum possible resurgence that can be caused by an insecticide when most favourable conditions for the manifestation of the effect exist in the field. Under such calculated levels of resurgence (vide Table 29) there were remarkable agreements in the resurgence effect manifested by the three doses of deltamethrin, methyl parathion and quinalphos in the green house studies and under field conditions. When we conceive resurgence as a phenomenon caused by an insecticide in an ecosystem by its inherent property it appears that a reliable estimation of the hazard will be feasible through the processing of the data adopting the above multiple covariance analysis technique. The observation in the green house studies that resurgence can be induced by a single application of the pesticide also comes true when the estimated population of N. lugens at 34 DAP was considered and not in the observed population. In all the treatments, as observed in green house studies, the higher levels of insecticides were found more resurgence inducing than their lower doses. When sprayed with higher doses, after prolonged weathering the residues adequate to exert a direct stimulatory effect on the residual population of the pest and on the migrating population would occur and this in combination with the plant mediated effect would have caused the observed resurgence. The data thus indicated that application of insecticides at levels higher than the recommended dosages will cause more resurgence than when the treatments are done at doses lower than the recommended levels.

The resurgence effect of methyl parathion (IRRI., 1976, 1977, 1978; Aquino et al., 1979; Reissig et al., 1982 b) in field had been reported earlier but high levels of 5 to 33 fold increase in the population observed by the authors was not noticed in the present investigation. It may be due to the low pest pressure in the field during the period of study.

The data on the population fluctuation of C.lividipennis, M. atrolineata, Tetragnatha sp. and L. pseudoannulata showed that the repeated insecticidal treatments did not cause a persistent deleterious effect on the population of these natural enemies (vide para 3.11 to 3.14). In the post-treatment population counts of these natural enemies also marginal variations alone were observed among the different treatments and in many of the treatments the populations were on par with those of the control plots. This happened by the fast multiplication of the residual population of the organisms in the treated plots supplemented by the population found migrating from the adjacent fields. In spite of the significant populations of C. lividipennis, M. atrolineata and Tetragnatha sp. correlations between the varying populations of the natural enemies and of the pest did not show statistical significance. The results thus indicated that the natural enemies of N. lugens do not play any significant role in causing resurgence of N. lugens under field conditions.

Chelliah (1979) and Heinrichs et al. (1982 b) also observed that the reduction in the population of natural enemies did not serve as a major factor causing resurgence of N. lugens. Reissig et al. (1982 b) found that resurgence inducing insecticides stimulated populations of N. lugens regardless of their toxicity to predators. But most of the earlier discussions on pest resurgence following insecticide application stressed the adverse effect of the toxicants on natural enemies as a factor contributing to resurgence (Kobayashi, 1961; Miyashita, 1963; Kritani, et al., 1972; Dyck and Orlido, 1977). But these observations were conjectural and not adequately supported by research data.

The results obtained from the present investigation showed that the resurgence induced by insecticides in a pest population is combination of the direct stimulatory effect on the reproductive potential of the insect and the indirect effect through the favourable changes brought in the host plants particularly in the nutrient status and biochemical composition of the plant tissues. The combined effect of these two categories of factors in types of induced causing resurgence was observed in field. A comparison of the levels of resurgence observed in N. lugens caused by the comparable doses of some of the resurgence inducing insecticides in the green house experiments, laboratory and field shown in Table 34 illustrates this point. For the identification and assessment of resurgence inducing properties of insecticides green house screening combined with the assessment of direct effect of the toxicants on the insects may be as reliable or technique as the field evaluation. A number of factors like the very nature of the insecticide, its dosage, stage of the crop at the time of application of the pesticide, number of sprayings, the time lag after the treatment, the variety of host plants of the insect and the species of the insect involved were found to influence the intensity of resurgence caused by different pesticides. These observations normally tempt one to suggest manipulation of the above factors for minimising the resurgence hazards

Table 34. Extent of resurgence of *N. lugens* observed in green house, laboratory and field experiments

Insecticides applied	Mean per cent increase in population over corresponding controls when					
	exposed on treated plants in green house		directly sprayed on insects		Sprayed in field	
	dose %		dose %		dose %	
Methyl parathion	0.025	44.04	0.022	11.86	0.025	4.68
	0.05	47.12	0.034	40.71	0.05	72.66
	0.1	55.18	0.045	31.13	0.1	116.70
Quinalphos	0.025	4.53	0.014	7.77	0.025	5.88
	0.05	15.09	0.033	12.63	0.05	1.02
	0.1	30.09	0.048	10.71	0.1	48.98
Deltamethrin	0.001	32.37	0.0008	41.82	0.001	80.98
	0.002	62.43	0.0012	58.19	0.002	203.57
	0.004	59.07	0.0025	25.41	0.004	166.87

from the insecticides. But it will be very hard to get such recommendations strictly adopted by the farmers under field condition and therefore the safest method will be to withdraw all the insecticides identified as capable of inducing resurgence in the major or minor pests in each agroecosystem as suggested by previous workers (Heinrichs *et al.*, 1982 b). The direct and indirect effects of different factors known to cause the resurgence of *N. lugens*, based on the data obtained from the present studies and the informations available in literature, have presented in Fig. 8.

Fig. 8. Diagram to indicate the direct and indirect effects of a resurgence-inducing insecticide on the population of *N. lugens* in rice field

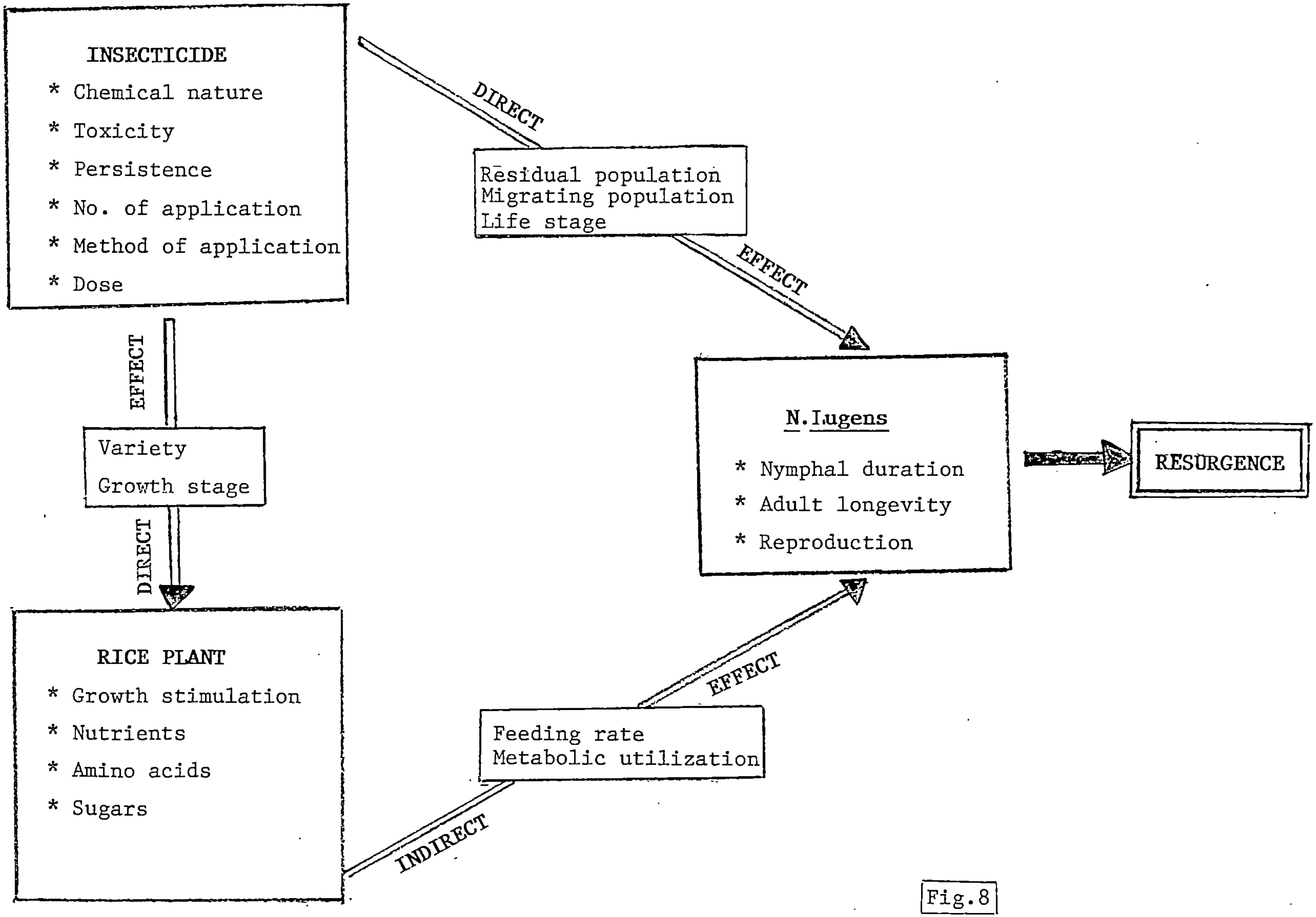

INSECTICIDE
* Chemical nature
* Toxicity
* Persistence
* No. of application
* Method of application
* Dose
DIRECT
Residual population
Migrating population
Life stage
EFFECT
EFFECT
Variety
Growth stage
DIRECT
N. lugens
* Nymphal duration
* Adult longevity
* Reproduction
RESURGENCE
RICE PLANT
* Growth stimulation
* Nutrients
* Amino acids
* Sugars
Feeding rate
Metabolic utilization
EFFECT
INDIRECT

Fig.8

SUMMARY

SUMMARY

A series of experiments were conducted, under green house conditions, to screen all the insecticides commonly used for the control of paddy pests in Kerala for their resurgence inducement in N. lugens. Thirteen insecticides were screened at their field doses and also at half and double that of field doses, with a view to avoiding chances of missing detection of resurgence effect due to inappropriate dosage used. The treatments were done once at each of the three critical growth stages of the crop (tillering, panicle initiation and booting) and twice or thrice by treating the crop at all possible combinations of growth stages so that the effect of number of insecticide applications and the influence of growth stages of the crop on the inducement of resurgence could be assessed. Progeny production of N. lugens assessed by exposing gravid females of the insect on the treated and control plants at 15 days after the treatment served as the index of resurgence.

Methyl parathion, deltamethrin, fenitrothion, fenthion, quinalphos and carbaryl induced resurgence. Based on the intensity of resurgence inducement the insecticides did not show significant variations among themselves. Based on the frequency of occurrence of resurgence among the different treatments relating to each insecticide (different dosage

levels and at different growth stages of the host) they could be ranked in the following descending order: methyl parathion, deltamethrin, fenitrothion, fenthion, quinalphos, carbaryl. The remaining insecticides, HCH, dimethoate, monocrotophos, phosphamidon, phorate, BPMC and carbofuran did not show any resurgence inducing property and some of them exerted a significant suppressing effect on the progeny production of N. lugens.

In three treatments in which deltamethrin was sprayed once, the resurgence effect was seen carried over to the second generation of N. lugens. But the treatments in which insecticide was repeatedly sprayed and in all the treatments relating to the other five resurgence inducing insecticides no carry over effect was observed. Hence the observation was considered erroneous and it was concluded that there was no carry over of resurgence effect over generations.

The data obtained from the experiment also showed that for the sure detection of resurgence caused by pesticides, they have to be used in screening trials at levels higher than their field doses.

Three consecutive sprayings done at tillering, PI and booting stages of the host plants exposed the resurgence effect of pesticides more thoroughly than when one or two sprayings were given at the critical growth stages of the crop. The results also showed that the growth stages of the crop had a higher influence than the number of sprayings on the resurgence effect of pesticides.

The data showed wide variations in the influence of growth stages of the host plant on the inducement of resurgence caused by different insecticides. When tillering stage was favourable for some insecticides, panicle initiation was better for some. In general the booting stage was least favourable for the manifestation of resurgence.

Persistence of plant mediated resurgence effects, induced by the insecticides, was studied by exposing N. lugens at different intervals after treatment and then assessing the progeny production. Such a study was done for the first time and the results showed that the effect persisted without any fall up to 15 days after treatment and at lower but significant levels at 20 days after treatment. At 25 days after treatment deltamethrin alone showed slight effect. Hence the application of resurgence inducing insecticides may induce resurgence in the pest population only temporarily and will not exert cumulative adverse effect in the niche.

Adopting the schedule of applying the insecticides at higher dose, and giving the treatments thrice, once each at tillering, PI and booting stages, 22 insecticides which were not covered in the previous experiment, were screened in the green house. Malathion, methyl demeton, FMC 35001, fenvalerate, permethrin, cypermethrin and flucythrinate (liquid formulations) showed resurgence. Diazinon, phorate, carbofuran and cartap (granules) were found to have resurgence effect on <u>N. lugens</u> when screened with two treatments at tillering and panicle initiation stages and the exposure of the test insects at 30 DAT.

At the recommended doses and methods of application the fungicides zineb, mancozeb, captafol, ediphenphos, kitazin, carbendazim and carboxin and the herbicides 2,4-D (sodium salt and ester), pendimethalin, fluchloralin, butachlor, propanil and thiobencarb were free from resurgence hazard.

The extent of resurgence induced by fenitrothion in <u>N. lugens</u>, when treated on 18 different varieties of rice, was studied adopting the procedure standardised in para 2.4. The results showed that the varieties of the host plants had high influence in the manifestation of resurgence. Fenitrothion screened as a highly resurgence inducing insecticide on T(N)-1 failed to show resurgence of <u>N. lugens</u> on eight out of 18 varieties tested in the experiment. Levels of resurgence and plant resistance to insecticides were not inversely related. The results indicated the necessity for using all popular varieties of host plants in an agroecosystem while screening insecticides for use in the area.

The resurgence inducing insecticides identified in the first series of experiments and one noninducing insecticide (HCH) were used for studying the mechanism of resurgence in detail. Phytotonic effect of each insecticide was ascertained through pot culture trials by observing the various growth parameters after treatment. There was no consistent trend in growth stimulation (number of leaves, plant height and leaf area index). The changes in plant height and leaf area indices were significantly correlated with the variations in insect populations at some of the crop growth stages, but a strong association between these factors and resurgence could not be established. Hence it was concluded that the phytotonic effect may not influence the plant mediated resurgence significantly in field.

The role of nutritional factors in inducing resurgence was investigated in relation to the build up of the population of N. lugens. Among the major and minor nutrient contents of the leaf sheaths of plants treated with resurgence inducing insecticides, nitrogen showed consistent variations at the different growth stages of the crop and among the biochemical constituents free amino acids and free sugars showed variations. The carbohydrate/nitrogen ratio as well as feeding index of N. lugens also manifested significant variations.

The variations observed in the above factors were correlated with the variations in resurging populations through simple correlation and path coefficient analysis. Results showed that the variations induced in the nutritional status of the host plant (total nitrogen, free amino acids and free sugars) and in the feeding rate of the insect could be attributed as major mechanisms of plant-mediated resurgence. The direct and indirect effect of different factors on resurgence and interactions among the factors varied from insecticide to insecticide, possibly depending on the chemical nature of the insecticides.

The direct effect of resurgence inducing insecticides on the reproductive potential of the insect was assessed by spraying last instar nymphs of N. lugens with varying sublethal dosages of pesticides and then assessing the progeny production of surviving insects on untreated plants. Methyl parathion and carbaryl caused significant resurgence at lower doses (LC_{10}, LC_{20} and LC_{30}) while deltamethrin showed resurgence at LC_{10}, LC_{20} and also at LC_{50} levels. Quinalphos had marginal effect. Fenitrothion and fenthion had no effect at any of the doses, while monocrotophos and HCH inhibited the reproductive rate.

The field experiment laid out in a farmer's field at Alleppey District, a pest prone area, formed the last part of the study. The insecticides identified as resurgence inducing ones were found to be so in the field experiment also except quinalphos. The higher doses of the insecticides caused higher resurgence. The level of resurgence observed in the field showed an added effect of the plant mediated resurgence inducement and the direct effect of the insecticides on the insect. The fluctuation in the predator fauna during the period of the experiment did not indicate any bearing on the incidence of resurgence.

The experiments revealed that the resurgence caused by some of the insecticides used for the control of N. lugens was contributed by plant mediated effects alone viz. the variations in the nutrient content and biochemical constituents of the host plant and in some other insecticides the plant mediated effects coupled with the direct stimulatory effect on the biotic potential of the insect contributed to the inducement of resurgence in the field. The manifestation of resurgence in an agroecosystem will be significantly influenced by the chemical nature, toxicity, persistence, dose, number and method of application of the insecticides; variety and growth stages of the crop; the size of the residual and migratory population as well as their life stages exposed to insecticidal application. Assessment of plant mediated resurgence in the green house followed by assessment of sublethal effects of insecticides through direct application on the insect be adopted as a rapid method of screening insecticides to be used in an agroecosystem, instead of adopting laborious field screening.

The resurgence effect induced by the insecticides did not show any cumulative effect or carry over through generations. Hence the resurgence problem created by the use of an insecticide in the field can easily be solved by withdrawing the insecticide and using a nonresurging one to check the enhanced population of the pest.

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APPENDICES

APPENDIX I

Means of observed values relating to Table 18

Treatments	Concentration (%)	Mean nutrient content of the leaf sheath (on dry weight basis)									Number of nymphs
		N (%)	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	
HCH	0.25	2.63	0.55	2.86	41.4	45.2	12.1	188	4.9	81.4	189
Fenitrothion	0.1	3.13	0.63	2.93	37.3	45.3	11.3	196	5.2	80.7	314
Fenthion	0.1	2.99	0.59	3.01	39.3	41.4	13.2	188	4.7	82.6	295
Methyl parathion	0.1	2.88	0.61	2.76	41.6	47.2	12.2	203	4.3	81.6	298
Quinalphos	0.1	2.92	0.59	2.88	38.2	39.3	11.2	197	4.7	78.7	213
Carbaryl	0.25	2.74	0.60	2.79	40.3	46.4	13.3	211	4.4	82.2	250
Deltamethrin	0.004	3.04	0.63	2.96	40.4	48.3	12.3	185	4.5	81.2	348
Control (water spray)		2.81	0.57	2.72	38.5	42.2	13.5	206	4.6	80.3	210

APPENDIX II

Means of observed values relating to Table 19

Treatments	Concentration	Mean nutrient content of the leaf sheath (on dry weight basis)									Number of nymphs
		N (%)	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	
HCH	0.25	1.94	0.51	3.17	35.4	37.2	11.2	236	4.5	88.7	159
Fenitrothion	0.1	2.68	0.59	3.43	38.3	36.2	12.3	236	4.7	87.7	212
Fenthion	0.1	2.77	0.55	3.51	36.3	43.1	12.2	220	4.2	86.7	249
Methyl parathion	0.1	2.63	0.57	3.61	37.2	39.2	13.1	231	4.3	89.3	288
Quinalphos	0.1	2.45	0.55	3.49	38.4	38.3	12.5	218	4.5	87.7	264
Carbaryl	0.25	2.29	0.56	3.31	36.4	41.3	14.4	227	4.6	88.3	212
Deltamethrin	0.004	2.62	0.59	3.66	37.4	34.5	14.2	212	4.2	87.9	235
Control (water spray)		2.28	0.53	3.28	38.1	40.3	12.1	214	4.3	88.2	178

APPENDIX III

Means of observed values relating to Table 20

Treatments	Concentration (%)	Mean nutrient content of the leaf sheath (on dry weight basis)									Number of nymphs
		N (%)	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	
HCH	0.25	1.44	0.42	2.78	33.8	41.6	8.2	231	3.3	69.5	222
Fenitrothion	0.1	1.84	0.42	2.91	34.2	45.1	7.6	236	3.2	69.3	213
Fenthion	0.1	1.62	0.45	2.61	33.4	40.2	8.2	222	3.4	73.4	221
Methyl parathion	0.1	1.79	0.49	2.92	34.8	46.2	8.3	241	3.8	71.7	250
Quinalphos	0.1	1.58	0.43	2.74	36.5	39.3	7.8	255	3.2	67.2	201
Carbaryl	0.25	1.40	0.47	2.65	37.6	38.1	7.7	217	3.9	68.3	212
Deltamethrin	0.004	1.68	0.44	2.52	32.8	41.7	8.1	229	3.6	70.3	192
Control (water spray)		1.39	0.48	2.78	38.3	38.5	7.9	248	3.9	73.5	171

APPENDIX IV

Means of observed values relating to Table 21

Treatments	Concentration (%)	Mean nutrient content of the leaf sheath (on dry weight basis)									Number of nymphs
		N (%)	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	
HCH	0.25	1.17	0.43	2.96	32.8	39.9	9.4	218	3.8	72.8	207
Fenitrothion	0.1	1.65	0.45	3.12	32.1	39.2	7.6	215	3.3	64.5	251
Fenthion	0.1	1.83	0.46	3.24	34.4	36.3	9.1	176	4.6	74.3	249
Methyl parathion	0.1	1.95	0.50	2.81	30.6	41.7	8.4	224	4.5	68.4	279
Quinalphos	0.1	1.41	0.45	3.06	35.4	41.3	10.2	191	3.5	71.3	234
Carbaryl	0.25	1.35	0.48	3.08	35.5	40.2	7.2	230	4.1	69.5	268
Deltamethrin	0.004	1.72	0.43	3.14	35.9	40.8	8.9	194	4.2	67.7	284
Control (water spray)		1.23	0.49	2.97	31.6	42.3	8.0	186	3.7	65.5	180

APPENDIX V

Means of observed values relating to Table 22

Treatments	Concentration (%)	Feeding index (mm^2)	Free amino acids (mg leu/g)	Free sugars	Total nitrogen	Carbohydrate/ nitrogen ratio	Number of nymphs
HCH	0.25	272	1.19	1.92	2.63	0.73	189
Fenitrothion	0.1	363	1.42	1.35	3.13	0.41	314
Fenthion	0.1	373	1.39	1.23	2.99	0.43	295
Methyl parathion	0.1	324	1.45	1.61	2.88	0.56	298
Quinalphos	0.1	307	1.28	1.82	2.92	0.62	213
Carbaryl	0.25	291	1.24	1.39	2.74	0.51	250
Deltamethrin	0.004	392	1.47	1.46	3.05	0.48	348
Control (water spray)		285	1.16	1.88	2.81	0.67	210

APPENDIX VI

Means of observed values relating to Table 23

Treatments	Concentration (%)	Feeding index (mm^2)	Free amino acids (mg leu/g)	Free sugars	Total nitrogen	Carbohydrate/nitrogen ratio	Number of nymphs
HCH	0.25	246	1.18	2.17	1.94	1.11	159
Fenitrothion	0.1	268	1.36	2.17	2.68	0.74	212
Fenthion	0.1	272	1.16	2.05	2.77	0.81	249
Methyl parathion	0.1	283	1.30	1.79	2.63	0.68	288
Quinalphos	0.1	295	1.22	2.23	2.45	0.91	264
Carbaryl	0.25	255	1.09	2.31	2.29	1.01	212
Deltamethrin	0.004	279	1.29	1.89	2.62	0.72	235
Control (water spray)		232	1.06	2.28	2.28	1.00	178

APPENDIX VII

Means of observed values relating to Table 24

Treatments	Concentration (%)	Feeding index (mm^2)	Free amino acids (mg leu/g)	Free sugars	Total nitrogen	Carbohydrate/ nitrogen ratio	Number of nymphs
HCH	0.25	216	1.01	1.53	1.44	1.06	222
Fenitrothion	0.1	242	1.09	1.89	1.84	1.06	213
Fenthion	0.1	235	1.03	1.72	1.62	1.03	221
Methyl parathion	0.1	256	1.11	1.75	1.79	0.98	250
Quinalphos	0.1	228	0.89	1.66	1.58	1.18	201
Carbaryl	0.25	219	0.97	1.69	1.40	1.21	212
Deltamethrin	0.004	246	1.14	1.53	1.68	0.91	192
Control (water spray)		208	0.92	1.59	1.39	1.14	171

APPENDIX VIII

Means of observed values relating to Table 25

Treatments	Concentration (%)	Feeding index (mm^2)	Free amino acids (mg leu/g)	Free sugars	Total nitrogen	Carbohydrate/nitrogen ratio	Number of nymphs
HCH	0.25	211	0.92	1.38	1.17	1.18	207
Fenitrothion	0.1	269	1.21	1.45	1.65	1.03	251
Fenthion	0.1	253	1.19	1.88	1.83	0.88	249
Methyl parathion	0.1	249	1.17	1.85	1.95	0.95	279
Quinalphos	0.1	237	1.08	1.58	1.41	1.12	234
Carbaryl	0.25	223	1.16	1.65	1.35	1.22	268
Deltamethrin	0.004	278	1.26	1.65	1.72	0.96	284
Control (water spray)		202	1.04	1.55	1.23	1.26	180

RESURGENCE OF BROWN PLANTHOPPER *Nilaparvata lugens* (Stal) ON RICE TREATED WITH VARIOUS INSECTICIDES

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ABSTRACT

A series of green house experiments were carried out for screening the insecticides, fungicides and herbicides recommended for the control of pests, diseases and weeds infesting rice in Kerala, for their resurgence inducement in *N. lugens*. Among the thirteen insecticides screened, each at three doses and applied at three critical growth stages of the crop as well as at their possible combinations, methyl parathion, deltamethrin, fenitrothion, fenthion, quinalphos and carbaryl were identified as resurgence inducing insecticides with no apparent differences among themselves in the intensity of resurgence caused. HCH, dimethoate, monocrotophos, phosphamidon, phorate, BPMC and carbofuran were found to be free from resurgence inducement and some of them even exerted a significant suppressing effect on the progeny production of *N. lugens*. There was no carry over of resurgence effect over generations. The results of the experiments also revealed that:

1. The manifestation of resurgence inducing property of insecticides was more at the higher doses than at the field doses or lower doses.

2. The frequency of occurrence of resurgence among the different treatments with resurgence inducing insecticides

showed that a single application at any of the three critical growth stages of rice and two applications combining any two of the three growth stages were on par while three consecutive treatments covering all the three growth stages was more favourable for manifestation of resurgence.

3. The growth stages of the host plant had significant influence on the manifestation of resurgence inducement of insecticides. It varied with the properties of insecticides used. Some manifested resurgence at tillering, some at panicle initiation and none at booting stage.

4. The resurgence effect induced by the insecticides was found to last in the treated plants for a period of 15 to 20 days after treatment and the results indicated, that there was no cumulative effect by repeated treatments on insect populations.

In the light of the above findings the method of screening resurgence inducing insecticides in the green house was standardised as the application of the insecticide at doses higher than the field doses thrice covering the tillering, panicle initiation and booting stages preceeding the exposure of insects for assessment of progeny production which may be done at 15 days after the third application.

In further screening adopting the procedure standardised above malathion, methyl demeton, FMC 35001, fenvalerate, permethrin and cypermethrin were found inducing resurgence in *N. lugens*. The granular insecticides were screened giving two treatments (tillering + panicle initiation) and exposing insects at 30 DAT for egg laying. Results revealed that diazinon, phorate, cartap and carbofuran caused resurgence of *N. lugens*. Endosulfan, formothion, phosalone, methamidophos, chlorpyriphos, DDVP and their combinations with HCH or carbaryl (liquid formulations), aldicarb, quinalphos and sevidol (granular) were free of resurgence hazard.

At the recommended doses and methods of application the fungicides zineb, mancozeb, captafol, ediphenphos, kitazin, carbendazim and carboxin and the herbicides 2,4-D (sodium salt and ester), pendimethalin, fluchloralin, butachlor, propanil and thiobencarb did not post any resurgence problem.

The inducement of resurgence by insecticide was seen significantly influenced by the variety of host plants of the insects involved. The levels of plant mediated resurgence inducement and resistance of the plants to insect attack were not mutually related. In screening insecticides for the control of a pest in an agroecosystem, the interaction of the popular varieties of the crop available in the area with resurgence inducement also should be studied.

The resurgence inducing mechanism of six identified insecticides was studied in detail. The results of a series of green house and laboratory experiments revealed that:

1. Resurgence inducing insecticides brought about some morphological changes in the crop causing some improvements in the stand but the magnitude of the changes were not adequate to influence the attraction of the insects or build up of the pest population.

2. The application of the insecticides caused significant variations in the nutrient content and biochemical constituents of treated plants causing consistent changes in the total nitrogen, free sugars and free amino acid contents.

3. The feeding of N. lugens on treated plants was significantly higher as indicated by the feeding indices.

4. The correlation studies and path coefficient analysis of the data relating to the magnitude of changes in the above factors caused by the application of insecticides could be attributed as the major cause of plant-mediated resurgence inducement.

The direct application of resurgence inducing insecticides revealed that some of the insecticides which showed plant mediated resurgence (methyl parathion, deltamethrin and carbaryl) had direct stimulating effect also on the progeny production of N. lugens at sublethal doses while some (fenthion and fenitrothion) did not show any increase in progeny production and some (quinalphos) showed only marginal effect. While carbaryl and methyl parathion were more stimulatory at lower levels, deltamethrin stimulated reproduction at both the lower and higher levels.

The field experiment revealed that the resurgence observed in the field was the added effect of plant-mediated resurgence observed in green house experiments and the direct effect of the pesticides caused by their sublethal doses. In general the conclusions from the green house experiments were in agreement with the results obtained from the field. It was seen that the changes in predatory population in field caused by the application of pesticides did not contribute significantly to the inducement of resurgence in N. lugens. It was also observed that the assessment of plant induced resurgence of insecticides in green house experiments and the direct effects of the toxicants on the insects will serve as an effective alternative elaborate field experiments for evaluating the resurgence effect of insecticides.