IPM STRATEGY IN BITTERGOURD USING NEW GENERATION INSECTICIDES AND BOTANICALS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"IPM strategy in bittergourd using new generation insecticides and botanicals"** is a bona-fide 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, fellowship or other similar title, of any other University or Society.

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Certified that this thesis, entitled **"IPM strategy in bittergourd using new generation insecticides and botanicals"** is a record of research work done independently by **Ms. Malarvizhi, G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Dedicated to

My Loving Parents

Introduction

INTRODUCTION

Bittergourd (*Momordica charantia* L.) is one of the popular cucurbitaceous vegetable crops grown in Kerala. In the food basket of India, bittergourd plays an important role, because of its high nutritional content such as carbohydrate (4.2%), protein (1.6%), fat (0.2%) and fibre (0.8%) and trace amount of minerals and vitamins. The plant has many medicinal uses. The fruit has germicidal properties and it is used for treating blood diseases and diabetis. The leaves are known to act as galactogogos, while the roots are astringent. Juice from the leaf is used for treating the external eruptions, burns and boils. The powder, which is obtained from the leaves, is good for treating ulcer in human beings.

Incidence of pests and diseases is the most important constraint of bittergourd cultivation (Jayapalan and Sushama, 2001). Bittergourd is attacked by various categories of pests throughout its growth period. Extensive damage is done by major pests like fruit fly *Dacus cucurbitae* Coq. and fruit borer *Margaronia indica* (Saunders) (Nair, 1989).

Kapur (1996) reported *Henosepilachna septima* (Dieke) as the common pest in bittergourd. Mathew (1996) found leafhopper, *Empoasca (Empoasca) motti* Pruthi as a new pest of bittergourd from Kerala causing hopper burn symptoms on leaves. Both nymphs and adults remain on the lower surface of leaves and suck the cell sap. Mathew *et al.* (1996) reported *Helicoverpa armigera* (Hubner) as a fruit borer of bittergourd. It caused about ten per cent loss of bittergourd fruits in South Kerala (Karthikeyan, 2003).

In order to control the pests of bittergourd, several categories of pesticides belonging to organochlorines, organophosphates, carbamates and synthetic pyrethroids are extensively used by the farmers as well as research scientists. Spraying of carbaryl (Sevin) 50 WP at 0.1 per cent, malathion 50 EC at 0.1 per cent and fenthion (Lebaycid) 80 EC at 0.1 per cent concentration controlled fruit fly, *Bactrocera cucurbitae* (Coquillett).

Banana fruit traps are used by the vegetable cultivators to manage fruit fly infestation. Carbaryl at 0.2 per cent was applied for the control of epilachna beetle (POP, 2000).

Monocrotophos at 0.05 per cent and acephate + Bt were also effective against leafhopper. Rational rotation of malathion 0.2 per cent + garlic at 20 g l^{-1} of spray solution and neem seed oil emulsion 2.5 per cent + garlic at 20 g l^{-1} of spray solution also controlled leafhopper (Gopalakrishnan, 2004). The intensive application of the synthetic pesticides resulted in residues, resurgence and resistance (Dhaliwal and Arora, 2001). So, newer molecules with newer modes of action like ethofenprox, *fipronil, profenofos, spinosad and deltafos which are required in small doses are to be* evaluated against the pest complex of bittergourd.

Ethofenprox at 100 g a.i. ha^{-1} was found to have superior effects on brinjal shoot and fruit borer than conventional insecticides (Srinivas and Peter, 1993). Application of fipronil at 25, 40 or 50 g a.i. ha^{-1} reduced diamond back moth population in cabbages (Panda *et al.*, 1999). Profenofos at 0.5 kg a.i. ha^{-1} at fortnightly intervals reduced *Plutella xylostella* (L.) and pyralid *Crocidolomia binotalis* (Z.) infesting cabbage (Mohan, 1985). Spinosad reduced the population of caterpillar pests like *Hellula undalis* (Fabr.), *C. binotalis* and *P. xylostella* but it was safe to non target organisms (Vadodaria *et al.*, 2001). Deltafos at 0.1 per cent caused 48-65 per cent reduction of white fly *Bemisia tabaci* (Genn.) in brinjal (Kumar *et al.*, 2001).

Botanicals are preferred for vegetable crops since these will not leave toxic residues in fruits. Hence neem seed kernel extract and citronella oil were also included for the present study. Botanicals such as neem seed kernel extract at four per cent controlled gall midge, *Asphondylia* sp. infesting brinjal flowers (Kumar *et al.*, 1998). Attractants such as citronella oil, dried mango juice and palm juice along with diazinon ten per cent caught more fruit fly *Dacus cucurbitae* (Lall and Singh, 1989). Natural organics such as wood ash dusting controlled potato tuber moth *Phthorimaea operculleła* (Zeller) during storage (Debnath *et al.*, 1998).

An evaluation of new insecticide molecules with newer modes of action, botanicals and natural organics was aimed in the present study to develop a suitable integrated pest management (IPM) package for bittergourd with the following objectives:

1. To evaluate the effect of new insecticide molecules, botanicals and natural organics against a pest, namely, the leaf beetle, *H. septima*; predator, *Cheilomenes sexmaculata* Fab. and pollinator, *Apis cerana indica* (F.) under laboratory conditions.
2. To evaluate the field efficacy of new molecules of insecticides, botanicals and natural organics against major pests of bittergourd.

Review of Literature

2. REVIEW OF LITERATURE

A comprehensive review of work done on control of vegetable pests and pests of other crops using new chemical, botanical and natural organic insecticides in India and abroad are summarized below.

2.1 CHEMICAL CONTROL OF PESTS OF VEGETABLES AND OTHER CROPS

2.1.1 Ethofenprox

Ethofenprox is a contact insecticide with wide spectrum of activity. It interferes with the nervous system of insects by inhibiting the transportation of sodium ions along nerve endings. It is active against insects resistant to pyrethroids, carbamates and organo phosphates.

2.1.1.1 Vegetable crops

2.1.1.1.1 Work done in India

Srinivas and Peter (1993) evaluated the efficacy of ethofenprox at 100 g a.i. ha^{-1} in Tamil Nadu and found that it gave significantly superior control on brinjal shoot and fruit borer *Leucinodes orbonalis* (Guen.) compared to the conventional insecticides. Lal and Meena (2001) field tested the efficacy of eight insecticides against diamond back moth (DBM) of cabbage in New Delhi and found that among the test insecticides cartap hydrochloride and ethofenprox recorded lowest population.

2.1.1.1.2 Work done abroad

Zambaux *et al.* (1997) observed that ethofenprox (150 g a.i. ha^{-1}) reduced cabbage lepidopterous pests like *Mamestra brassicae* (L.), *Pieris brassicae* (L.), *Pieris rapae* (L.) *and P. xylostella* in France.

2.1.1.2 *Other crops*

2.1.1.2.1 *Work done in India*

Peter *et al.* (1989) conducted studies in Tamil Nadu and found that ethofenprox 12.5 to 25 g a.i. ha^{-1} was very effective for the control of *Nilaparvata lugens* (Stol) on rice without causing deleterious effect on spiders and the predator *Cyrtorhinus lividipennis* (Reuter). Krishnaiah and Kalode (1993) noted that ethofenprox at 100 g a.i. ha^{-1} effectively checked the build up of *N. lugens* in Andhra Pradesh without detrimental effect on natural enemies and hence, it is preferred in IPM against leafhoppers and planthoppers of rice.

Ethofenprox at 0.075 kg a.i. ha^{-1} was very effective on Brown planthopper and showed higher grain yield (68.35 q ha^{-1}) in rice (Panda *et al.*, 1995). Prasad and Prasad (1995) tested the efficacy of seven insecticides against rice leaf folder *Cnaphalocrocis medinalis* (Guenee) in Bihar and found that ethofenprox gave a grain yield of 3.10 t ha^{-1} and the highest benefit cost ratio.

Ethofenprox at 75 g a.i. ha^{-1} gave significantly superior control compared to untreated check in reducing pod damage and recorded the highest yield of 2373 kg ha^{-1} in pigeon pea (Gururaj and Sachan, 1998). Among the nine insecticides tested against rice leaf folder in Orissa, ethofenprox was the most superior insecticide followed by cartap hydrochloride, monocrotophos and cypermethrin in reducing larval population and increasing the grain yield (Mishra *et al.*, 1998).

Mohapatra *et al.* (2000) evaluated the efficacy of some synthetic insecticides in Orissa against cashew shoot tip caterpillar and observed that all test insecticides including ethofenprox at 0.015 per cent effectively controlled the cashew shoot tip caterpillar under field condition. Mohapatra (2001) evaluated the efficacy of some synthetic insecticides and neem products against cashew leaf folder *Caloptilia tislea* and found that ethofenprox at 0.015 per cent was the most effective insecticide.

Spraying of ethofenprox showed high toxicity to the larva of *M. brassicae* but it was safe to its egg parasitoid, *Trichogramma dendrolini* (Takada *et al.*, 2001). Krishnaiah *et al.* (2002) evaluated the toxicity of neem products and synthetic insecticides against *N. lugens* and *Nephotettix virescens* (Dist.) and noted that they developed cross-resistance to ethofenprox. Spraying of ethofenprox on mustard plant cv. Pusa Kalyani resulted in 75 per cent reduction of aphid population over control at one day after treatment (Arivudainambi and Prasad, 2003). Karthikeyan (2003) observed that ethofenprox was effective in controlling the leafhopper in bittergourd upto seven days after spraying and it was found as effective as acetamiprid and imidacloprid.

2.1.1.2.2 Work done abroad

Ethofenprox was found to be most toxic insecticide to adults of sweet potato whitefly *B. tabaci* (Habu, 1991). Ethofenprox had high adulticidal activity and reduced the number of feeding and oviposition punctures of *Liriomyza trifolii* (Burgess) affecting vegetables and ornamentals in Japan (Saito *et al.*, 1992).

Kinjo and Matsui (1994) noted that ethofenprox reduced the longetivity and fecundity of sweet potato whitefly, *B. tabaci* in greenhouses or nurseries. Ethofenprox was the most effective insecticide in controlling the vine leafhopper, *Empoasca vitis* (Gothe) for more than a month and it also favoured mite insurgence in Italy (Lembo *et al.*, 1998). Tanaka *et al.* (2000) noted that ethofenprox caused toxicity to predators of rice plant hopper.

2.1.2 Fipronil

It belongs to phenyl pyrazole group and acts by interfering with the passage of chloride ions through Gamma Amino Butyric Acid (GABA) regulated chloride channels disrupting central nervous system. Biochemical assays indicate that fipronil binds to the insect GABA receptor with higher affinity than the vertebrate GABA receptor.

2.1.2.1 Vegetable crops

2.1.2.1.1 Work done in India

The bioefficacy studies of fipronil in India (Orissa) against DBM by Panda *et al.* (1999) revealed that application at 25, 40 and 50g a.i. ha^{-1} caused 67.8 to 84.8 per cent reduction of *P. xylostella* infesting cabbage.

2.1.2.1.2 Work done abroad

Rushtapakornchai *et al.* (1996) observed that 0.3 per cent granules of fipronil were effective against tomato whitefly, *B. tabaci* and leaf miner, *L. trifolii* at Thailand. Fipronil caused cent per cent mortality of third instar larvae of diamond back moth in vegetable fields at China (Shi-Zuhua *et al.*, 1998).

Film coating of *Allium porrum* L. seeds with fipronil in Southern Netherlands gave good control against *Thrips tabaci* (Lind.) infesting leek (Ester *et al.*, 1999). Fipronil gave good leaf protection and ensured higher yields against colarado potato beetle (Igrc *et al.*, 1999). Mau *et al.* (1999) noted that fipronil was highly effective on *T. tabaci* affecting onion in Turkey.

Ester *et al.* (2001) reported that treating onion seeds with fipronil gave satisfactory control against *Delia antiqua* (Meigen) and they also noted that film coating of fipronil in leek seeds gave good protection against *Acrolepiopsis assectella* (Zeller). Evaluation of fipronil against *Leptinotarsa decemlineata* in two different places in Russia showed that 0.03 per cent fipronil gave reduction in Moscow but the same concentration at another place resulted in greater than 20 per cent of beetles being resistant to fipronil (Roslavsteva, 2001).

Kazadev *et al.* (2002) observed that fipronil at low concentration provided good control of Colarado potato beetle in Russia. Fipronil provided higher returns in integrated pest control and gave a cost benefit ratio of 2.72 which was on par with 2.06 of other methods in Chinese Kale at Thailand (Chawanapong *et al.*, 2003).

2.1.2.2 Other crops

2.1.2.2.1 Work done in India

Application of fipronil granules at 75 g a.i. ha^{-1} was effective against rice stem borer in West Bengal and registered 52 to 65 per cent increase in yield over control (Rath, 2001). Lakshmi *et al.* (2001) found that fipronil at 100 ppm was safe to *C. lividipennis* a predator of rice brown plant hopper in Andhra Pradesh.

Efficacy of different doses of granular and liquid formulation of fipronil was compared with one synthetic granular and liquid insecticide in Karnal against sugarcane shoot borer, *Chilo infuscatellus* (Snellen) and root borer, *Emmalocera depressella* (Swinhoe) by Sardana (2001) and found that fipronil at 0.3 G and 5 per cent SC at 75 g a.i. ha^{-1} were effective against shoot borer and at 200 g a.i. ha^{-1} against root borer than synthetic granular and liquid insecticides.

Cent per cent mortality of early instar larvae of rice leaf folder *C. medinalis* was observed within three days after application of fipronil at 50 ml mu^{-1} (1ha=15mu). Sand treatment of fipronil at 0.125 per cent caused repellence to subterranean termite workers (Ibrahim *et al.*, 2003).

Rao *et al.* (2003) noted that granular application of fipronil at 75 g a.i. ha^{-1} recorded lowest leaf folder and *Spodoptera litura* (Fabr.) damage in Soya bean in Madhya Pradesh. Dhingra *et al.* (2003) noted fipronil at 10g a.i.ha^{-1} against *Leptocorisa varicornis* (Thunberg) significantly reduced the grain damage and increased the yield in rice.

2.1.2.2.2 Work done abroad

Spraying of fipronil at 80 g a.i. ha^{-1} in Brazil controlled rice rootworm, *Oryzophagus oryzae* (Marshell) (Oliveria and De Oliveria, 1994). Liete *et al.* (1995) field tested the efficacy of fipronil at Brazil and noted that fipronil SC at

200, 250 and 500 ml ha^{-1} at 12days after transplanting and fipronil 2G 100 g a.i ha^{-1} at 21 days after transplanting of rice gave 87 and 82 per cent reduction respectively to rice water weevil.

Study conducted in Brazil showed that application of fipronil 20 G at a concentration 1,2 and 3 g per bait was efficient against *Cosmopolites sordidus* (Germere) in banana (Batista *et al.*, 1996). Kaaken *et al.* (1996) evaluated seven conventional insecticides and found that fipronil was the least toxic to adult convergent ladybird beetle.

Handerson and Forschler (1997) reported that fipronil at low concentration of 0.1 to 10 ppm provided good control of formosan termite colonies. Balanca *et al.* (1997) evaluated fipronil in France against Niger grasshopper and found that fipronil 0.6 g a.i. ha^{-1} was effective in grasshopper outbreaks with 47 per cent mortality obtained in two days and 91 per cent mortality in ten days.

Granular application of fipronil in Malawi (Central Africa) tea plantations reduced the termite damage for 10-12 months (Ruttan and Mukumbareza, 1997). Spraying of fipronil at 0.038-0.05 lbs a.i. ha^{-1} provided good control of plantbugs, *Lygus hespercus* and *L. lineolaries* affecting cotton in USA (Shaw *et al.*, 1997).

Lee (2000) found that fipronil at 0.01 per cent was effective against ants in Penang island, Malaysia. Among the test insecticides such as carbofuran GR, imidacloprid WS, chlorpyriphos GR and fipronil GR, imidachloprid and fipronil showed promise for termite control in South Africa (Reckert *et al.*, 2001).

Regent 200 SC, at 0.1 litres was effective against European corn borer *Ostrinia nubilalis* (Hbn.) in Transylvania (Muresan *et al.*, 2001). Kececioglu and

Madalar (2002) field tested the efficacy of insecticides such as acephate, fipronil and imidacloprid against western flower thrips *Frankliniella occidentalis* (Pergande) and found that acephate, fipronil and imidaclorpid gave 64.95, 67.00 and 77.94 per cent mortality, respectively.

Scarpellini *et al.* (2002) tested the effectiveness of four synthetic insecticides in SaoPaulo, Brazil against cotton boll weevil and observed that all test insecticides including fipronil 800WG (40,48 and 64 g a.i. ha^{-1}) gave good control, compared to the standard. Zhu Wen Da *et al.* (2002) evaluated efficacy of Regent against rice stem borer and found that the efficacy of Regent was as high as 97.62 and 96.15 per cent in terms of dead heart and mortality of larvae of stem borer and appeared superior to the conventional insecticides such as monosultap and disultap.

2.1.3 Profenofos

It is a systemic and contact poison and belongs to organophosphate group.

2.1.3.1 Vegetables

2.1.3.1.1 Work done in India

Mohan (1985a) also evaluated the efficacy of seven insecticides under field condition against the pests of okra in Karnataka and reported that profenofos followed by carbaryl recorded highest marketable yield.

Mohan (1985b) reported that profenofos at 0.5 kg a.i. ha^{-1} sprayed at fortnightly intervals was superior against the yponomeutid P. *xylostella* and pyralid C. *binotalis* infesting cabbage in Karnataka when compared to quinalphos, permethrin, BPMC, diflubenzuron, bromophos and decamethrin. Mohan (1985c) tested the efficacy of eight insecticides against the coccinellid, *H. vignitioctopunctata* (Fabr.) infesting brinjal and found that profenofos at 0.5 kg a.i. ha^{-1} was effective followed by permethrin at 10 days after spraying. Singh *et al.*

(2002) carried out a field study in Hissar on brinjal and found that profenofos at 800 ml a.i. ha^{-1} was the most effective in controlling the brinjal whitefly.

Mallapur *et al.* (2002) evaluated the efficacy of profenofos in Karnataka against chilli fruit borer and found that it showed highest larval mortality at 1000 ml and 1500 ml ha^{-1}.

2.1.3.1.2 Work done abroad

Dina (1981) tested the efficacy of three insecticides against the pod damage in three cowpea cultivars and observed that among the test insecticides, profenofos was effective and gave good protection against pod damage in cv. IfeBrown.

Feng and Wang (1984) evaluated the toxicity of nine insecticides against *P. xylostella* and its parasite *Apanteles plutellae* (Kurd.) under laboratory conditions in Taiwan and concluded that profenofos, acephate, dichlorvos and fenvalerate were suitable for use against the pest with out adversely affecting the natural enemies.

According to Calderson and Hare (1986), high volume spray application of profenofos @ 0.25 to 0.5 kg a.i. ha^{-1} at 7-10 days interval caused 40 to 100 per cent mortality of *P. xylostella* affecting cabbage and Chinese kale in Malaysia, Thailand, Philippiness and Thaiwan. Lee *et al.* (1986) studied the toxicity of 19 insecticides against aphid infesting Chinese cabbage in Korea Republic and observed that profenofos caused 43 per cent mortality in *Aphis gossypii* (Glov.) and heptenophos and acephate reduced 50 per cent population of *L. eryisimi.*

Profenofos with a low LC_{50} value of 500 ppm was the most effective compound against fourth instar larvae of gelechiid potato pest *Pthorimaea opercullela (*Zeller) (Abdel *et al.* 1987). According to Thisthlaton (1987) profenofos, acephate, cypermethrin and deltamethrin were effective in controlling the diamond back moth in New Guinea.

Sayed and Elghar (1989) tested the efficacy of three insecticides at several doses on cabbage in Egypt against *Brevicoryne brassicae* Linn. and found that profenofos at lowest rate of 100 to 130 g a.i. ha^{-1} afforded 68 per cent control of aphid after 21 days of treatment. Natskova (1991) observed that endosulfan, profenofos and bifenthrin did not cause any resistance on *Aphis gossypii* (Glov.) infesting cucumber and chrysanthemum in greenhouses.

Field trials carried out by Williamson and Murray (1993) on tomatoes cv. Jamaica showed that profenofos at 0.4 g a.i. litre^{-1} was most effective in reducing the tomato pinworm. Spraying profenofos @1.2 ml litre^{-1} at fortnightly intervals controlled severe attack of DBM infesting cabbages cv. KKcross at Jamaica.

Application of profenofos + cypermethrin against the aleyrodid *B. tabaci* on tomato in Guatemala gave good control of 80 per cent for 2-3 days (Saguero, 1994). Sammour and Kabbany (1993) studied the effects of acyl urea and insecticide mixture against cowpea aphid and found profenofos in mixture with acyl urea caused reduction in fecundity in *A.craccivora* (Koch).

Profenofos followed by monocrotophos and dimethoate resulted in 100 percent mortality of larvae of *Helicoverpa armigera* (Hubner), *Mythimna separata* (Moore) and *Autographa nigrisigna* (Walker) feeding on potato foliage at Bonair valley in Pakistan (Kaling *et al.*, 1995). Sallam and Hasseny (2003) screened six insecticides against *T. tabaci* (Lind.) infesting onion during 20th February and 18th March 2002 in the second season and observed that among the insecticides tested, carbosulfan, profenofos, methomyl and pirimophos methyl were effective in controlling the pest.

2.1.3.2.2 Work done abroad

Application of 750 g profenofos ha^{-1} caused 97 to 97.9 per cent reduction in citrus rust mite at Sao Paulo, Brazil (Franco *et al.*, 1997). Profenofos was the most effective contact toxicant against fourth instar larvae of *H. armigera* followed by chlorpyriphos, endosulfan and mephosulfan (Fahmy *et al.*, 1982).

Tkachuk *et al.* (1983) tested five modern insecticides against green house white fly infesting gerbera and found that profenofos caused 26.6 per cent reduction in population. Mc Clanahan and Founk (1983) tested the toxicity of various standard and new insecticides against the green peach aphid *M. persicae* and reported that acephate, methamidophos, profenofos, phorate and aldicarb reduced the aphid population.

Application of profenofos @ 4 kg ha^{-1} in baits reduced 85 to 95 per cent of larval population of cutworms infesting pepper at Bulgaria (Nikolov, 1981).

Ascher and Nemmy (1990) noted that profenofos gave greater than 50 per cent inhibition effect on the ovicidal activity of *S. litura* . Williamson and Murray (1992) tested the toxicities of seven insecticides on a laboratory strain of *Schizaphis graminum* (Rondani) in wheat in Egypt and found that among the test insecticides, profenofos and malathion were highly toxic followed by primicarb and carbosulfan.

Guindy and Shaban (1993) reported that profenofos, tamaron and primid were the most toxic compounds against the cotton pests *A. gossypii, Tetranychus urticae* (Bezert) and *S. litura*. During flowering stage of rose, application of profenofos gave reduced number of thrips in a green house trial at Sanremo, Italy (Rasnii *et al.*, 1993). Saleh (1994) evaluated the efficacy of six insecticides against the third and fifth instar larvae of tortoise beetle, *Cassida* *vittata* (Ill.) affecting sugarbeet crops and reported that among the insecticides primiphosmethyl and profenofos were the most potent insecticides to these larvae.

Among the six insecticides screened against *Leucoptera coffella* (Guerin) in coffee plantation at Western Jamaica, profenofos and miral 500 SC resulted in five and seven per cent reduction respectively in the number of mines per leaf after six weeks (Raid and Robinson, 1994).

El-Kady *et al.* (2002) reported that Egyptian strains of *B. tabaci* did not exhibit resistance to the organophosphate profenofos or the neonicotinoid imidacloprid. Spraying of 0.15 per cent profenofos against soya bean leaf miner *Aproaerema modicella* (D.) was effective in reducing the larval population and it recorded a grain yield of 29.62 q ha^{-1} (Keshbhat *et al.*, 2002).

2.1.4 Spinosad

Spinosyns are fermentation derived molecules that contain a 12 membered macrocyclic lactone in a unique tetra cyclic ring. More than 20 spinosyns (A toY) have been identified and resulted from variation in substitution patterns on the two sugars (forosamine and 2,3,4 –tri-o-methyl rhamnose) and the tetracylic ring system. The product is water based and contains no volatile organic solvents, making it more environmentally and user friendly. It acts on the nervous system of the insects in a new and unique way, which did not show cross-resistance. It has high efficacy upon ingestion and contact, and has a large spectrum of activity. Because of its anti resistance property it is included in IPM. Spinosad, is the name given to the mixture of Spinosyn A and Spinosyn D, active metabolites produced during fermentation by the actinomycete bacterium, *Saccharopolyspora spinosa* (Mertz). It is poorly soluble in water, non volatile and non persistent. Its half-life in sunlight is less than one day in soil and water and about two days in plants. Mammalians fed spinosad excrete 60-80 per cent of the dose unchanged or in the form of metabolites after 48 hours in faeces and urine.

The ADI (Admissible Daily Intake) was fixed at 0.02 mg kg^{-1} body weight per day by US Environmental Protection Agency.

2.1.4.1 Vegetable crops

2.1.4.1.1 Work done in India

Vadodaria *et al.* (2001) reported that spinosad was highly effective against a number of caterpillar pests *viz.*, *H. undalis* (Fabr.), *C. binotalis* and *P. xylostella*. It was safe to non-target organisms, *viz.*, beneficial insects. Spinosad at 48 EC 75 g a.i. ha^{-1} recorded low larval population. Dey and Somchowdhary (2001) in West Bengal found that application of spinosad @15 to 25 g a.i. ha^{-1} controlled the diamond back moth of cabbage and it was safe to two most important parasitoids, *Cotesia plutellae* (Kurdjumov) and *Brachymeria* sp.

Arora *et al.* (2003) tested different concentration of insecticides against third instar larvae of *P. xylostella* infesting cauliflower at Hissar and found that spinosad, was the most toxic to this pest than monocrotophos.

2.1.4.1.2 Work done abroad

King and Hennessey (1996) found that spinosad combined with sugar yeast hydrolysate mixture gave a good control of carribean fruit fly. Yee and Toscano (1998) conducted laboratory studies to test the effects of synthetic and natural insecticides on lettuce leaf consumption by larvae of *S. exigua* (Hubner) and noted that spinosad at 50 ppm caused cent per cent mortality within one day after exposure.

Spinosad R resulted in a reduction of 54 per cent of larvae and 78 per cent of pupae of *L. trifolii* without any adverse effects on larval parasitoids of leafminer. So, this biological product is compatible with IPM (Gahbiche and Aoun, 1999). Spinosad was highly toxic to the third instar larvae of *Trichoplusia ni* (Hbn.) in Texas (USA) and it caused greater than 98 per cent mortality at 96 hours after treatment (Liu-Tongxian and Liu-Tx, 1999).

Among the organophosphorous insecticides tested against cabbage root fly, fipronil, spinosad, diflubenzuron and cyromazine showed considerable promise (Jukes *et al.*, 2001) Spinosad was found to be highly effective against thrips infesting greenhouse cucumber and had minimum impact on *Orosius insidiosus* and *Encarsia formosa* (Woolley) that were used in integrated pest management programmes for greenhouse cucumber (Jones *et al.*, 2002).

Spinosad 48 SC, a naturally derived biological product was more effective than Talstar 100 EC (bifenthrin), a synthetic pyrethriod in controlling the *F.occidentalis* infesting both cucumber and tomato in greenhouses in Canada (Nawrocka and Enkegaard, 2002).

Film coating of spinosad @ 24 to 48 g a.i./1000000 seeds of cabbage (*Brassicae oleracea var. capitata* L.) and cauliflower (*Brassica oleracea* var. *botrytis* L.) gave good control of cabbage root fly larvae and caterpillar (Ester *et al.*, 2003). Hill and Foster (2003) observed that spraying of spinosad controlled DBM but it had less effect on its parasitoid *Diadegma insularae* than permethrin.

2.1.4.2 Other crops

2.1.4.2.1 Work done in India

Among the six different insecticides tested against cotton *Helicoverpa zea* (Boddhie), spinosad and thiodiocarp controlled *H. zea* in non-Bt cotton and also reduced rates of lamba cyhalothrin, spinosad and thiodiocarp which controlled *H. zea* in dryland B.t cotton system (Brickle *et al.*, 2001).

2.1.4.2.2 Work done abroad

Hendrix *et al.* (1997) carried out a field trial and found that spinosad performance was better than standard and it conserved beneficials like spiders, parasitic wasps, lacewings and ladybird beetles in Mississipi delta region. Spinosad effectively controlled the *H. zea* in New Orleans, USA (Murray and Lloyd, 1997).

Hasty *et al.* (1997) carried out a field trial on cotton and tested synthetic insecticides against cotton bud worm and cotton bollworms in USA and found that among all the insecticides tested, spinosad had high spectrum of activity than Pirate R, fipronil and cypermethrin. Spinosad at 0.2 per cent maintained low level of thrips on citrus for 10 weeks and more in Israel (Alon-hontea, 1998).

Miles and Dutton (2000) tested the effectiveness of spinosad against beneficials, natural predators and pollinators in greenhouse IPM programmes and found that it was safe to use in IPM programmes.

Spraying of spinosad at 100 ppm was effective against flower thrips affecting daisy flower in greenhouse condition (Clyod and Sadof, 2000). Cent per cent mortality of young larval stadia of leafminer was recorded in green bean due to spinosad (Gahbiche, 2001).

Olszak *et al.* (2001) field tested the efficacy of three synthetic insecticides and botanicals in Poland against the plum fruit moth and leaf rollers and found that all the compounds tested were highly effective against the above pests. Spinosad was safe for the pupae and adults of predator *C. carnea* at the maximum field rate (Vinuela *et al.*, 2001).

Bylemans (2002) reported that Tracer is legal and it was a tip for thrips control in strawberry. Spraying of spinosad, a selective insecticide reduced mean number of thrips per plant below the level. than standard insecticide methamidophos in onion (Workman *et al.*, 2002).

Torres *et al.* (2002) reported that lamda cyhalothrin and monocrotophos were significantly more toxic to predatory stinkbug *Podosius nigrispinus* (Daltas) on cotton than spinosad. Olszak and Plucienik (2002) reported that spraying of spinosad against the codling moth, plum fruit moth and leaf rollers was highly effective in reducing the fruit damage.

When maize plants were treated with spinosad @ 80ml per acre to control stem borer *Chilo partellus* (Swinhoe) in Faisalabad, Pakistan, the infestation was reduced from 10.72 per cent before spray to 3.05 per cent, one week after spraying (Ahmed *et al.*, 2002). Gravena *et al.* (2002) reported that spraying of spinosad in combination with mineral oil at four different doses, namely 7.5,10, 12.5, 15 ml of commercial product per 100 litre of water caused reduction of citrus leaf miner up to 10 days after spraying.

Spinosad alone @ 25 ml ha^{-1} gave significant reduction of *S. litoralis* in combination with Lannate or Reldan in lettuce and strawberries at Italy. Chen *et al.* (2003) evaluated five insecticides for contact toxicity to apple maggot flies during a 10 minutes exposure treatment and found that azinphos methyl was the most toxic having LC_{50} and LC_{90} value of 108 and 115 ppm respectively, followed by spinosad which possessed LC_{50} and LC_{90} value of 21 and 35 ppm respectively.

Study conducted by Miles *et al.* (2003) showed that spinosad was safe to bees when applied to the flowering crops during the periods of bee activity. Spinosad 0.1 to 1mg a.i. ha^{-1} of grain caused cent per cent mortality of *Rhyzopertha dominica* (F.) on wheat storage (Fang and Subramanyam, 2003).

Musser and Shelton (2003) reported that spinosad and indoxacarb were less toxic to abundant predator in sweet corn namely *Colemigilla maculata* (Hurst.), *Harmonia axyrisis* (Plooi) and *O. insiodus* than synthetic pyrethroid lamda cyhalothrin.

2.1.5 Deltafos

It is a combination of insecticides namely triazophos + deltamethrin. Acts as a contact and stomach poison.

2.1.5.1 Vegetable crops

2.1.5.1.1 Work done in India

Kumar *et al.* (2000) carried out a field trial at ANGR Agricultural University, Hyderabad and observed that deltafos 0.1 per cent was the most effective in controlling the shoot and fruit borer of brinjal and recorded the highest maketable fruit yield. Mixed formulation of insecticide, namely, Spark 0.1 per cent caused 48 to 65 per cent reduction of white fly in brinjal in Rajendra Nagar, Hyderabad (Kumar *et al.,* 2001). They also noted that Spark caused significant reduction of brinjal leafhopper over control.

2.1.5.1.2 Work done abroad

Talpur *et al.* (1993) tested the effectiveness of five pyrethroid combinations at recommended doses against noctuid *E. vitella* infesting bhendi in Pakistan and found that deltafos reduced *E. vitella* incidence within 24 hours after application.

2.1.5.2 Other crops

2.1.5.2.1 Work done in India

A mixture of 0.05 per cent triazophos and 0.02 per cent deltamethrin were the most effective against the whitefly infesting cotton (Rao *et al.*, 1990). Dhawan *et al.* (1991) carried out a field test on the effectiveness of deltafos with several insecticides against the bollworms and sucking pests during the reproductive phases of cotton crop and reported that deltafos controlled the cotton bollworm and kept the population of sucking pests below the economic threshold.

Singh and Gupta (1993) carried out a field trial to assess the efficacy of several insecticides against the cotton whitefly and leafhopper and noted that among the test insecticides, fenvalerate, cypermethrin and alphamethrin caused reduction in leafhopper with in 48 hour after application. Pal *et al.* (1996) found Spark as the effective treatment against the *H. armigera* on chickpea followed by Polytrin C.

Spraying insecticide mixture of one per cent deltametrin and 35 per cent triazophos at 100ml ha^{-1} against spotted bollworm *E. insulana* (Boisd.) in American cotton gave cent per cent mortality with in 72 hours after spraying (Brar *et al.,* 1998). Sharma *et al.* (2000) tested bioefficacy of different insecticides against the aphid infesting chrysanthemum and found that the aphid population was reduced from 61/9 plant to 33/9 plant and remained effective up to 14 days after spraying.

Srivastva and Sehgal (2002) tested the effectiveness of three synthetic pyrethroids, two organophosphates and some insecticide mixtures against the pigeon pea pod borer during the Rabi seasons in Uttaranchal and reported that a mixture of insecticides provided efficient reduction over control.

2.1.5.2.2 Work done abroad

Zaman (1989) field tested the efficacy of five insecticides against the sanjose scale infesting plum in Pakistan and reported that deltamethrin + triazophos at 720 ppm a.i. achieved complete control of the pest population on the leaves and barks of plum trees.

2.2 BOTANICAL CONTROL OF PESTS OF VEGETABLES AND OTHER CROPS

2.2.1 Neem Seed Kernel Extract

Azadirachtin is the most active principle in neem seed kernel. The quantity of the compound present in the kernel varies due to the environmental factors and genetic nature. The highest yield of Azadirachtin was 10 g kg^{-1} of the seed kernel. Azadirachtin is a tetranortriterpenoid, which has deterant, oviposition, feeding, growth distrupting, fecundity and fitness reducing properties to insects (Schmutter, 1990). Azadirachtin was identified and isolated from the neem seed by Butterworth and Morgan (1968). It was found to be formed by a group of closely related isomers Az A to Az I. Az A was more in quantity in neem seed kernel. Az E was regarded as the most effective insect growth regulator (Ley *et al.*, 1993).

Oligophagous species are more sensitive to Azadirachtin than polyphagous species (Simmonds and Blaney, 1984). Apart from Azadirachtin, neem seed kernel have salannin, salannol, salanoacetate, 3 deacetylsalanin, azadirachtin, 1,4 epooxy azardion, gedunin, nimbinen and deacetyl nimbinenine (Jones *et al.*, 1989).

2.2.1.1 Vegetable crops

2.2.1.1.1 Work done in India

Mane (1968) reported the repellent action of Neem Seed Kernel against *Aulacophora foveicollis* (Lucas). NSKE caused cent per cent mortality within 10 days after treatment on the larvae of *S. littoralis* (Behera and Satapathy, 1996). Regupathy *et al.* (1997) recommended NSKE at five percent for the control of leaf miner infesting cucurbits.

Krishnamoorthy *et al.* (1998) recommended freshly prepared NSKE at four per cent for the management of *P. xylostella* in cabbage and other crucifer pests. NSKE at four per cent controlled the gall midge, *Asphondylia* sp. infesting brinjal flowers and fruits during February 1994, September 1994 and December 1995 in Karnataka at the peak incidence of the pest (Kumar *et al.*, 1998).

Ragumoorthi *et al.* (1998) evaluated five different neem products against the moringa fruit fly, *Gitonia distigma* (Meigon) and observed that NSKE was most effective with high feeding deterrency (43.75 to 62.50 per cent), low fecundity (51.90 to 74.26 per cent reduction), low hatchability (46.75 to 51.25 per cent), high maggot mortality (18.50 to 24.75 per cent), high puparium mortality (24.75 to 31.5 per cent) and high adult malformation (7.75 to 18.25 per cent) at Chandigarh, India.

Field trial conducted in Tamil Nadu during Kharif and rabi seasons by Raja *et al.* (1999) revealed that NSKE five per cent reduced the fruit borer damage to 11.56 per cent in brinjal followed by endosulfan + neem oil (11.37 per cent), NSKE + endosulfan (11.4 per cent) and carbaryl (13 per cent) against 36.9 per cent in the control.

Desai and Desai (2000) noted that neem extract caused more than 30 per cent mortality of *S.litura* and *L. erysimi.* Krishnamoorthy and Krishnakumar (2000) found that NSKE at four per cent was effective against *P. xylostella* and *C. binotalis* affecting cabbage.

Srinivasan and Babu (2001) tested the toxicity of NSKE five per cent and five neem products at Tamil Nadu Agricultural University against the whitefly on aubergines and found that NSKE recorded lower mean population followed by Nimbecidine and Neemgold.

2.2.1.2.2 Work done abroad

Meisner *et al.* (1981) observed 90 per cent larval mortality of *E. insulana* when treated with water extract of neem seed kernel at one per cent concentration.Verkerk and Wright (1993) showed that water extract of neem seed kernel was effective than methanolic NSKE against *P. xylostella* infesting cabbage.

Highest net gain was observed on fields treated with five per cent NSKE than synthetic insecticide lamda cyhalothrin against the cowpea pod borer during the late season sown crops in south Nigeria (Emoisaiure and Ubana, 1998).

2.2.1.2 Other crops

2.2.1.2.1 Work done in India

Baitha *et al.* (1993) observed that NSKE five per cent was the best treatment against the rice hispa followed by neem oil at three per cent. NSKE interfered with the ecdysteroid titers, produced morphogenetic effects and adversely affected the reproductive potential of the rice moth *Corcyra cephalonica* (Stainton.) (Chakraborthi and Chatterjee, 1996). Ten per cent NSKE caused 60.9 per cent reduction in the oviposition of *H.armigera* for a period of 0 to 24 hours (Jeyakumar and Gupta, 1999).

Umapathy and Rajendran (1999) in Tamil Nadu, tested three granular insecticides at two levels each against *Aceria jasmini* (Chan.) in comparison with soil application of neem cake at 250 and 500 kg ha^{-1}, soil application of neem cake at 250 kg ha^{-1} combined with foliar spray of NSKE at 10 per cent and neemcake at 250 kg plus neem oil 3 per cent foliar spray and found that granular insecticides at higher doses of 2 kg a.i. ha^{-1} caused 76.1 per cent reduction over control and NSKE ten per cent was also effective as granular insecticides.

Spraying of NSKE on 30^{th} and 59^{th} day after planting gave 18.2 per cent reduction of sugarcane shoot borer incidence on the variety COC.92061 over control in Tamil Nadu (Thirumurugan *et al.*, 2000). Karuppuchamy *et al.* (2001) field tested the efficacy of botanical insecticides against the pomegranate fruit borer on cv. Ganesh in Tamil Nadu and found that NSKE recorded superior control followed by neem oil and neem cake extract.

Neem seed kernel extract at 2 and 3 per cent concentrations were effective against the sorghum ear head bug similar to malathion and recorded highest grain yield of 1262 and 1185 kg ha^{-1} (Ramamurthy and Rajaram, 2001). Singh (2002) studied the ovicidal action of ecofriendly insecticides against *Spilosoma obliqua* (Walker) and observed that NSKE prevented one fourth of the eggs from hatching.

Neem products such as Achook, NSKE, Bioneem, Margocide, Neemark and Neemgold were evaluated against safflower aphid and mortality was assessed at 12, 24, 36, 48 and 60 hours after treatment and the results reavealed that all neem products caused significant reduction in safflower aphid over control (Dhembare *et al.*, 2002). Prabhakar *et al.* (2003) found that two sprayings of NSKE at five per cent in the bio intensive IPM module against the castor semilooper gave 50 per cent reduction in semilooper population in Tamil Nadu.

2.2.1.2.2 Work done abroad

Meisner *et al.* (1980) reported that NSKE at 0.4 to 0.1 per cent showed significant feeding inhibition of *S. litoralis* on lucerne. Schmutter (1990) proved that seed kernel extract was the most active one followed by hard shell and fallen leaves extract against the *S. gregaria*.

2.2.2 Citronella oil

Citronella oil is a volatile oil and it acts as a contact poison. It is obtained from the leaves and stem of the plant *Cymbopogan winterianus* (Jowitt). The oil contains 30 per cent citronellal and 40 per cent geraniol. Mainly used in insect repellent products. It also contains various monoterpene alcohols sesquiterpenes and acetate. Citronella oil acts as antifeedant or feeding deterrant in insects (Saradamma and Dale, 1981).

2.2.2.1 Vegetable crops

2.2.2.1.1 Work done in India

Gupta and Verma (1982) field tested the effectiveness of sprays of 0.025 per cent fenitrothion alone and in combination with various attractants such as 0.5 per cent gur, 0.5 per cent molasses, 0.25 per cent dried mango juice, 0.25 per cent citronella oil and 0.25 per cent protein hydrolysate against bittergourd fruit fly, *D. cucurbitae* in comparison to malathion alone or in combination sprays applied at 10 days interval and found that all combination of fenitrothion with each of the attractants except citronella oil was significantly more effective than the recommended spray bait consisting of 0.05 per cent malathion and 0.5 per cent gur in Haryana.

In tests of bait traps against fruit fly, various combinations of fermented palm juice, sugar, dried mango juice and oil of citronella were mixed with ten per cent diazinon, the results revealed that diazinon in mixture with citronella oil, dried mango juice and palm juice caught more fruit fly *D. cucurbitae* in melons (Lall and Singh, 1989).

2.2.2.1 Other crops

2.2.2.1.1 Work done in India

Citronella oil was the most effective repellant against the Indian honeybee, *A. cerana indica* at 0.5 and 1 per cent concentration for 30 hr followed by chenopodium, ajawan, lantana and eucalyptus oil (Patel and Kumar, 1989). Sridevi and Dhingra (1997) tested the toxicity of vegetable oils against the susceptible strain of *Tribolium castaneum* (Herbst) and observed that citronella oil exhibited positive temperature coefficient.

Citronella oil and palmarosa oil at 15ml kg^{-1} of groundnut pods gave protection to pods by inhibiting the oviposition of bruchid, *Caryedon serratus* (Olivier) for 6 months (Kumar *et al.*, 1998). Sridevi *et al.* (2000) found that citronella oil with piperonyl butoxide (1:4 ratio) showed an additive effect against adults of susceptible strains of *T. castaneum*.

Commercial products such as citrus clean (mixture of citronella oil, pine oil and oil extracted from lemon grass and marigold) applied to the eggs of *C. cephalonica* resulted in 100 per cent mortality when applied at concentrations of 50, 75 or 100 per cent. (Dwivedi *et al.*, 2000).

2.2.2.1.2 Work done abroad

Cent per cent control was observed against fruit sucking moth in apple orchard when treated with citronella oil than control and this was proved an effective repellent (Bosch, 1971). Malerbo *et al.* (1998) tested the effects of attractants and repellants on the behaviour of honeybees (*Apis mellifera* L.) in *in vitro* condition and noted that citronella oil was the most effective repellent.

2.3 NATURAL ORGANIC CONTROL OF PESTS

Natural organics can be used especially in smaller plots of vegetables. It is a simple, non-toxic method which can be used at reduced cost by small-scale farmers. In addition to controlling the pests, it provides mineral nutrients to the crop.

2.3.1 Vegetable crops

2.3.1.1 Work done in India

The leaf extracts of *Polygonum hydropiper* (L.), *Chromolaena odoratum* (L.) and *Azadirachta indica* were compared with woodash and malathion against red pumpkin beetle *A. foveicollis* at Jorhat, India and found that malathion 0.1 per cent concentration was the most effective treatment followed by *A. indica* and woodash (Das and Isahaque, 1998).

Dusting healthy tubers of potato with fine woodash controlled infestations of potato tubermoth, *P. operculella* in potato storage (Debranath *et al.*, 1998).

2.3.1.2 Work done abroad

Out of six organics tested for the control of *Meloidogyne incognita* on aubergines in a pot experiment, saw dust and woodash significantly reduced the gall formation and root damage on brinjal caused by *M. incognita* (Morale and

Kurundkar, 1987). Three parts of woodash to four parts of cowpea prevented the population growth of *Callosobruchus maculatus* (F.) during traditional storage method in North Cameroon (Wolfsan *et al.*, 1991).

2.3.2 Other crops

2.3.2.1 Work done abroad

Among the powders of five different plant products and the woodash of *Khaya senegalenseis* (Desv.) the most significant reduction of maize weevil, *Sitophilus zeamais* Mots.) in stored maize was observed in woodash at 21 days after treatment followed by *A. indica* and *M. azadirach* (Yasaf *et al.*, 1998).

Songa and Rono (1998) observed woodash as a better treatment than corn oil and 1.6 per cent primiphos methyl + 0.3 per cent permethrin in Kenya against the bruchid beetle in *Phaseolus vulgaris* (L.).

Woodash offered the highest percent of protection for most pepper cultivars against the pepper fruit fly, *Atherigona orientalis* (Schines) in Nigeria than the poultry manure and compost (Ogbalu, 1999).

Materials and Methods

3. MATERIALS AND METHODS

The investigation on the "IPM strategy in bittergourd using new generation insecticides and botanicals" were carried out in the field as well as in the laboratory of Department of Entomology, College of Horticulture, Vellanikkara during 2003-2004

a. Laboratory evaluation on the toxicity of five synthetic insecticides, few botanicals and one natural organic (woodash) against the pest *H. septima*, the predator *C. sexmaculata* and the pollinator *A. cerana indica.*

b. Field evaluation on the efficacy of insecticides, botanicals and natural organics against the key pests of bittergourd.

3.1 LABORATORY EVALUATION ON THE EFFICACY OF INSECTICIDES, BOTANICALS AND NATURAL ORGANIC AGAINST *H. septima, C. sexmaculata* AND HONEYBEE *A. cerana indica*

The toxicity of the insecticides, botanicals and natural organic on the leaf beetle, *H. septima*, predator *C. sexmaculata* and honeybee *A. cerana indica* was studied under laboratory conditions. The treatments are given in Table 1.

3.1.1 Leaf beetle, *H. septima*

The adults of epilachna beetle were used for the bioassay. Grubs of epilachna beetle were collected from the field and reared in rearing cages. Inside the rearing cages vials were kept and half of the vials were filled with water and bittergourd vines were inserted in to it. The grubs were released and reared on the vines. The leaf dip method recommended by FAO (1979) was used to know the mortality of the insects against different insecticides. Leaves of uniform size and age were collected from bittergourd plants. They were then immersed in different synthetic chemicals and botanicals for 10 minutes with gentle agitation. In natural organic treatment, woodash dusting was done at 10 g per treatment. Then the different

Table 1. Details of treatments for the laboratory experiment

Sl. No	Treatments	Trade name	Chemical formula	Formu-lation	Dose	Manufacturing company
1	Ethofenprox	Nukil	$C_{25}H_{28}O_3$	10 EC	2ml l^{-1}	Dhanuka Pesticides Limited Soha Mankola Road, Tehsil:NOH, District:Haryana
2	Fipronil	Regent	$C_{12}H_4Cl_2F_6N_4O_5$	5% SC	1ml l^{-1}	Bayer Crop Science India Limited, 10 Industrial Area, Bhopal
3	Profenofos	Carina	$C_{11}H_{15}B_rClO_3P_S$	50 EC	2ml l^{-1}	P.I. Industries Ltd., 237, GIDC, Panoli, Ankleswar-394116, Gujarat
4	Spinosad	Tracer	$C_{41}H_{65}NO_{10}$ + $C_{42}H_{67}NO_{10}$	48 EC	0.3ml l^{-1}	De_Nocil Crop Protection Ltd., Pirojsha Nagar, Vikhroli (E), Mumbai-400079
5	Deltafos	Spark	$C_{22}H_{19}B_{r2}NO_3$	36 EC	2ml l^{-1}	Bayer Crop Science India Ltd., 10 Industrial Area, Govindhapura, Bhopal
6	NSKE 5%	-	-	Aqueous Extract	50 g l^{-1}	-
7	Citronella oil 2.5%	-	-	Emulsion	25 ml l^{-1} + 5ml teepol	TMV Shenoy, Cochin
8	Woodash	-	-	Dust	25 g per cage	Nil
9	Control	-	-	No treatments	_	-

insecticide treated leaves were dried under fan for 5 minutes and kept in Petridishes with petiole ends wrapped up with moist cotton. Three replications were maintained for each treatment. An untreated control was maintained by dipping the leaves in water alone.

Ten uniform sized and aged adult epilachna beetles were transferred to the different insecticide treated leaves and also in untreated control, which were kept in Petridishes by using camel hair brush and then it was covered with lid. Observation on adult mortality and symptoms of poisoning were recorded on alternate days till all the beetles died.

3.1.2 Honeybee, *A. cerana indica*

Net cages were prepared to study the effect of different insecticides (Plate 1). Worker honeybees were collected during early morning at 7 a.m and released inside the net cages, which contained bittergourd vines treated with different insecticides. Three replications were maintained for each treatment. Ten insects were released per net cage. Observation on bee mortality was taken at hourly intervals in all the treatments including the control. The symptoms of poisoning of the honey bees were also observed.

3.1.3 Coccinellid predator, *C. sexmaculata*

Rearing of cowpea aphid was done for rearing the predator, *C. sexmaculata*. For rearing the aphid, cowpea seeds were soaked overnight in water and then transferred to museum jars containing moistened absorbent cotton. Aphids were transferred using camel hairbrush to these germinated seeds and reared. Grubs of the predator were released and reared on these aphids. The adults of predatory coccinellid beetles were used for the bioassay.

Coccinellid beetles were released into the net cages contained bittergourd vines treated with different insecticides. Three replications were maintained for each treatment. Ten insects were released per net cage. Observation on beetle mortality was

Plate 1. Net cage used for laboratory experiment

Plate 2. Field view of the experimental plot

Plate 3. Banana fruit trap against *Bactrocera cucurbitae*

taken at hourly intervals in all the treatments including the control. The symptoms of poisoning of the insects were also observed till all the beetles died.

3.1.4 Data analysis

Per cent mortality was corrected using Abbots formula as follows:

Per cent control or corrected mortality = X-Y/X x 100

Where X = Per cent live insects in the control

Y= Per cent live insects in the treatments

Then the data were statistically analysed in following completely randomized block design.

3.2 FIELD EVALUATION ON THE EFFICACY OF INSECTICIDES, BOTANICALS AND NATURAL ORGANICS AGAINST THE KEY PESTS OF BITTERGOURD

A field experiment was laid out in randomized block design with twelve treatments and three replications at the research field of College of Horticulture, Kerala Agricultural University, Vellanikkara during October, 2003 to February 2004. Preethi, a high yielding variety of bittergourd was used for the experiment. Seeds were sown at a spacing of 0.75 m on 22-10-03. The plot size was 17.06 m^2 per treatment per replication. All agronomic practices were followed as per the Package of Practices Recommendations (KAU, 2000). Before sowing of seeds, burning of pits was done on 17-10-03 with dried grasses and coconut leaves to destroy the eggs and pupae of *B. cucurbitae* found in the soil. Banana fruit trap was placed from flowering onwards in all the treatments including control to minimise the fruit fly attack.

The details of treatments (insecticides, botanicals and natural organics) are presented in the Table 1a.

Table 1a. Details of treatments for the field experiment

Sl. No	Treatments	Trade name	Chemical formula	Formulation	Dose
1	Ethofenprox	Nukil	$C_{25}H_{28}O_3$	10 EC	2ml l-^{1}
2	Fipronil	Regent	$C_{12}H_4Cl_2F_6N_4O_5$	5% SC	1ml l^{-1}
3	Profenofos	Carina	$C_{11}H_{15}B_rClO_3P_S$	50 EC	2ml l^{-1}
4	Spinosad	Tracer	$C_{41}H_{65}NO_{10}$ + $C_{42}H_{67}NO_{10}$	48 EC	0.3ml l^{-1}
5	Deltafos	Spark	$C_{22}H_{19}B_{r2}NO_3$	36 EC	2ml l^{-1}
6	NSKE 5% at fortnightly intervals	-	-	Aqueous Extract	50 g l^{-1}
7	NSKE 5% at weekly intervals	-	-	Aqueous Extract	50 g l^{-1}
8	Citronella oil 2.5% at fortnightly intervals	-	-	Emulsion	25 ml l^{-1} + 5ml teepol
9	Citronella oil 2.5% at weekly intervals	-	-	Emulsion	25 ml l^{-1} + 5ml teepol
10	Woodash at fortnightly intervals	-	-	Dust	500 g/plot
11	Woodash at weekly intervals	-	-	Dust	500 g/plot
12	Control	-	-	No treatments	_

3.2.1 Schedule of treatment application

a. First spray : 10.12.03, 48 days after sowing

b. Second spray : 25.12.03,15 days after 1st spray, and 63 days after sowing

c. Third spray : 9. 1 .04,15 days after 2nd spray, and 78 days after sowing

d. Fourth spray : 24.1.04, 15 days after 3rd spray, and 93 days after sowing

3.2.2 Methods of application of insecticides, botanicals and natural organics

The insecticides were sprayed using a pneumatic hand sprayer fitted with a hollow cone nozzle. Woodash was taken in a cloth bag and dusted on the plants.

3.2.3 Field observation

Observations on pest incidence and intensity were recorded at intervals of 1, 3,5, 7, 10 and 14 days after treatment. Pretreatment count was also made before treatment application.

3.2.3.1 Sucking pests and foliage feeders

For assessing the population of sucking pests and foliage feeders, five plants were selected at random from each replication of the treatment and the pests were counted from fifteen leaves taken at random, @ three leaves per plant, one each from top, middle and bottom canopy. The pest intensity was expressed as mean number per leaf. In the case of leaf miner the pest intensity was expressed as mines per leaf. The data on the pest counts were subjected to square root transformation and statistically analysed.

3.2.3.2 Fruit fly and fruit borers

At the time of harvest the total number and weight of fruits infested with fruit fly and fruit borers were recorded separately for each treatment. Per cent infestation by number and weight basis was worked out. Data on per cent infestation of fruits were transformed to square root transformation and statistically analysed.

3.2.3.3 Gall fly

Per cent gall fly infestation was calculated by counting the number of gall fly infested vines to the total number of vines from each replication of the treatment. The data were subjected to square root transformation and statistically analysed.

3.2.4 Data analysis

Data were subjected to square root transformation and analysed following analysis of variance following randomized block design (Gomez and Gomez, 1984).

3.2.5 Total yield

The number and weight of fruits harvested were recorded separately during each harvest and the data were statistically analysed.

3.2.6 Parasitoids and predators

The parasitoids and predators present on the leaves were recorded while taking observations on pests. Spiders and coccinellid predators present on these leaves were observed. The parasitised caterpillars of *D. indica* were counted to calculate percentage larval parasitism.

3.2.7 Benefit: cost ratio

The benefit: cost ratio for the various treatments including insecticides, botanicals and natural organic were worked out. The formula used was:

$$\text{Benefit: cost ratio} = \frac{\text{Value of increased yield over control - Cost of application of insecticide}}{\text{Cost of application of insecticide}} \times 100$$

3.2.8 Meteorological observations

Maximum and minimum temperature, sun shine hours, relative humidiy, rainfall and wind velocity during the cropping period were recorded. The mean weekly values of the metereological parameters during the period was worked out and presented in Appendix 1.

Results

4. RESULTS

The investigations on the "IPM strategy in bittergourd using newer generation insecticides and botanicals" was conducted during the year 2003 – 2004 under the following two sections:

a. Laboratory evaluation on efficacy of synthetic insecticides, botanicals and natural organic against *H. septima*, *C. sexmaculata* and *A. cerana indica.*
b. Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against the key pests of bitter gourd.

4.1. LABORATORY EVALUATION OF EFFICACY OF SYNTHETIC INSECTICIDES, BOTANICALS AND NATURAL ORGANIC AGAINST *H. septima, C. sexmaculata* AND *A. cerana indica*

4.1.1 Laboratory evaluation on efficacy of synthetic insecticides, botanicals and a natural organic against *H. septima*

The results obtained from the laboratory evaluation of efficacy of synthetic insecticides, botanicals and a natural organic against the pest *H. septima* are given in Table 2 and the symptoms of poisoning for various treatment are given in Table 3.

At one day after treatment (DAT), the highest per cent mortality (95.83) was recorded in profenofos and the lowest per cent mortality was recorded in wood ash (13.70) followed by neem seed kernel extract (NSKE) with a value of 22.22. Profenofos was significantly superior to fipronil, ethofenprox, NSKE and woodash, but was on par with citronella oil, deltafos and spinosad.

At three DAT, the highest per cent mortality (100) was recorded by profenofos closely followed by citronella oil (95.83) and deltafos (91.67). Profenofos was found to be on par with citronella oil, deltafos, spinosad and NSKE. Woodash, ethofenprox and fipronil recorded lower per cent mortalities (49.99, 50.00 and 58.33)

Table 2. Per cent mortality of adult epilachna beetle in different treatments

Sl. No.	Treatments	Per cent mortality at different intervals	
		1 DAT	3 DAT
1	Ethofenprox 0.02%	30.187 (5.259)[c]	50.003 (7.040)[cd]
2	Fipronil 0.01%	56.480 (7.526)[b]	58.330 (7.567)[bc]
3	Profenofos 0.1%	95.833 (9.810)[a]	100.00 (10.025)[a]
4	Spinosad 0.014%	75.923 (8.722)[ab]	77.773 (8.805)[abc]
5	Deltafos 0.07%	80.553 (8.986)[ab]	91.667 (9.580)[ab]
6	NSKE 5%	22.223 (4.343)[cd]	75.267 (0.680)[abc]
7	Citronella oil 2.5%	83.793 (9.175)[ab]	95.833 (9.810)[ab]
8	Woodash 10 g	13.703 (3.725)[d]	49.997 (7.029)[cd]

In a column, mean followed by a common letter are not significantly different by DMRT (P=0.05)

Values in parenthesis are √ x+ 0.5 transformed values.

DAT - Days After Treatment

Table 3. Symptoms of poisoning of adult epilachna beetle in different treatments

Sl. No.	Treatments	Symptoms of poisoning
1	Ethofenprox 0.02%	Hyperactivity and death in upside down position
2	Fipronil 0.01%	Hyperextension of legs, paralysis and death
3	Profenofos 0.1%	Blackening of nearly anterior $3/4^{th}$ of the body and death.
4	Spinosad 0.014%	Hyperextension of legs, paralysis and death in upside down position
5	Deltafos 0.07%	Hyper activity and death in upside down position
6	NSKE 5%	Downward extension of legs and death in upside down position
7	Citronella oil 2.5%	Blackening, occurrence of jitters and death
8	Woodash 10 g	Extension of wings, blackening and death

and these were significantly inferior in controlling epilachna population. NSKE showed low toxicity at three DAT, the toxicity had increased by fifth day.

At five DAT, there was cent per cent mortality of beetles in control.

4.1.2 Laboratory evaluation on efficacy of synthetic insecticides, botanicals and a natural organic against the pollinator, Indian honeybee

The results obtained from the laboratory evaluation of efficacy of synthetic insecticides, botanicals and a natural organic against the pollinator, *A. cerana indica* are given in Table 4 and the symptoms of poisoning for various treatment are given in Table 5.

At one hour after treatment, the highest per cent mortality (58.143) was recorded in fipronil and lowest per cent mortality (14.81) was recorded in NSKE. Fipronil was found to be on par with other treatments except NSKE, which was found to be safest to honeybees at one hour.

At two hours after treatment, the highest per cent mortality (93.33) was recored in ethofenprox and the lowest per cent mortality (32.933) was recorded in spinosad closely followed by NSKE (35.55). Treatment ethofenprox was on par with profenofos, deltafos and citronella oil. The treatments, spinosad and NSKE were comparatively safe to honey bees at two hours after treatment.

At three hours after treatment, the highest per cent mortality (100) was recorded in two treatments, namely ethofenprox and profenofos and lowest per cent mortality (41.11) was recorded in NSKE. The next safe treatment to honey bees was spinosad (47.77). Ethofenprox and profenofos were on par with deltafos, fipronil, citronella oil and woodash. These were highly toxic to honeybees at three hours after treatment.

Table 4. Per cent mortality of honeybees in different treatments

Sl. No.	Treatments	Per cent mortality at different intervals			
		1 h	2 h	3 h	4 h
1	Ethofenprox 0.02%	42.500 (6.488)^{ab}	93.333 (9.674)^{a}	100.00 (10.025)^{a}	100.00 (10.025)^{a}
2	Fipronil 0.01%	58.143 (7.321)^{a}	61.637 (7.848)^{ab}	91.667 (9.580)^{ab}	100.00 (10.025)^{a}
3	Profenofos 0.1%	27.907 (5.199)^{ab}	82.220 (9.064)^{a}	100.00 (10.025)^{a}	100.00 (10.025)^{a}
4	Spinosad 0.014%	32.800 (5.722)^{ab}	32.933 (5.682)^{b}	47.77 (6.900)^{bc}	100.00 (10.025)^{a}
5	Deltafos 0.07%	48.873 (6.939)^{a}	82.220 (9.064)^{a}	93.333 (9.674)^{ab}	100.00 (10.025)^{a}
6	NSKE 5%	14.813 (2.706)^{b}	35.553 (5.999)^{b}	41.110 (6.429)^{c}	100.00 (10.025)^{a}
7	Citronella oil 2.5%	31.943 (5.275)^{ab}	73.333 (6.429)^{a}	90.737 (9.545)^{ab}	100.00 (10.025)^{a}
8	Wood ash 25 g	28.370 (4.820)^{ab}	54.070 (7.349)^{ab}	71.110 (8.271)^{abc}	100.00 (10.025)^{a}

In a column, mean followed by a common letter are not significantly different by DMRT (P=0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values.

h = hour

Table 5. Symptoms of poisoning of honey bees in different treatments

Sl. No.	Treatments	Symptoms of poisoning
1	Ethofenprox 0.02%	Sudden falling of bees, slow movement by upward raising of abdomen and death
2	Fipronil 0.01%	Excitation, slow movement, extension of legs and death
3	Profenofos 0.1%	Slow movement and discolouration of body and death
4	Spinosad 0.014%	Raising of abdominal tip, excitation and death
5	Deltafos 0.07%	Jitters, excitation and death
6	NSKE 5%	Slow movement, excitation, extension of legs and death
7	Citronella oil 2.5%	Sudden falling of bees, upside down death blackening of bees on abdomen and death
8	Woodash 10 g	Hyper extension of legs, slow movement slight discolouration of bees and death

At four hours after treatment, there was cent per cent mortality of bees in all the treatments except control, but in control cent per cent mortality was observed after six hours.

4.1.3 Laboratory evaluation of efficacy of synthetic insecticides, botanicals and a natural organic against the predator *C. sexmaculata*

The results obtained from the laboratory evaluation of the efficacy of synthetic insecticides, botanicals and a natural organic against the predator are given in Table 6 and the symptoms of poisoning for various treatment are given in Table 7.

The highest per cent mortality (16.67) was recorded in fipronil and citronella oil and the lowest per cent mortality (0.000) was recorded in spinosad at one hour after treatment. Fipronil and citronella oil were on par with deltafos, ethofenprox, NSKE, woodash and profenofos. At two hours after treatment, all the treatments had similar effect on *C. sexmaculata* and the per cent mortality varied from 20.00 in citronella oil to 11.11 in spinosad.

At three hours after treatment the lowest per cent mortality of 14.25 was recorded on spinosad and the highest mortality was recorded in citronella oil (29.167). Treatments like ethofenprox, deltafos, and NSKE were on par with citronella oil.

There was no significant difference between treatments at four hours after treatment. Here also spinosad recorded the lowest per cent mortality. At five hours after treatment, the lowest per cent mortality (33.33) was recorded in spinosad and the highest per cent mortality (71.67) was recorded on citronella oil and NSKE. Treatments such as citronella oil and NSKE differed significantly from other treatments with higher toxicity to the predatory beetle.

Cent per cent mortality was recorded by deltafos and citronella oil at six hours after treatment. Treatments such as deltafos and citronella oil were significantly

Table 6. Per cent mortality of adult *Cheilomenes sexmaculata* in different treatments

Sl. No.	Treatments	Per cent mortality at different intervals						
		1 h	2 h	3 h	4 h	5 h	6 h	7 h
1	Ethofenprox 0.02%	13.333 (3.669)^{ab}	18.517 (4.313)^{a}	26.757 (5.130)^{ab}	33.33 (5.688)^{a}	53.333 (7.307)^{b}	91.667 (9.580)^{b}	100.00 (10.025)^{a}
2	Fipronil 0.01%	16.667 (4.001)^{a}	18.990 (4.350)^{a}	20.000 (4.430)^{b}	27.773 (5.258)^{a}	46.667 (5.819)^{b}	77.777 (8.805)^{b}	100.00 (10.025)^{a}
3	Profenofos 0.1%	10.370 (2.881)^{ab}	14.25 (3.311)^{a}	18.990 (4.353)^{b}	22.220 (3.985)^{a}	66.667 (8.176)^{b}	91.667 (9.580)^{b}	100.00 (10.025)^{a}
4	Spinosad 0.014%	0.000 (0.707)^{b}	11.110 (2.960)^{a}	14.257 (3.311)^{c}	20.00 (4.430)^{a}	33.333 (5.752)^{b}	77.777 (8.805)^{b}	100.00 (10.025)^{a}
5	Deltafos 0.07%	14.813 (3.860)^{ab}	14.257 (3.311)^{a}	23.780 (4.872)^{ab}	33.33 (5.688)^{a}	60.000 (7.705)^{b}	100.00 (10.025^{a}	100.00 (10.025)^{a}
6	NSKE 5%	13.333 (3.669)^{ab}	17.037 (4.059)^{a}	21.400 (4.535)^{ab}	31.943 (5.677)^{a}	71.667 (8.480)^{a}	91.667 (9.580)^{a}	100.00 (10.025)^{a}
7	Citronella oil 2.5%	16.667 (4.001)^{a}	20.000 (4.430)^{a}	29.167 (5.254)^{a}	50.000 (7.069)^{a}	71.667 (8.480)^{a}	100.00 (10.025^{a}	100.00 (10.025)^{a}
8	Wood ash 25 g	11.110 (2.960)^{ab}	18.990 (4.353)^{a}	20.833 (4.459)^{b}	25.000 (4.772)^{a}	63.33 (7.909)^{b}	77.777 (8.805)^{b}	100.00 (10.025)^{a}

In a column, mean followed by common letter are not significantly different by DMRT P= (0.05)

Values in parenthesis are √ x+0.5 transformed values.

h - hour

Table 7. Symptoms of poisoning of adult *Cheilomenes sexmaculata* in different treatments

Sl. No.	Treatments	Symptoms of poisoning
1	Ethofenprox 0.02%	Sudden falling of insects, slow movement of beetles and death
2	Fipronil 0.01%	Slow movement, extension of legs and death
3	Profenofos 0.1%	Slight discolouration and death in upside down position
4	Spinosad 0.014%	Sudden falling, excitation and death
5	Deltafos 0.07%	Slow movement, extension of legs and death
6	NSKE 5%	Slow movement of beetles, extension of legs and death
7	Citronella oil 2.5%	Sudden falling and death in upside down position
8	Woodash 10g	Hyper extension of legs, slow movement and death

Plate 4. Infestation by *Bactrocera cucurbitae*

Plate 5. Hopper burn caused by *Empoasca (E.) motti*

Plate 6. Infestation by *Diaphania indica* on fruits

Plate 7. Infestation by *Diaphania indica* on leaves

Plate 8. Grub of *Henosepilachna septima*

Plate 9. Gall fly infestation on vine

Plate 10. Larval parasitoids on *Diaphania indica*

inferior to other treatments, which were statistically on par. At seven hours after treatment there was complete mortality in all treatments except control, but in control cent per cent mortality was observed after 36 hours.

4.2 FIELD EVALUATION ON EFFICACY OF SYNTHETIC INSECTICIDES, BOTANICALS AND NATURAL ORGANICS AGAINST THE KEY PESTS OF BITTER GOURD.

The results on the efficacy of different insecticides, botanicals and natural organic against the pests are summarized below.

The following pests were observed in the field experiment.

a. Leaf beetle	: *Henosepilachna septima* (Coccinellidae:Coleoptera)
b. Pumpkin caterpillar	: *Diaphania indica* (Pyralidae: Lepidoptera)
c. Leafhopper	: *Empoasca (E.) motti* (Cicadellidae: Hemiptera)
d. Aphid	: *Aphis gossypii* (Aphididae: Hemiptera)
e. Gall fly	: *Neolasioptera falcata* (Cecidomyiidae: Diptera)
f. Serpentine leaf miner	: *Liriomyza trifolii* (Agromyzidae: Diptera)
g. Whitefly	: *Bemisia tabaci* (Aleyrodidae:Hemiptera)

4.2.1 Efficacy of test insecticides on the population of leafhopper *E. (E.) motti*

The results of the pre treatment and post treatment count on the population of leafhoppers are given in the Tables 8, 10, 12 and 14 and the percentage reduction of leafhoppers over control at different intervals are given in the Tables 9, 11, 13 and 15.

4.2.1.1 First spray

The pretreatment count (PTC) before the first spraying showed that the mean leafhopper count ranged from 2.173 to 4.253 per leaf. Post treatment count at one, three, five, seven, ten and fourteen DAT also revealed that there was an increasing intensity of leafhopper population from one day after spraying and ethofenprox recorded the lowest value at all intervals. The highest count at all

Table 8. Population density of leafhopper in different treatments after the first spray

Sl. No.	Treatments	Mean no. of nymphs per leaf						
		PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	2.787 (1.807)^{a}	0.566 (1.031)^{e}	0.443 (0.971)^{f}	0.595 (1.139)^{g}	0.630 (1.062)^{de}	0.850 (1.161)^{b}	0.967 (1.210)^{d}
2	Fipronil 0.01%	4.253 (2.175)^{a}	0.731 (1.108)^{cde}	0.787 (1.131)^{de}	0.844 (1.157)^{de}	1.200 (1.296)^{ab}	1.223 (1.307)^{ab}	1.243 (1.309)^{bc}
3	Profenofos 0.1%	2.900 (1.836)^{a}	0.787 (1.131)^{cde}	0.643 (1.069)^{ef}	0.766 (1.126)^{efg}	0.883 (1.193)^{de}	0.967 (1.210)^{ab}	1.100 (1.269)^{bc}
4	Spinosad 0.01%	2.967 (1.852)^{a}	0.620 (1.051)^{de}	0.800 (1.140)^{cde}	0.857 (1.159)^{deg}	0.780 (1.131)^{cde}	0.850 (1.161)^{b}	0.967 (1.210)^{d}
5	Deltafos 0.07%	2.760 (1.784)^{a}	0.889 (1.175)^{bcd}	0.587 (1.042)^{ef}	0.721 (1.101)^{fg}	0.877 (1.170)^{cde}	1.133 (1.276)^{ab}	1.310 (1.338)^{bc}
6	NSKE 5% at fortnightly intervals	3.267 (1.992)^{a}	0.844 (1.155)^{bcde}	0.733 (1.110)^{cde}	1.087 (1.251)^{bcd}	0.820 (1.145)^{cde}	1.067 (1.250)^{ab}	1.278 (1.333)^{bc}
7	NSKE 5% at weekly intervals	2.253 (1.643)^{a}	0.800 (1.140)^{cde}	0.911 (1.186)^{abcd}	1.000 (1.224)^{bcd}	0.893 (1.178)^{cde}	0.807 (1.142)^{b}	1.296 (1.339)^{bc}
8	Citronella oil 2.5% at fortnightly intervals	2.600 (1.758)^{a}	1.044 (1.235)^{bc}	0.767 (1.125)^{cde}	1.333 (1.351)^{bc}	0.933 (1.197)^{bcd}	0.893 (1.148)^{b}	1.463 (1.397)^{ab}
9	Citronella oil 2.5% at weekly intervals	3.533 (2.606)^{a}	1.111 (1.269)^{bcd}	1.120 (1.271)^{abc}	1.184 (1.292)^{bcd}	0.953 (1.203)^{bcd}	1.100 (1.263)^{ab}	1.222 (1.311)^{bc}
10	Woodash 500 g at fortnightly intervals	2.173 (1.758)^{a}	0.867 (1.168)^{bcd}	0.974 (1.213)^{ab}	1.133 (1.276)^{bcde}	1.087 (1.260)^{bc}	1.150 (1.284)^{ab}	1.710 (1.481)^{d}
11	Woodash 500 g at weekly intervals	3.867 (2.084)^{a}	0.853 (1.160)^{bcde}	0.900 (1.183)^{bcd}	1.400 (1.377)^{ab}	1.310 (1.345)^{ab}	0.993 (1.105)^{ab}	1.189 (1.296)^{c}
12	Control	2.600 (1.756)^{a}	1.167 (1.291)^{a}	1.567 (1.437)^{a}	1.833 (1.527)^{a}	1.933 (1.536)^{a}	1.989 (1.558)^{a}	2.091 (1.610)^{a}

In a column, mean followed by common letter are not significantly different by DMRT P = (0.05)
Values in parenthesis are $\sqrt{x+0.5}$ transformed values.
DAT= Days After Treatment
PTC - Pre Treatment Count

Table 9. Per cent reduction in the population of leafhopper in different treatments compared to control after the first spray

Sl. No.	Treatments	Per cent reduction over control					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	68.19	71.71	67.50	67.60	57.20	53.75
2	Fipronil 0.01%	54.06	49.60	53.90	37.92	38.04	40.55
3	Profenofos 0.1%	49.26	58.93	58.20	54.30	51.30	47.39
4	Spinosad 0.014%	46.87	48.90	53.21	59.63	52.23	53.75
5	Deltafos 0.07%	23.82	62.52	60.60	54.60	43.03	37.35
6	NSKE 5 % at fortnightly intervals	27.60	53.20	40.69	57.50	46.35	38.80
7	NSKE 5% at weekly intervals	31.40	41.86	45.44	53.80	59.30	38.03
8	Citronella oil 2.5% at fortnightly intervals	11.78	51.00	27.27	51.70	55.10	30.03
9	Citronella oil 2.5% at weekly intervals	4.79	28.50	35.40	50.60	44.69	41.55
10	Woodash 500g at fortnightly intervals	25.70	37.84	45.82	43.7	43.03	18.20
11	Woodash 500g at weekly intervals	26.90	42.50	23.60	32.20	42.18	43.13

DAT= Days After Treatment

intervals was recorded in control (Table 8). All the chemical treatments recorded a population density of less than one nymph per leaf upto five DAT except fipronil.

First day after treatment (DAT) the mean population of leafhopper ranged from 0.566 to 1.167 nymphs per leaf. Ethofenprox was statistically on par with spinosad, fipronil, profenofos, both treatments of NSKE and woodash dusting at weekly intervals. At three DAT, ethofenprox, deltafos and profenofos were found to be superior to other treatments with a mean leafhopper population of 0.443, 0.587 and 0.643, respectively.

At five DAT, deltafos and profenofos were on par with ethofenprox, which recorded significantly lower values. At seven DAT, fipronil recorded higher population compared to five DAT. At 14 DAT, ethofenprox and spinosad were found to be significantly superior to other treatments with a mean population of leafhopper (0.967).

The per cent reduction in the population of leafhopper was also high in ethofenprox with 68.19 at one DAT to 53.75 at fourteen DAT when compared to other treatments (Table 9). Here the maximum reduction in population was observed at three DAT (71.7 per cent). Among other treatments highest per cent reduction was in profenofos at three DAT (58.9 per cent), in spinosad at seven DAT, in deltafos, it was on three DAT. Among botanicals and natural organics, higher per cent reduction was observed in NSKE and citronella oil.

4.2.1.2 Second spray

During second spray the chemicals recorded lower leafhopper population, compared to other treatments (Table 10). All chemicals recorded less than one nymph per leaf up to five DAT compared to seven DAT during first spray. The population was high in botanicals and natural organics. Ethofenprox recorded lowest population at all intervals observed.

Table 10. Population density of leafhopper in different treatments after the second spray

Sl. No.	Treatments	Mean no. of nymphs per leaf					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	0.520 (1.009)^{c}	0.620 (1.058)^{e}	0.765 (1.124)^{c}	1.633 (1.459)^{g}	2.078 (1.595)^{e}	2.173 (1.635)^{c}
2	Fipronil 0.01%	0.751 (1.116)^{b}	0.847 (1.159)^{cde}	0.973 (1.210)^{bc}	2.233 (1.635)^{de}	2.884 (1.696)^{cde}	2.600 (1.758)^{b}
3	Profenofos 0.1%	0.863 (1.165)^{b}	0.900 (1.183)^{de}	0.989 (1.219)^{bc}	2.33 (1.662)^{efg}	2.733 (1.780)^{cde}	2.389 (1.678)^{bc}
4	Spinosad 0.014%	0.531 (1.013)^{bc}	0.765 (1.124)^{de}	0.900 (1.183)^{bc}	1.688 (1.470)^{defg}	2.133 (1.617)^{de}	2.787 (1.807)^{b}
5	Deltafos 0.07%	0.665 (1.067)^{b}	0.878 (1.172)^{cde}	0.967 (1.198)^{bc}	2.233 (1.635)^{fg}	2.243 (1.647)^{cd}	2.600 (1.758)^{b}
6	NSKE 5% at fortnightly intervals	1.065 (1.236)^{ab}	1.354 (1.361)^{ab}	1.232 (1.315)^{abc}	2.610 (1.726)^{bcd}	2.911 (1.819)^{bc}	2.967 (1.852)^{b}
7	NSKE 5% at weekly intervals	1.020 (1.230)^{b}	1.042 (1.236)^{bcde}	1.043 (1.239)^{bc}	2.389 (1.678)^{bcd}	2.173 (1.758)^{de}	2.760 (1.789)^{b}
8	Citronella oil 2.5% at fortnightly intervals	1.320 (1.339)^{ab}	1.467 (1.397)^{ab}	1.553 (1.483)^{a}	3.087 (1.861)^{bc}	3.267 (1.906)^{bc}	3.533 (2.066)^{b}
9	Citronella oil 2.5% at weekly intervals	1.220 (1.311)^{ab}	1.189 (1.299)^{bcd}	1.022 (1.232)^{bc}	2.664 (1.765)^{bcd}	2.253 (1.643)^{bcd}	2.887 (1.081)^{b}
10	Woodash 500 g at fortnightly intervals	0.891 (1.177)^{b}	1.411 (1.380)^{ab}	1.758 (1.501)^{a}	3.300 (1.942)^{bcde}	3.510 (1.977)^{a}	3.267 (1.922)^{ab}
11	Woodash 500 g at weekly intervals	1.587 (1.433)^{ab}	1.200 (1.296)^{bcd}	1.043 (1.239)^{bc}	3.155 (1.906)^{ab}	3.453 (1.980)^{bc}	4.253 (2.175)^{ab}
12	Control	2.467 (1.579)^{a}	3.500 (2.000)^{a}	3.556 (2.014)^{a}	3.620 (2.030)^{a}	3.700 (2.050)^{a}	3.867 (2.084)^{a}

In a column, mean followed by common letter are not significantly different by DMRT ($P=0.05$)
Values on parenthesis are $\sqrt{x+0.5}$ transformed values
DAT - Days After Treatment

Table 11. Per cent reduction in the population of leafhopper in different treatments compared to control after the second spray

Sl. No.	Treatments	Per cent reduction over control					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	78.92	82.28	78.48	54.88	43.80	43.80
2	Fipronil 0.01%	69.55	75.80	72.63	38.31	35.56	32.76
3	Profenofos 0.1%	65.01	74.20	72.18	35.63	26.13	38.22
4	Spinosad 0.014%	78.47	72.80	74.69	53.37	42.35	27.92
5	Deltafos 0.07%	73.04	65.35	72.80	38.30	39.37	34.24
6	NSKE 5% at fortnightly intervals	56.83	61.30	65.35	27.90	21.32	28.60
7	NSKE 5% at weekly intervals	58.65	70.20	70.66	34.00	41.20	23.27
8	Citronella oil 2.5% at fortnightly intervals	46.49	58.08	56.32	14.72	11.70	8.63
9	Citronella oil 2.5% at weekly intervals	50.54	66.02	71.25	26.408	39.18	25.64
10	Woodash 500 g at fortnightly intervals	63.88	59.60	50.50	8.839	5.13	5.51
11	Woodash 500 g at weekly intervals	35.60	65.70	70.66	12.84	6.67	-9.98

DAT - Days After Treatment

At one DAT the mean leafhopper population ranged from 0.520 (ethofenprox) to 2.467 (control). Ethofenprox was found to be on par with spinosad. (Table 10). At three DAT, spinosad, profenofos, fipronil, deltafos and NSKE spraying at weekly intervals recorded significantly lower population and they were on par with ethofenprox.

Fipronil, spinosad, profenofos, deltafos, both treatments of NSKE and citronella oil at weekly interval spraying were on par in effectiveness to ethofenprox and were significantly superior in controlling leafhopper population at five DAT.

At seven DAT, there were no significant differences between the treatments. Ethofenprox was on par with fipronil, profenofos, spinosad and NSKE spraying at weekly intervals at 10 DAT. At 14 DAT, the lowest mean leafhopper count of 2.173 per leaf was recorded in ethofenprox and control recorded highest mean leafhopper count of 3.867 nymphs per leaf. Ethofenprox and profenofos were significantly superior when compared to other treatments in controlling leafhoppers.

The per cent reduction was also highest in ethofenprox ranging from 78.92 at one DAT to 43.80 at 14 DAT when compared to other treatments at different intervals (Table 11). Among chemicals, highest value was recorded in ethofenprox at three DAT (82.28). All the treatments caused more than 50 per cent reduction in the leafhopper population upto five DAT. Ethofenprox and spinosad only recorded higher reduction of above 50 per cent at seven DAT. NSKE, woodash and citronella oil at weekly intervals recorded high reduction in leafhopper population among the botanicals (70.66,70.66 and 71.25 respectively).

4.2.1.3 Third spray

The leafhopper population was very high during the third spray. Here also ethofenprox recorded the lowest leafhopper population.

Table 12. Population density of leafhopper in different treatments after the third spray

Sl. No.	Treatments	Mean no. nymphs per leaf				
		1 DAT	3 DAT	5 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	2.778 (1.806)^{g}	3.33 (1.902)^{f}	2.877 (1.836)^{h}	3.967 (2.113)^{g}	4.107 (2.138)^{f}
2	Fipronil 0.01%	3.923 (2.103)^{bcd}	3.673 (2.037)^{d}	4.310 (2.191)^{c}	5.767 (2.503)^{cd}	5.860 (2.521)^{de}
3	Profenofos 0.1%	3.153 (1.904)^{efg}	3.599 (2.014)^{e}	4.127 (2.146)^{f}	5.653 (2.980)^{de}	5.997 (2.549)^{de}
4	Spinosad 0.014%	2.989 (1.866)^{fg}	3.644 (2.027)^{d}	4.093 (2.143)^{f}	4.059 (2.103)^{g}	4.267 (2.178)^{f}
5	Deltafos 0.07%	3.453 (2.243)^{def}	3.899 (2.097)^{c}	4.347 (2.201)^{de}	5.233 (2.383)^{f}	5.589 (2.469)^{e}
6	NSKE 5% at fortnightly intervals	3.898 (2.097)^{bcd}	4.140 (2.145)^{b}	4.777 (2.296)^{bc}	5.887 (3.100)^{c}	6.227 (2.063)^{cd}
7	NSKE 5% at weekly intervals	3.653 (2.033)^{cde}	3.833 (2.064)^{c}	3.343 (1.958)^{g}	5.553 (2.460)^{e}	5.733 (2.496)^{de}
8	Citronella oil 2.5% at fortnightly intervals	4.288 (2.175)^{b}	4.309 (2.188)^{b}	4.730 (2.287)^{c}	6.083 (2.559)^{b}	6.573 (2.660)^{bc}
9	Citronella oil 2.5% at weekly intervals	4.107 (2.138)^{bc}	4.267 (2.178)^{b}	4.492 (2.232)^{d}	6.054 (2.553)^{b}	6.610 (2.662)^{abc}
10	Woodash 500 g at fortnightly intervals	4.907 (2.322)^{a}	4.309 (2.188)^{b}	4.933 (2.330)^{a}	6.900 (2.720)^{a}	7.110 (2.793)^{a}
11	Woodash 500 g at weekly intervals	4.003 (2.117)^{bc}	4.233 (2.167)^{b}	5.107 (2.368)^{a}	6.863 (3.110)^{a}	7.064 (2.750)^{ab}
12	Control	4.140 (2.145)^{bc}	4.798 (2.302)^{a}	5.113 (2.369)^{a}	6.837 (2.705)^{a}	6.954 (2.730)^{ab}

In a column mean, followed by common letter are not significantly different by DMRT (P=0.05).
Values on parenthesis are $\sqrt{x+0.5}$ transformed values.
DAT - Days After Treatment

Table 13. Per cent reduction in the population of leafhopper in different treatments compared to control after third spray

Sl. No.	Treatments	Per cent reduction over control				
		1 DAT	3 DAT	5 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	32.80	30.50	34.60	41.97	40.97
2	Fipronil 0.01%	5.29	23.07	15.70	15.65	15.73
3	Profenofos 0.1%	23.80	24.90	19.28	17.31	13.76
4	Spinosad 0.014%	27.80	24.05	19.94	40.63	38.74
5	Deltafos 0.07%	16.50	18.73	14.98	23.60	19.62
6	NSKE 5% at fortnightly intervals	3.84	13.70	33.60	13.89	10.45
7	NSKE 5% at weekly intervals	11.76	20.11	43.73	18.78	5.47
8	Citronella oil 2.5% at fortnightly intervals	-3.50	10.19	7.49	11.02	4.94
9	Citronella oil 2.5% at weekly intervals	0.70	11.06	12.14	11.45	4.946
10	Woodash 500 g at fortnightly intervals	-18.50	10.19	3.52	-0.92	-2.24
11	Woodash 500 g at weekly intervals	3.30	0.07	0.11	-0.38	-1.58

DAT - Days After Treatment

At one DAT, the lowest mean leafhopper count of 2.778 nymphs per leaf was recorded in ethofenprox and it was on par with spinosad and profenofos when compared to other treatments and the highest mean leaf hopper count of 4.907 nymphs per leaf was recorded in woodash dusting at fortnightly interval spraying and observed to be significantly inferior among all other treatments (Table 12). At three DAT, the mean leafhopper count ranged from 3.33 to 4.798 nymphs per leaf. Ethofenprox was significantly superior with lowest leafhopper population.

At five DAT, ethofenprox was significantly superior compared to other treatments. The next better treatment was NSKE spraying at weekly intervals, which recorded 3.343 nymphs per leaf. At five, ten and 14 DAT wood ash dusting at fortnightly and weekly intervals and control recorded significantly higher population. At 14 DAT, ethofenprox and spinosad were significantly superior in controlling leafhopper infestation.

The per cent reduction of leaf hopper was also high in ethofenprox at different intervals when compared to other treatments ranging from 32.8 at one DAT to 41.97 per cent at ten DAT (Table 13). The per cent reduction was very low compared to first and second spray. NSKE spraying at weekly intervals recorded the highest reduction at five DAT (43.73).

4.2.1.4 Fourth spray

The leafhopper population was very high during the fourth spray. At one DAT, the lowest mean leafhopper population of 3.923 per leaf was recorded in ethofenprox while control recorded the highest leafhopper population of 7.064 per leaf (Table 14). The treatments did not differ significantly.

Ethofenprox recorded lowest leaf hopper population at three, five, seven, ten and fourteen DAT. Woodash dusting recorded higher leafhopper population at three, five and seven DAT. Profenofos, spinosad and fipronil were equal in effectiveness in controlling leafhopper population at five DAT. At 14 DAT,

Table 14. Population density of leafhopper in different treatments after the fourth spray

Sl. No.	Treatments	Mean no. of nymphs per leaf					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	3.923 (2.103)^{a}	4.210 (2.095)^{a}	5.589 (2.467)^{f}	5.733 (2.496)^{f}	6.333 (2.613)^{b}	6.578 (2.660)^{f}
2	Fipronil 0.01%	4.443 (2.216)^{a}	5.997 (2.549)^{a}	6.510 (2.645)^{def}	6.573 (2.660)^{ef}	7.277 (2.783)^{ab}	7.497 (2.827)^{d}
3	Profenofos 0.1%	4.413 (2.216)^{a}	5.350 (2.417)^{a}	6.253 (2.598)^{ef}	6.610 (2.662)ef	6.733 (2.680)^{ab}	6.954 (2.731)^{c}
4	Spinosad 0.014%	4.407 (2.206)^{a}	4.960 (2.328)^{a}	6.277 (2.603)^{ef}	6.378 (2.622)^{ef}	6.400 (2.627)^{b}	7.289 (2.785)^{d}
5	Deltafos 0.07%	4.731 (2.216)^{a}	6.147 (2.577)^{a}	6.767 (2.695)^{cde}	6.978 (2.734)^{de}	7.954 (2.906)^{ab}	8.132 (2.921)^{c}
6	NSKE 5% at fortnightly intervals	5.593 (2.467)^{a}	6.790 (2.700)^{a}	7.878 (2.890)^{bcd}	7.843 (2.888)^{cd}	8.130 (2.920)^{ab}	8.288 (2.959)^{c}
7	NSKE 5% at weekly intervals	4.487 (2.214)^{a}	6.563 (2.658)^{a}	7.610 (3.202)^{cde}	7.810 (2.882)^{cd}	8.020 (2.915)^{ab}	8.264 (2.959)^{c}
8	Citronella oil 2.5% at fortnightly intervals	5.713 (2.492)^{a}	7.473 (2.821)^{a}	7.878 (2.890)^{bcd}	8.020 (2.915)^{bcd}	8.520 (2.993)^{ab}	8.964 (2.993)^{b}
9	Citronella oil 2.5% at weekly intervals	5.610 (2.470)^{a}	7.064 (2.750)^{a}	7.683 (2.861)^{cde}	7.954 (2.906)^{cd}	8.455 (2.992)^{ab}	8.876 (2.959)^{b}
10	Woodash 500g at fortnightly intervals	5.800 (2.508)^{a}	7.110 (2.793)^{a}	7.999 (2.916)^{bc}	8.392 (2.986)^{bc}	9.044 (3.069)^{ab}	9.487 (3.159)^{a}
11	Woodash 500g at weekly intervals	5.762 (2.495)^{a}	7.540 (2.835)^{a}	7.997 (2.915)^{bc}	8.387 (2.980)^{bc}	8.864 (3.056)^{ab}	9.011 (3.079)^{a}
12	Control	7.064 (2.750)^{a}	7.278 (2.440)^{a}	7.979 (2.9110)^{a}	8.194 (2.943)^{a}	9.553 (3.168)^{a}	9.664 (3.186)^{a}

In a column, mean followed by common letter are not significantly different by DMRT ($P=0.05$)
Values on parenthesis are $\sqrt{x+0.5}$ transformed values
DAT - Days After Treatment

Table 15. Per cent reduction in the population of leafhopper at different treatments after the fourth spray

Sl. No.	Treatments	Per cent reduction					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	44.46	42.15	42.76	30.03	33.70	31.93
2	Fipronil 0.01%	36.85	17.60	18.4	19.78	23.82	22.42
3	Profenofos 0.1%	37.50	36.03	21.6	19.33	29.51	28.04
4	Spinosad 0.014%	37.6	31.84	21.33	22.16	33.00	24.5
5	Deltafos 0.07%	33.0	15.5	15.18	14.84	16.73	15.85
6	NSKE 5% at fortnightly intervals	20.82	6.70	1.26	4.28	14.8	14.23
7	NSKE 5% at weekly intervals	36.4	10.89	4.62	4.49	16.04	14.48
8	Citronella oil 2.5% at fortnightly intervals	19.12	-2.6	1.23	2.12	10.8	7.24
9	Citronella oil 2.5% at weekly intervals	23.6	2.9	3.70	2.92	11.5	8.15
10	Woodash 500 g at fortnightly intervals	17.89	2.3	-0.2	-2.4	5.328	1.83
11	Woodash 500 g at weekly intervals	18.43	-3.5	-0.22	-2.3	7.2	6.75

DAT - Days After Treatment

ethofenprox recorded significantly low population closely followed by profenofos, fipronil and spinosad were the next best treatments.

The percent reduction in leafhopper population was more in ethofenprox at all the intervals observed (Table 15). However the values were lower than first and second spray. At one DAT, ethofenprox resulted in a 44.46 per cent reduction in population, 42.15 per cent at three DAT and 42.76 per cent at five DAT. Among botanicals NSKE spray at weekly intervals caused 36.4 per cent reduction.

The mean leafhopper population per leaf and the per cent reduction of leafhopper over control after the first, second, third and fourth spray revealed that ethofenprox recorded the lowest leafhopper count and highest per cent reduction.

4.2.2 Efficacy of synthetic insecticides, botanicals and natural organics against epilachna population, *H. septima*

The infestation of epilachna beetle was mild in first and second spray, thereafter the incidence of epilachna beetle was nil.

4.2.2.1 First spray

The pre treatment and post treatment count on the population of epilachna beetle are presented in Table 16 and 18 and the per cent reduction in the population of epilachna beetle over control are presented in Table 17 and 19.

The pre treatment count showed that the leaf beetle population ranged from 0.800 to 1.967 in the different treatments at the different intervals. However, the observation taken at different intervals after the first spray showed that all the treatments recorded lower values from one DAT to 14 DAT and the chemical treatments recorded very low values compared to biopesticides. The treatments were statistically on par at all intervals, with the exception of profenofos, which recorded significantly lower population at one DAT and three DAT, compared to control.

Table 16. Population density of leaf beetle in different treatments after the first spray

Sl. No.	Treatments	Mean no of leaf beetle per leaf						
		PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	1.731 (2.507)^{a}	0.333 (0.907)^{ab}	0.277 (0.872)^{a}	0.221 (0.846)^{ab}	0.145 (0.801)^{a}	0.091 (0.769)^{a}	0.080 (0.762)^{a}
2	Fipronil 0.01%	1.369 (1.437)^{ab}	0.311 (0.900)^{ab}	0.265 (0.866)^{a}	0.253 (0.860)^{ab}	0.177 (0.818)^{a}	0.088 (0.765)^{a}	0.050 (0.742)^{a}
3	Profenofos 0.1%	1.525 (1.830)^{a}	0.221 (0.846)^{b}	0.212 (0.841)^{a}	0.167 (0.816)^{b}	0.100 (0.770)^{a}	0.070 (0.723)^{a}	0.045 (0.738)^{a}
4	Spinosad 0.014%	1.324 (1.253)^{ab}	0.260 (0.764)^{ab}	0.217 (0.845)^{a}	0.178 (0.817)^{ab}	0.111 (0.780)^{a}	0.078 (0.759)^{a}	0.047 (0.739)^{a}
5	Deltafos 0.07%	1.254 (1.114)^{ab}	0.266 (0.766)^{ab}	0.244 (0.837)^{a}	0.199 (0.828)^{ab}	0.134 (0.796)^{a}	0.089 (0.766)^{a}	0.088 (0.767)^{a}
6	NSKE 5% at fortnightly intervals	1.167 (1.29)^{ab}	0.500 (1.00)^{ab}	0.400 (0.928)^{a}	0.310 (0.881)^{ab}	0.280 (0.880)^{a}	0.190 (0.831)^{a}	0.140 (0.800)^{a}
7	NSKE 5% at weekly intervals	1.074 (1.125)^{ab}	0.630 (0.063)^{ab}	0.560 (1.020)^{a}	0.311 (0.881)^{ab}	0.290 (0.886)^{a}	0.180 (0.822)^{a}	0.130 (0.794)^{a}
8	Citronella oil 2.5% at fortnightly intervals	1.488 (1.603)^{a}	0.330 (0.911)^{ab}	0.311 (0.908)^{a}	0.244 (0.837)^{ab}	0.240 (0.853)^{a}	0.160 (0.812)^{a}	0.145 (0.801)^{a}
9	Citronella oil 2.5% at weekly intervals	1.365 (1.363)^{ab}	0.333 (0.911)^{ab}	0.326 (0.908)^{a}	0.265 (0.866)^{ab}	0.210 (0.839)^{a}	0.150 (0.808)^{a}	0.133 (0.796)^{a}
10	Woodash 500 g at fortnightly intervals	1.304 (1.363)^{ab}	0.463 (0.971)^{ab}	0.393 (0.944)^{a}	0.266 (0.866)^{ab}	0.220 (0.850)^{a}	0.160 (0.8120)^{a}	0.167 (0.816)^{a}
11	Woodash 500 g at weekly intervals	1.967 (1.653)^{a}	0.393 (0.944)^{ab}	0.330 (0.911)^{a}	0.260 (0.864)^{ab}	0.240 (0.862)^{a}	0.130 (0.794)^{a}	0.110 (0.775)^{a}
12	Control	0.800 (1.146)^{b}	0.660 (1.07)^{a}	0.410 (0.932)^{a}	0.330 (0.911)^{a}	0.290 (0.855)^{a}	0.199 (0.828)^{a}	0.178 (0.817)^{a}

In a column, mean followed by a common letter are not significantly by DMRT ($P=0.05$)
Values in parenthesis are $\sqrt{x+0.5}$ transformed values.
DAT - Days After Spraying

Table 17. Per cent reduction in the population of leaf beetle in different treatments compared to control after the first spray

Sl. No.	Treatments	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	49.54	32.43	33.03	50.00	54.27	55.05
2	Fipronil 0.01%	52.57	35.36	23.33	38.96	55.77	71.91
3	Profenofos 0.1%	66.51	48.29	49.39	65.55	64.82	94.71
4	Spinosad 0.014%	60.60	47.07	46.06	61.72	60.80	73.59
5	Deltafos 0.07%	9.69	40.48	39.69	53.79	55.27	50.56
6	NSKE 5% at fortnightly intervals	24.24	2.43	6.06	3.44	4.52	21.34
7	NSKE 5% at weekly intervals	4.54	-36.58	5.75	0.00	9.54	26.96
8	Citronella oil 2.5% at fortnightly intervals	50.00	24.14	26.06	17.24	19.59	19.41
9	Citronella oil 2.5% at weekly intervals	49.54	26.48	19.69	27.58	24.62	25.28
10	Woodash 500g at fortnightly intervals	29.84	4.14	19.39	24.13	19.59	6.17
11	Woodash 500g at weekly intervals	40.45	19.15	21.21	17.24	34.67	38.20

*DAS =Days After Treatment

Table 18. Population density of leaf beetle in different treatments after the second spray

Sl. No.	Treatments	Mean no. of leaf beetle per leaf					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	0.077 (0.758)[ab]	0.068 (0.753)[b]	0.044 (0.737)[a]	0.022 (0.722)[a]	0.020 (0.721)[a]	0.010 (0.712)[a]
2	Fipronil 0.01%	0.068 (0.753)[ab]	0.062 (0.747)[b]	0.040 (0.732)[a]	0.020 (0.721)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
3	Profenofos 0.1%	0.022 (0.722)[a]	0.020 (0.721)[b]	0.020 (0.721)[a]	0.017 (0.719)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
4	Spinosad 0.014%	0.045 (0.739)[ab]	0.044 (0.737)[b]	0.040 (0.732)[a]	0.022 (0.722)[a]	0.020 (0.721)[a]	0.000 (0.707)[a]
5	Deltafos 0.07%	0.053 (0.743)[ab]	0.042 (0.736)[b]	0.030 (0.728)[a]	0.020 (0.721)[a]	0.020 (0.721)[a]	0.000 (0.707)[a]
6	NSKE 5% at fortnightly intervals	0.145 (0.801)[ab]	0.089 (0.766)[b]	0.075 (0.757)[a]	0.068 (0.753)[a]	0.044 (0.737)[a]	0.022 (0.722)[a]
7	NSKE 5% at weekly intervals	0.134 (0.796)[ab]	0.077 (0.758)[b]	0.067 (0.752)[a]	0.053 (0.745)[a]	0.033 (0.730)[a]	0.020 (0.721)[a]
8	Citronella oil 2.5% at fortnightly intervals	0.089 (0.763)[ab]	0.066 (0.752)[b]	0.053 (0.745)[ab]	0.040 (0.737)[a]	0.022 (0.722)[a]	0.020 (0.721)[a]
9	Citronella oil 2.5% at weekly intervals	0.087 (0.762)[ab]	0.044 (0.739)[b]	0.030 (0.728)[a]	0.022 (0.722)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
10	Woodash 500 g at fortnightly intervals	0.068 (0.753)[ab]	0.045 (0.739)[b]	0.038 (0.731)[a]	0.033 (0.730)[a]	0.022 (0.722)[a]	0.000 (0.707)[a]
11	Woodash 500 g at weekly intervals	0.0.67 (0.750)[ab]	0.035 (0.730)[b]	0.044 (0.737)[a]	0.035 (0.730)[a]	0.017 (0.719)[a]	0.022 (0.722)[a]
12	Control	0.153 (0.799)[a]	0.089 (0.766)[a]	0.075 (0.757)[a]	0.045 (0.738)[a]	0.044 (0.737)[a]	0.033 (0.730)[a]

In a column, mean followed by a common letter are not significantly by DMRT (P=0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values.

DAT - Days After Treatment

Table 19. Per cent reduction in the population of leaf beetle in different treatments after the second spray

Sl. No.	Treatments	Mean no. of leaf beetle per leaf					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	49.60	23.50	34.66	51.11	54.54	69.69
2	Fipronil 0.01%	55.55	30.33	46.66	55.55	100.00	100.00
3	Profenofos 0.1%	85.62	77.50	73.33	62.22	100.00	100.00
4	Spinosad 0.014%	70.58	50.56	46.66	51.11	55.45	100.00
5	Deltafos 0.07%	65.35	52.80	60.00	55.55	55.45	100.00
6	NSKE 5% at fortnightly intervals	5.22	0.00	0.00	-18.66	0.00	33.33
7	NSKE 5% at weekly intervals	12.41	13.48	10.66	-17.77	25.00	39.39
8	Citronella oil 2.5% at fortnightly intervals	41.83	25.84	29.33	11.11	50.00	39.39
9	Citronella oil 2.5% at weekly intervals	43.13	50.56	60.00	51.11	100.00	100.00
10	Woodash 500 g at fortnightly intervals	55.55	49.43	49.33	26.66	54.54	100.00
11	Woodash 500 g at weekly intervals	56.20	60.67	34.66	22.22	61.36	33.33

In a column, mean followed by a common letter are not significantly by DMRT (P=0.05)
Values in parenthesis are $\sqrt{x+0.5}$ transformed values.
DAT - Days After Treatment

The per cent reduction in population was also the highest in profenofos closely followed by spinosad compared to other treatments from one DAT to 14 DAT. At one DAT, profenofos recorded a population reduction of 66.51 per cent, while at 14 DAT it was 94.71 per cent. Among botanicals citronella oil recorded higher per cent reduction of 50 per cent at one DAT. There after the per cent reduction was low and at 14 DAT, it was 25.28 per cent. Wood ash also caused reduction in leaf beetle population even though the values are comparatively low.

4.2.2.2 Second spray

During the second spray the epilachna population was negligible with the highest value of 0.153 recorded in control at one DAT. Per cent reduction was high in profenofos at different intervals (73.33 to 100). Wood ash dusting recorded comparatively high reduction in leaf beetle population.

4.2.3 Efficacy of test insecticides, botanicals and natural organics on the population of leaf miner, *L. trifolii*

The leaf miner population showed a decreased trend from first spray onwards.

4.2.3.1 First spray

The leaf miner, *L. trifolii* was observed only during the first spray. The population density of leafminer before treatment and after treatment are presented in Table 20 and the percentage reduction in population over control in different treatments at different intervals is presented in Table 21.

The pretreatment count showed that leaf miner population varied from 0.211 to 0.485 mines per leaf in different treatments. At one DAT, the mean population ranged from 0.022 mines per leaf to 0.332 mines per leaf (Table 20). The lowest value was recorded in deltafos and the highest value was recorded in control. Deltafos recorded the lowest with 0.022 mines per leaf on one DAT to 0.020mines per

Table 20. Population density of leafminer in different treatments after the first spray

Sl. No.	Treatments	Mean no. of mines per leaf						
		PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	0.410 (0.954)^{a}	0.044 (0.737)^{de}	0.134 (0.796)^{ab}	0.067 (0.750)^{a}	0.044 (0.737)^{abc}	0.044 (0.737)^{a}	0.089 (0.766)^{a}
2	Fipronil 0.01%	0.285 (0.886)^{b}	0.109 (0.780)^{bcd}	0.044 (0.737)^{ab}	0.022 (0.722)^{a}	0.020 (0.721)^{bc}	0.020 (0.721)^{a}	0.044 (0.736)^{a}
3	Profenofos 0.1%	0.353 (0.924)^{ab}	0.044 (0.737)^{de}	0.020 (0.721)^{b}	0.020 (0.721)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{a}	0.010 (0.714)^{a}
4	Spinosad 0.014%	0.377 (0.936)^{ab}	0.064 (0.750)^{cd}	0.064 (0.750)^{ab}	0.044 (0.737)^{a}	0.022 (0.722)^{bc}	0.022 (0.722)^{a}	0.020 (0.721)^{a}
5	Deltafos 0.07%	0.309 (0.899)^{ab}	0.022 (0.722)^{d}	0.020 (0.721)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
6	NSKE 5% at fortnightly intervals	0.423 (0.961)^{a}	0.089 (0.766)^{cd}	0.066 (0.752)^{ab}	0.066 (0.752)^{a}	0.044 (0.737)^{abc}	0.022 (0.722)^{a}	0.020 (0.721)^{a}
7	NSKE 5% at weekly intervals	0.485 (0.993)^{a}	0.066 (0.752)^{cd}	0.044 (0.737)^{ab}	0.040 (0.731)^{a}	0.042 (0.736)^{abc}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
8	Citronella oil 2.5% at fortnightly intervals	0.457 (0.978)^{a}	0.265 (0.874)^{ab}	0.151 (0.805)^{a}	0.132 (0.792)^{a}	0.132 (0.792)^{a}	0.087 (0.764)^{a}	0.089 (0.766)^{a}
9	Citronella oil 2.5% at weekly intervals	0.429 (0.963)^{a}	0.199 (0.833)^{abc}	0.153 (0.804)^{a}	0.111 (0.781)^{a}	0.067 (0.750)^{ab}	0.044 (0.737)^{a}	0.065 (0.751)^{a}
10	Woodash 500 g at fortnightly intervals	0.377 (0.936)^{ab}	0.111 (0.781)^{bcd}	0.110 (0.779)^{ab}	0.107 (0.776)^{a}	0.044 (0.737)^{abc}	0.042 (0.736)^{a}	0.042 (0.736)^{a}
11	Woodash 500 g at weekly intervals	0.282 (0.886)^{b}	0.200 (0.836)^{abc}	0.151 (0.805)^{a}	0.087 (0.764)^{a}	0.042 (0.736)^{abc}	0.020 (0.721)^{a}	0.010 (0.714)^{a}
12	Control	0.211 (0.842)^{b}	0.332 (0.908)^{a}	0.155 (0.809)^{a}	0.153 (0.804)^{a}	0.107 (0.776)^{ab}	0.087 (0.764)^{a}	0.067 (0.750)^{a}

In a column mean, followed by a common letter are not significantly by DMRT (P 0.05).
Values in parenthesis are $\sqrt{x+0.5}$ transformed values.
DAT - Days After Treatment
PTC - Pre Treatment Count

Table 21. Percentage reduction in the population of leaf miner at different treatments compared to control after the first spray

Sl. No.	Treatments	Per cent reduction					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1.	Ethofenfrox 0.02%	86.74	13.5	56.20	58.87	49.42	-32.83
2.	Fipronil 0.01%	67.16	71.6	85.62	81.30	77.01	34.32
3.	Profenofos 0.1%	86.74	87.09	86.92	100.0	100.0	85.07
4.	Spinosad 0.014%	80.72	58.70	71.24	79.43	74.71	70.14
5.	Deltafos 0.07%	93.37	87.09	100.0	100.0	100.0	100.0
6.	NSKE 5%at fortnightly intervals	73.19	57.41	56.86	58.87	74.71	70.14
7.	NSKE 5%at weekly intervals	80.12	71.6	73.85	60.74	100.0	100.0
8.	Citronella oil 2.5% at fortnightly intervals	20.18	2.58	13.72	-23.36	0.00	-32.83
9.	Citronella oil2.5% at weekly intervals	40.06	1.29	27.45	37.38	49.42	2.985
10.	Woodash 500 g at fortnightly intervals	66.56	29.03	30.06	58.87	51.72	37.31
11.	Woodash 500 g at weekly intervals	39.75	2.58	43.13	60.74	77.01	72.37

DAT - Days After Treatment

leaf at three DAT and zero values from five DAT onwards. All the chemical treatments and NSKE were found to be effective in controlling leaf miner infestation.

At one DAT, the highest per cent reduction (93.37) over control was recorded in deltafos (Table 21) while deltafos and profenofos recorded (87.09) highest reduction at three DAT. Cent per cent reduction of leaf miner over control was recorded in deltafos at five DAT and seven DAT. Among the botanicals NSKE recorded higher percent reduction of leaf miner infestation.

4.2.4 Efficacy of test insecticides, botanicals and natural organics on the population of pumpkin caterpillar, *D. indica*

The population of pumpkin caterpillar was low during the cropping period. The pre treatment count showed that the population ranged from 0.020 to 0.177 larvae per leaf in different treatments. Spinosad, citronella oil, NSKE, fipronil and deltafos recorded very low values at different intervals (Table 22).

The highest per cent reduction of pumpkin caterpillar over control was 92.12 and 91.33 respectively in spinosad and citronella oil spray at weekly intervals at one DAT (Table 23). Spinosad, deltafos, citronella oil and NSKE recorded cent per cent reduction from three DAT and fipronil from five DAT.

4.2.5 Efficacy of test insecticides, botanicals and natural organics on the population of gall fly, *N. falcata*

In the present investigation, the population of gall fly was negligible at the end of the first spray. The results of the pre and post treatment counts on the per cent infestation of gallfly are given in Table 24.

4.2.5.1 First Spray

The pre treatment count showed that the per cent gall fly infestation ranged from 2.71 to 19.83 in different treatments. Observations taken at different intervals

Table 22. Population density of pumpkin caterpillar in different treatments after the first spray

Treatments	Mean no. of larvae per leaf						
	PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
Ethofenprox 0.02%	0.088 (0.767)^{bc}	0.088 (0.767)^{bc}	0.044 (0.737)^{ab}	0.022 (0.722)^{ab}	0.020 (0.721)^{b}	0.017 (0.719)^{a}	0.022 (0.722)^{a}
Fipronil 0.01%	0.133 (0.793)^{ab}	0.066 (0.752)^{bc}	0.044 (0.736)^{ab}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)	0.000 (0.707)^{a}
Profenofos 0.1%	0.020 (0.721)^{c}	0.044 (0.737)^{bc}	0.042 (0.736)^{ab}	0.022 (0.722)^{ab}	0.017 (0.719)^{b}	0.013 (0.716)^{a}	0.022 (0.722)^{a}
Spinosad 0.014%	0.088 (0.767)^{bc}	0.020 (0.720)^{c}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}
Deltafos 0.07%	0.088 (0.767)^{bc}	0.044 (0.737)^{bc}	0.042 (0.736)^{b}	0.020 (0.721)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
NSKE 5% at fortnighty intervals	0.044 (0.737)^{bc}	0.087 (0.762)^{bc}	0.022 (0.722)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
NSKE 5% at weekly intervals	0.111 (0.781)^{ab}	0.066 (0.752)^{bc}	0.013 (0.716)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
Citronella oil 2.5% at fortnightly intervals	0.199 (0.831)^{a}	0.044 (0.736)^{bc}	0.020 (0.721)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
Citronella oil 2.5% at weekly intervals	0.089 (0.766)^{bc}	0.022 (0.722)^{c}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}	0.000 (0.707)^{a}
Woodash 500 g at fortnightly intervals	0.177 (0.818)^{ab}	0.132 (0.793)^{ab}	0.130 (0.789)^{ab}	0.044 (0.737)^{ab}	0.040 (0.735)^{b}	0.020 (0.721)^{a}	0.020 (0.721)^{a}
Woodash 500 g at weekly intervals	0.066 (0.752)^{bc}	0.111 (0.781)^{abc}	0.087 (0.762)^{b}	0.022 (0.722)^{ab}	0.018 (0.720)^{b}	0.013 (0.716)^{a}	0.000 (0.707)^{a}
Control	0.177 (0.819)^{ab}	0.254 (0.850)^{a}	0.218 (0.846)^{a}	0.089 (0.765)^{a}	0.042 (0.736)^{a}	0.038 (0.733)^{a}	0.044 (0.737)^{a}

In a column, mean followed by a common letter are not significantly by DMRT (P=0.05).
Values in parenthesis are √ x+ 0.5 transformed values.
DAT - Days After Treatment
PTC - Pre Treatment Count

Table 23. Per cent reduction in the population of pumpkin caterpillars in different treatments compared to control after the first spray

Sl. No.	Treatments	Per cent reduction over control					
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	65.35	79.81	75.28	52.38	55.26	50.00
2	Fipronil 0.01%	74.01	79. 81	100.00	100.00	100.00	100.00
3	Profenofos 0.1%	82.67	80.73	75.28	59.52	65.78	50.00
4	Spinosad 0.014%	92.12	100.00	100.00	100.00	100.00	100.00
5	Deltafos 0.07%	82.67	100.00	100.00	100.00	100.00	100.00
6	NSKE 5% at fortnightly intervals	65.74	89.90	100.00	100.00	100.00	100.00
7	NSKE 5% at weekly intervals	74.01	100.00	100.00	100.00	100.00	100.00
8	Citronella oil 2.5% at fortnightly intervals	82.67	100.00	100.00	100.00	100.00	100.00
9	Citronella oil 2.5% at weekly intervals	91.33	100.00	100.00	100.00	100.00	100.00
10	Woodash 500 g at fortnightly intervals	48.03	40.36	50.56	4.76	47.36	54.54
11	Woodash 500 g at weekly intervals	56.29	60.09	75.28	57.14	65.78	100.00

DAT - Days After Treatment

Table 24. Per cent infestation of gall fly in different treatments after the first spray

Sl. No.	Treatments	Per cent infestation						
		PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	4.11 (2.147)[a]	2.21 (1.643)[b]	2.23 (1.652)[b]	1.78 (1.509)[b]	1.33 (1.352)[a]	1.11 (1.268)[a]	1.41 (1.382)[a]
2	Fiproni 0.01%	4.62 (2.262)[a]	1.13 (1.276)[b]	1.00 (1.224))[b]	1.33 (1.352)[b]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
3	Profenofos 0.1%	6.27 (2.601)[a]	4.46 (2.227)[b]	3.27 (1.941)[b]	2.39 (1.71)[b]	3.33 (1.957)[a]	1.14 (1.280)[a]	1.12 (1.272)[a]
4	Spinosad 0.014%	3.52 (2.004)[a]	1.45 (1.396)[b]	1.40 (1.378))[b]	1.17 (1.292)[b]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
5	Deltafos 0.07%	3.76 (2.063)[a]	1.29 (1.337)[b]	1.21 (1.303)[b]	1.110 (1.264)[b]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
6	NSKE 5%at fortnightly intervals	19.83 (4.508)[a]	6.18 (2.584)[b]	3.27 (1.941)[b]	3.33 (1.957)[b]	1.22 (1.311)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
7	NSKE 5% at weekly intervals	3.26 (1.93)[a]	1.29 (1.330)[b]	0.000 (0.707)[b]	0.000 (0.707)[b]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]
8	Citronella oil 2.5% at fortnightly intervals	2.71 (1.79)[a]	2.24 (1.655)[b]	1.44 (1.392)[b]	1.28 (1.334)[b]	1.2 (1.303)[a]	1.13 (1.276)[a]	1.12 (1.272)[a]
9	Citronella oil 2.5% at weekly intervals	7.53 (2.833)[a]	4.76 (2.293)[b]	3.17 (1.915)[b]	1.87 (1.539)[b]	1.4 (1.378)[a]	0.000 (0.707)[a]	1.12 (1.272)[a]
10	Woodash 500 g at fortnightly intervals	9.57 (3.173)[a]	5.01 (2.347)[b]	3.46 (1.989)[b]	3.33 (1.957)[ab]	2.41 (1.705)[a]	2.3 (1.673)[a]	1.17 (1.292)[a]
11	Woodash 500 g at weekly intervals	4.78 (2.297)[a]	3.27 (1.941)[b]	2.48 (1.726)[b]	1.33 (1.352)[a]	1.23 (1.315)[a]	5.01 (2.347)[a]	3.4 (1.974)[a]
12	Control	3.12 (1.902)[a]	9.56 (3.171)[a]	6.17 (2.582)[a]	3.46 (1.989)[ab]	3.32 (1.954)[a]	2.41 (1.705)[a]	2.21 (1.646)[a]

In a column, mean followed by a common letter are not significantly different by DMRT (P=0.05)

Values in parenthesis are √ x+ 0.5 transformed values.

DAT - Days After Treatment

PTC - Pre Treatment Count

Table 25. Population density of aphids in different treatments after the fourth spray

Sl. No.	Treatments	Mean no. of nymphs per leaf					
		1DAT	3DAT	5DAT	7DAT	10DAT	14DAT
1	Ethofenprox 0.02%	0.000 (0.707)^{a}	0.010 (0.712)^{a}	0.020 (0.720)^{a}	0.06 (0.747)^{a}	0.06 (0.747)^{a}	0.09 (0.764)^{b}
2	Fipronil 0.01%	0.010 (0.712)^{a}	0.020 (0.720)^{a}	0.010 (0.712)^{a}	0.03 (0.728)^{a}	0.05 (0.742)^{a}	0.07 (0.757)^{b}
3	Profenofos 0.1%	0.000 (0.707)^{a}	0.010 (0.712)^{a}	0.021 (0.722)^{a}	0.05 (0.742)^{a}	0.13 (0.794)^{a}	0.39 (0.943)^{ab}
4	Spinosad 0.014%	0.020 (0.721)^{a}	0.020 (0.721)^{a}	0.03 (0.728)^{a}	0.11 (0.781)^{a}	0.21 (0.839)^{a}	0.48 (0.990)^{ab}
5	Deltafos 0.07%	0.000 (0.707)^{a}	0.010 (0.720)^{a}	0.04 (0.733)^{a}	0.06 (0.747)^{a}	0.09 (0.767)^{a}	0.13 (0.794)^{b}
6	NSKE 5% at fortnightly intervals	0.013 (0.794)^{a}	0.03 (0.728)^{a}	0.04 (0.733)^{a}	0.15 (0.805)^{a}	0.26 (0.871)^{a}	0.37 (0.933)^{ab}
7	NSKE 5% at weekly intervals	0.015 (0.805)^{a}	0.04 (0.733)^{a}	0.05 (0.742)^{a}	0.082 (0.762)^{a}	0.06 (0.747)^{a}	0.15 (0.805)^{ab}
8	Citronella oil 2.5% at fortnightly intervals	0.000 (0.707)^{a}	0.010 (0.720)^{a}	0.03 (0.728)^{a}	0.21 (0.840)^{a}	0.50 (0.997)^{a}	0.78 (1.128)^{ab}
9	Citronella oil 2.5% at weekly intervals	0.014 (0.800)^{a}	0.04 (0.733)^{a}	0.06 (0.747)^{a}	0.08 (0.762)^{a}	0.020 (0.836)^{a}	0.62 (1.056)^{ab}
10	Woodash 500g at fortnightly intervals	0.000 (0.707)^{a}	0.010 (0.712)^{a}	0.05 (0.742)^{a}	0.06 (0.747)^{a}	0.06 (0.747)^{a}	0.09 (0.764)^{b}
11	Woodash 500g at weekly intervals	0.000 (0.707)^{a}	0.000 (0.707)^{a}	0.010 (0.712)^{a}	0.020 (0.720)^{a}	0.010 (0.712)^{a}	0.06 (0.733)[illegible]
12	Control	0.021 (0.722)^{a}	0.020 (0.721)^{a}	0.06 (0.747)^{a}	0.09 (0.767)a	1.01 (1.227)^{a}	1.31 (1.340)^{a}

In a column, mean followed by a common letter are not significantly different by DMRT (P=0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values.

DAT - Days After Treatment

showed that none of the treatments differed significantly. NSKE spraying at weekly intervals, fipronil, deltafos and spinosad recorded lower values at all intervals tested.

4.2.6 Efficacy of test insecticides, botanicals and natural organics against the aphid population, *A. gossypii*

In the present investigation, the population was negligible upto third spray and mild infestation was noted during the fourth spray.

4.2.6.1 Fourth spray

The observation taken at different intervals showed that all the treatments recorded low values. All the treatments were statistically on par Table 25.

4.2.7 Efficacy of synthetic insecticides, botanicals and natural organics against white fly population, *B. tabaci*

In the present investigation, the population of white fly was negligible in all the treatments during all the four sprays.

4.2.8 Efficacy of test insecticides, botanicals and natural organics on fruit fly, *B. cucurbitae*

The data on the per cent of fruit fly infestation in bitter gourd both in terms of weight and number are presented in Table 26.

4.2.8.1 First harvest

In the first harvest at four DAT, the per cent infestation ranged from 47.78 in woodash at fortnightly intervals to 12.69 in control. Among the chemical treatments, profenofos and ethofenprox recorded higher values, (40.86 and 40.00 respectively) while deltafos had the lowest per cent infestation (23.64). All treatments were statistically on par.

On fruit weight basis, NSKE at weekly intervals (14.45), woodash at weekly intervals (11.25) and deltafos (12.97) were found significantly superior to woodash application at fortnightly intervals but were on par with other treatments.

Table 26. Per cent infestation by fruit fly in different treatments during different harvests

Sl. No.	Treatments	Per cent infestation									
		First harvest (4 DAT)		Second harvest (14 DAT)		Third harvest (13 DAT)		Fourth harvest (14 DAT)		Total	
		Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)
1	Ethofenprox 0.02%	40.00 (6.339)[ab]	22.31 (4.588)[ab]	20.50 (4.495)[cd]	13.43 (3.531)[a]	33.63 (5.798)[a]	12.75 (3.620)[abc]	28.37 (5.351)[ab]	30.10 (5.492)[a]	28.72 (5.386)[a]	15.907 (4.033)[a]
2	Fipronil 0.01%	24.89 (4.518)[ab]	24.63 (4.838)[ab]	35.17 (5.972)[a]	11.48 (3.282)[a]	28.33 (5.314)[a]	20.85 (4.580)[ab]	16.34 (4.046)[cd]	20.69 (4.601)[ab]	28.837 (5.408)[a]	16.477 (4.115)[a]
3	Profenofos 0.1%	40.86 (60.301)[ab]	28.25 (5.121)[ab]	21.91 (4.705)[cd]	13.21 (3.628)[a]	38.05 (6.172)[a]	19.44 (3.330)[abc]	21.81 (4.526)[bc]	18.82 (4.255)[ab]	26.48 (5.177)[a]	16.073 (4.062)[a]
4	Spinosad 0.014%	31.20 (5.179)[ab]	16.94 (4.069)[ab]	22.29 (4.642)[cd]	11.30 (3.431)[a]	31.47 (5.570)[a]	20.85 (4.595)[abc]	20.88 (4.620)[abc]	18.33 (4.262)[ab]	25.660 (15.082)[a]	15.547 (3.996)[a]
5	Deltafos 0.07%	23.64 (4.913)[ab]	12.97 (3.653)[ab]	19.07 (4.266)[cd]	6.43 (2.574)[a]	28.91 (4.813)[a]	26.31 (5.084)[a]	23.71 (4.674)[abc]	14.33 (3.691)[ab]	20.693 (4.584)[a]	12.943 (33.659)[a]
6	NSKE 5% at fortnightly intervals	35.66 (5.943)[ab]	22.46 (4.701)[ab]	24.95 (5.027)[bcd]	12.46 (3.569)[a]	27.22 (5.191)[a]	14.26 (3.824)[abc]	28.12 (5.262)[ab]	23.62 (4.896)[ab]	28.380 (5.365)[a]	16.340 (4.092)[a]
7	NSKE 5% at weekly intervals	28.97 (5.290)[ab]	14.45 (3.544)[b]	16.64 (4.128)[d]	9.183 (3.091)[a]	25.49 (5.016)[a]	11.05 (8.821)[abc]	15.65 (3.925)[cd]	15.37 (3.923)[ab]	21.413 (4.646)[a]	12.067 (3.531)[a]
8	Citronella oil 2.5% at fortnightly intervals	17.73 (4.266)[ab]	16.90 (4.166)[ab]	22.92 (4.829)[cd]	14.78 (3.903)[a]	18.60 (3.781)[a]	5.47 (2.063)[c]	14.64 (3.388)[cd]	20.58 (8.816)[ab]	25.283 (5.075)[a]	19.837 (4.467)[a]
9	Citronella oil 2.5% at weekly intervals	30.56 (5.569)[ab]	17.67 (4.250)[ab]	17.87 (4.271)[cd]	7.08 (2.750)[a]	16.60 (3.596)[a]	11.93 (3.083)[abc]	13.23 (3.661)[d]	18.55 (4.354)[ab]	22.907 (4.834)[a]	15.240 (3.949)[a]
10	Woodash 500 g at fortnightly intervals	47.78 (6.869)[a]	45.26 (6.491)[a]	35.61 (5.856)[ab]	10.29 (3.267)[a]	30.610 (5.548)[a]	17.97 (4.248)[abc]	15.87 (3.414)[cd]	9.83 (2.838)[b]	34.753 (5.863)[a]	13.053 (3.632)[a]
11	Woodash 500 g at weekly intervals	18.03 (4.262)[ab]	11.23 (3.407)[b]	21.77 (15.218)[abc]	11.72 (3.450)[a]	30.67 (4.729)[a]	7.367 (2.474)[bc]	25.03 (4.850)[ab]	33.37 (5.668)[a]	30.693 (5.542)[a]	14.713 (3.877)[a]
12	Control	12.69 (3.399)[a]	11.167 (3.269)[b]	19.510 (4.460)[dc]	7.273 (2.767)[a]	25.23 (4.836)[a]	25.93 (5.135)[a]	23.32 (4.854)[ab]	18.02 (4.269)[ab]	24.950 (5.038)[a]	13.357 (3.722)[a]

In a column, mean followed by a common letter are not significantly by DMRT (P=0.05)
Values in parenthesis are $\sqrt{x+0.5}$ transformed values

4.2.8.2 Second harvest

During the second harvest, which was on 14 DAT, spraying of NSKE at weekly intervals recorded the lowest per cent by fruit number and was significantly superior to fipronil and woodash (35.17 and 35.61, respectively). With respect to weight of fruits, the treatments did not vary significantly. The lowest per cent was recorded by deltafos (6.43).

4.2.8.3 Third harvest

During third harvest (13 DAT) even though the treatments were on par, the lowest per cent by number was in citronella oil at weekly intervals (16.6). With respect to fruit weight, citronella oil at fortnightly intervals and woodash at weekly intervals were significantly superior to deltafos and fipronil.

4.2.8.4 Fourth harvest

Both treatments of citronella oil and NSKE spray at weekly intervals showed reduction in per cent infestation by number in the fourth harvest (14 DAT). NSKE at weekly intervals and woodash at fortnightly intervals gave better performance with respect to per cent infestation by weight (15.37 and 9.83 respectively).

4.2.9 Efficacy of test insecticides, botanicals and natural organics on fruit borers, *H. amigera and D. indica*

The data on the per cent infestation by fruit borers during different harvests are presented in Table 27.

4.2.9.1 First harvest

In the first harvest (4 DAT) the per cent infestation by number ranged from 1.833 to 17.50 in different treatments and ethofenprox and woodash applied at fortnightly intervals recorded lower infestation (1.83 and 2.20, respectively). With respect to weight of fruits, it ranged from 6.67 to 19.68 and spinosad recorded the lowest infestation. The treatments did not differ significantly.

Table 27. Per cent infestation by fruit borer in different treatments during different harvests

Sl. No.	Treatments	Per cent infestation									
		First harvest (4 DAT)		Second harvest (14 DAT)		Third harvest (13 DAT)		Fourth harvest (14 DAT)		Total	
		Fruit No.	Fruit wt. (kg.).	Fruit No.	Fruit wt. (kg.).	Fruit No.	Fruit wt. (kg.).	Fruit No.	Fruit wt. (kg.).	Fruit No.	Fruit wt. (kg.).
1	Ethofenprox 0.02%	1.833 (1.288)^{a}	18.20 (3.623)^{a}	4.22 (3.013)^{ab}	8.80 (3.025)^{ab}	3.68 (1.977)^{a}	6.320 (2.554)^{a}	4.33 (1.989)^{ab}	8.587 (2.667)^{ab}	6.617 (2.647)^{a}	8.493 (2.930)^{a}
2	Fipronil 0.01%	4.33 (1.696)^{a}	8.673 (2.647)^{a}	16.89 (3.926)^{a}	13.99 (3.691)^{a}	2.22 (1.540)^{a}	4.197 (1.973)^{a}	0.767 (1.029)^{bc}	1.233 (1.555)^{b}	11.60 (3.372)^{a}	8.333 (2.948)^{a}
3	Profenofos 0.1%	13.11 (3.590)^{a}	11.37 (3.394)^{a}	10.58 (3.309)^{ab}	13.64 (3.705)^{a}	3.83 (1.626)^{a}	2.76 (1.460)^{a}	3.647 (1.793)^{abc}	2.593 (1.632)^{b}	7.150 (2.750)^{a}	10.017 (3.222)^{a}
4	Spinosad 0.014%	7.00 (2.017)^{a}	6.67 (1.981)^{a}	2.69 (1.447)^{b}	2.63 (1.437)^{d}	0.95 (1.082)^{a}	1.70 (1.113)^{a}	3.470 (1.821)^{abc}	6.513 (2.372)^{b}	4.723 (2.223)^{a}	5.356 (2.367)^{a}
5	Deltafos 0.07%	11.17 (3.240)^{a}	10.77 (2.919)^{a}	4.933 (1.23)^{b}	5.05 (2.296)^{bc}	4.22 (1.960)^{a}	4.14 (1.967)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	3.580 (2.003)^{a}	4.704 (2.182)^{a}
6	NSKE 5% at fortnightly intervals	11.05 (2.847)^{a}	11.75 (3.051)^{a}	6.98 (1.23)^{ab}	6.17 (2.316)^{bc}	2.86 (1.806)^{a}	5.713 (2.49)^{a}	2.267 (1.537)^{abc}	4.140 (1.960)^{b}	4.847 (2.211)^{a}	5.495 (2.298)^{a}
7	NSKE 5% at weekly intervals	6.69 (2.393)^{a}	20.85 (3.698)^{a}	6.267 (2.508)^{ab}	9.31 (3.024)^{ab}	2.16 (1.495)^{a}	3.33 (1.799)^{a}	1.957 (1.464)^{abc}	3.120 (1.745)^{b}	3.601 (1.990)^{a}	5.618 (2.417)^{a}
8	Citronella oil 2.5%at fortnightly intervals	6.80 (1.995)^{a}	13.75 (2.625)^{a}	2.910 (1.844)^{b}	8.69 (2.815)^{b}	0.667 (0.998)^{a}	1.64 (1.248)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	3.133 (1.845)^{a}	8.219 (2.825)^{a}
9	Citronella oil 2.5%at weekly intervals	9.96 (3.212)^{a}	19.68 (4.243)^{a}	5.890 (2.467)^{ab}	6.13 (2.341)^{bc}	1.733 (1.390)^{a}	3.88 91.899)^{a}	12.50 (3.351)^{a}	9.397 (3.139)^{a}	7.603 (2.795)^{a}	6.803 (2.655)^{a}
10	Woodash 500g at fortnightly intervals	2.20 (1.435)^{a}	16.12 (3.438)^{a}	3.767 (1.857)^{b}	4.46 (2.020)^{cd}	0.833 (1.049)^{a}	1.35 (1.184)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	4.206 (2.094)^{a}	6.704 (2.602)^{a}
11	Woodash 500g at weekly intervals	6.88 (2.371)^{a}	8.687 (2679)^{a}	3.867 (1.880)^{b}	1.80 (1.428)^{d}	6.667 (1.981)^{a}	2.433 (1.402)^{a}	1.587 (1.236)^{bc}	2.533 (1.424)^{b}	5.764 (2.478)^{a}	7.612 (2.834)^{a}
12	Control	17.50 (4.123)^{a}	13.06 (3.680)^{a}	10.00 (3.157)^{ab}	5.46 (2.424)^{bc}	8.827 (1.988)^{a}	6.007 92.550)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	7.444 (2.800)^{a}	8.890 (3.055)^{a}

In a column, mean followed by a common letter are not significantly by DMRT (P=0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values

4.2.9.2 Second harvest

During the second harvest (14 DAT) spinosad (2.69), citronella oil a fortnightly intervals (2.910) woodash dusting at fortnightly intervals (3.767) and deltafos (4.933) were found to be significantly superior over fipronil (16.89) based on number. On weight basis also, application of woodash at weekly intervals and spinosad were significantly superior to all other treatments with low per cent infestation (2.63 and 2.69 respectively). Here also fipronil recorded the highest infestation.

4.2.9.3 Third harvest

During the third harvest (13 DAT) the treatments were found to be on par with respect to infestation by number and weight. The lowest per cent by number was recorded in citronella oil at fortnightly intervals (0.667), woodash at fortnightly intervals (0.833) and spinosad (0.95). With respect to fruit weight also, application of wood ash at fortnightly intervals, citronella oil at fortnightly intervals and spinosad recorded comparatively lower infestation.

4.2.9.4 Fourth harvest

During the fourth harvest (14 DAT) infestation was nil in citronella oil and woodash application at fortnightly intervals, deltafos and control.

In general, analysis of the data on borer infestation during the four harvests revealed that among chemical treatments, spinosad and among botanical treatments, citronella oil and woodash were effective in controlling fruit borer infestation.

4.2.10 Total Yield

The total yield obtained in different treatments is presented in Table 28. The fruit number varied from 101.33 in NSKE at weekly intervals to 82 in woodash at

Table 28. Total yield, marketable yield and per cent marketable yield in different treatments from 17.06 m^2

Sl. No.	Treatments	Total yield		Marketable yield		Per cent marketable yield	
		Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)	Fruit No.	Fruit weight (kg)
1	Ethofenprox 0.02%	130.66	8.29	85.66	6.42	64.60	70.37
2	Fipronil 0.01%	138.33	8.23	87.66	6.24	62.86	78.03
3	Profenofos 0.1%	141.33	10.03	91.00	7.34	65.36	74.31
4	Spinosad 0.014%	122.66	8.26	85.00	6.55	70.17	83.21
5	Deltafos 0.07%	156.33	12.69	118.33	10.38	75.69	78.30
6	NSKE 5% at fortnightly intervals	168.00	10.59	112.33	8.33	66.75	81.35
7	NSKE 5% at weekly intervals	181.33	7.39	133.33	9.39	74.95	81.86
8	Citronella oil 2.5% at fortnightly intervals	141.33	8.65	103.00	6.29	67.84	75.61
9	Citronella oil 2.5% at weekly intervals	171.00	11.57	122.00	9.66	71.11	83.49
10	Woodash 500 g at fortnightly intervals	82.00	4.96	54.33	3.25	60.99	56.49
11	Woodash 500 g at weekly intervals	129.33	9.06	83.66	7.00	63.50	75.81
12	Control	147.33	10.95	99.33	8.29	67.58	76.57
	CD (0.05)	NS	NS	NS	NS	NS	NS

Table 29. Economics of insecticides, botanicals and natural organics

Treatments	Mean yield of healthy fruit (kg/ha)	Increased yield over control (kg/ha)	Percentage of increased yield over control	Value of increased yield over control Rs.8/kg	Cost of plant protection	Net profit Rs.	Benefit cost ratio
Ethofenprox 0.02%	4654	364	8.48	2912	12,405.76	-9494	-0.76 : 1
Fipronil 0.01%	4577	287	6.68	2296	13,141	-10,845	-0.82 : 1
Profenofos 0.1%	4302	12	0.27	96	10,975	-10,879	-0.99 : 1
Spinosad 0.014%	4191	-99	-2.3	-792	16,910	-17,702	-1.04 : 1
Deltafos 0.07%	7286	2996	69.83	23,968	11,785	12,183	1.03 : 1
NSKE 5%at fortnightly intervals	4884	594	13.84	4752	10,428	-5676	-0.54 : 1
NSKE 5% at weekly intervals	5504	1214	28.29	9712	20,856	-11,144	-0.53 : 1
Citronella oil 2.5% at fortnightly intervals	5052	762	17.76	60.96	33,702	-27,606	-0.81 : 1
Citronella oil 2.5% at weekly intervals	5656	1366	31.84	10,928	67,404	-56,476	-0.83 : 1
Wood ash 2.5% at fortnightly intervals	2790	-1500	-34.96	-12,000	8,789	-20,789	-2.3 : 1
Wood ash 2.5% at weekly intervals	4085	-205	-4.77	-1640	17,578	-15,938	-0.90 : 1
Control	4290	-	-	-	-	-	-

fortnightly intervals. There was no significant difference among the treatments. The data showed that deltafos recorded the highest yield of 12.69 kg. per plot followed by citronella oil spraying at weekly intervals which recorded 11.57 kg. per plot. Control recorded 10.95 kg. per plot. Lowest yield was recorded in woodash at fortnightly intervals 4.90 kg. per plot.

4.2.10.1 Marketable yield

The marketable yield obtained in different treatments is presented in Table 28. NSKE spray at weekly intervals recorded the maximum number of fruits (133.33) and deltafos recorded highest marketable yield of 10.38 kg. per plot .

4.2.10.2 Per cent marketable yield

The marketable yield obtained in different treatments is presented in Table 28. Citronella oil spray at weekly intervals recorded the highest per cent marketable yield by weight 83.49 per cent closely followed by spinosad (83.21). The treatments did not vary significantly with respect to per cent marketable yield by number and weight.

4.2.10.3 Benefit Cost Ratio.

The Benefit Cost Ratio showed that deltafos alone gave a BCR of above one (1.03:1) (Table 29).

4.2.11 Parasites

Occurrence of braconid parasitoids on *D. indica* was found only during pre treatment observation and after the first spray (Table 30). The incidence of parasitoids was very much negligible in the subsequent sprays.

At one DAT, the parasitism on *D. indica* was observed in citronella oil spray at fortnightly intervals and woodash dust at fortnightly intervals. Citronella oil spray at fortnightly intervals recorded 50 per cent braconid parasitism on *D. indica* followed by woodash dust at fortnightly intervals. At three DAT, parasitism on

Table 30. Per cent parasitism on the larvae of *Diaphania indica*

Sl. No.	Treatments	Per cent parasitism at different intervals						
		PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT
1	Ethofenprox 0.02%	25	0	0	0	0	0	0
2	Fipronil 0.01%	0	0	0	0	0	0	0
3	Profenofos0.1%	0	0	0	0	0	0	0
4	Spinosad 0.01%	0	0	0	0	0	0	0
5	Deltafos 0.07%	55	0	0	0	0	0	0
6	NSKE 5% at fortnightly intervals	0	0	0	0	0	0	0
7	NSKE 5% at weekly intervals	49.62	0	0	0	0	0	0
8	Citronella oil 2.5% at fortnightly intervals	0	50	0	0	0	0	0
9	Citronella oil 2.5% at weekly intervals	49.81	0	0	0	0	0	0
10	Woodash 500 g at fortnightly intervals	0	16.92	0	0	55	0	0
11	Woodash 500 g at weekly intervals	0	0	0	100	0	0	0
12	Control	0	0	22	0	0	0	45.12

DAT - Days After Treatment
PTC - Pre Treatment Count

Table 31. Population density of spiders in different treatments after the first spray

Treatments	Mean no. of spiders per leaf						
	PTC	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14DAT
Ethofenprox 0.02%	0.098 (0.773)^{a}	0.089 (0.767)^{b}	0.022 (0.721)^{a}	0.000 (0.707)^{c}	0.022 (0.722)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}
Fipronil 0.01%	0.053 (0.743)^{a}	0.000 (0.707)^{c}	0.044 (0.737)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	0.000 (0.707)
Profenofos 0.1%	0.244 (0.855)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{a}	0.000 (0.707)^{c}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	0.000 (0.707)^{a}
Spinosad 0.014%	0.177 (0.821)^{a}	0.064 (0.750)^{b}	0.044 (0.737)^{a}	0.020 (0.721)^{bc}	0.000 (0.707)^{c}	0.000 (0.707)^{b}	0.000 (0.707)^{a}
Deltafos0.07%	0.066 (0.751)^{a}	0.000 (0.707)^{c}	0.022 (0.721)^{a}	0.000 (0.707)^{c}	0.020 (0.721)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}
NSKE 5% at fortnightly intervals	0.111 (0.781)^{a}	0.066 (0.750)^{b}	0.042 (0.736)^{a}	0.020 (0.721)^{bc}	0.022 (0.722)^{b}	0.022 (0.722)^{b}	0.022 (0.722)^{a}
NSKE 5%at weekly intervals	0.352 (0.913)^{a}	0.064 (0.750)^{b}	0.089 (0.767)^{a}	0.042 (0.736)^{b}	0.022 (0.722)^{b}	0.000 (0.707)^{b}	0.000 (0.707)^{a}
Citronella oil 2.5% at fortnightly intervals	0.111 (0.781)^{a}	0.133 (0.793)^{b}	0.109 (0.777)^{a}	0.088 (0.766)^{b}	0.042 (0.736)^{ab}	0.020 (0.721)^{b}	0.020 (0.721)^{a}
Citronella oil at weekly intervals	0.044 (0.737)^{a}	0.177 (0.822)^{b}	0.133 (0.793)^{a}	0.066 (0.753)^{b}	0.040 (0.736)^{ab}	0.020 (0.721)^{b}	0.000 (0.707)^{a}
Woodash 500 g at fortnightly intervals	0.144 (0.801)^{a}	0.111 (0.781)^{b}	0.109 (0.777)^{a}	0.044 (0.737)^{b}	0.020 (0.721)^{b}	0.020 (0.721)^{b}	0.000 (0.707)^{a}
Wood ash 500g at weekly intervals	0.177 (0.821)^{a}	0.084 (0.767)^{b}	0.155 (0.808)^{a}	0.089 (0.767)^{b}	0.062 (0.750)^{a}	0.040 (0.735)^{b}	0.020 (0.721)^{a}
Control	0.199 (0.833)^{a}	0.376 (0.934)^{b}	0.244 (0.855)^{a}	0.177 (0.793)^{a}	0.064 (0.751)^{a}	0.062 (0.750)^{a}	0.044 (0.737)^{a}

In a column, mean followed by common letter are not significantly different by DMRT P=(0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values

DAT=Days After Treatment

Table 32. Population density of coccinellids in different treatments after the fourth spray

Treatments	Mean no. of coccinellids per leaf					
	1DAT	3DAT	5DAT	7DAT	10DAT	14DAT
Ethofenprox 0.02%	0.044 (0.737)[a]	0.020 (0.721)[a]	0.133 (0.831)[a]	0.199 (0.856)[b]	0.111 (0.776)[b]	0.133 (0.831)[b]
Fipronil 0.01%	0.000 (0.707)[a]	0.000 (0.707)[a]	0.020 (0.721)[a]	0.044 (0.737)[b]	0.044 (0.737)[b]	0.000 (0.707)[c]
Profenofos 0.1%	0.000 (0.707)[a]	0.044 (0.737)[a]	0.111 (0.776)[a]	0.133 (0.831)[b]	0.109 (0.764)[b]	0.111 (0.776)[b]
Spinosad 0.014%	0.044 (0.737)[a]	0.109 (0.764)[a]	0.133 (0.831)[a]	0.199 (0.856)[b]	0.243 (0.888)[b]	0.133 (0.831)[b]
Deltafos 0.07%	0.000 (0.707)[a]	0.020 (0.721)[a]	0.000 (0.707)[a]	0.020 (0.721)[b]	0.044 (0.736)[b]	0.044 (0.737)[b]
NSKE 5% at fortnightly intervals	0.020 (0.721)a	0.109 (0.764)[a]	0.084 (0.763)[a]	0.111 (0.776)[b]	0.311 (0.940)[b]	0.321 (0.946)[b]
NSKE 5%at weekly intervals	0.020 (0.721)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.020 (0.721)[b]	0.111 (0.776)[b]	0.110 (0.775)[b]
Citronella oil 2.5%at Fortnightly intervals	0.000 (0.707)[a]	0.044 (0.737)[a]	0.000 (0.707)[a]	0.000 (0.707)[b]	0.020 (0.721)[b]	0.089 (0.763)[b]
Citronella oil 2.5% at weekly intervals	0.044 (0.737)[a]	0.177 (0.777)[a]	0.199 (0.856)[a]	0.243 (0.888)[b]	0.243 (0.888)[b]	0.398 (0.948)[b]
Woodash 500 g at fortnightly intervals	0.064 (0.750)[a]	0.044 (0.737)[a]	0.020 (0.721)[a]	0.044 (0.737)[b]	0.089 (0.763)[b]	0.044 (0.737)[b]
Woodash 500 g at weekly intervals	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[a]	0.000 (0.707)[b]	0.020 (0.721)[b]	0.042 (0.736)[b]
Control	0.321 (0.946)[a]	0.398 (0.948)[a]	0.500 (1.026)[a]	0.553 (1.051)[a]	0.500 (1.026)[a]	0.607 (1.074)[a]

In a column, mean followed by common letter are not significantly different by DMRT P=(0.05)

Values in parenthesis are $\sqrt{x+0.5}$ transformed values

DAT = Days After Treatment

D. indica was found only in control. woodash at weekly dusting intervals recorded cent percent parasitism on *D. indica* at five DAT. At seven DAT parasitism on *D. indica* was recorded only in woodash at fortnightly interval dusting (55 per cent). At 10 and 14 DAT there was no parasitism except in control.

4.2.11.1 Predators

4.2.11.1.1 Spiders

The pretreatment count (PTC) before the first spray showed a mean spider count ranging from 0.044 to 0.352 per leaf (Table 31). The spider population decreased after the first spray. All the botanicals and natural organics recorded the presence of spiders while the chemicals were harmful to spider predators. Among chemicals, very low population of spiders was supported by spinosad upto five DAT.

4.2.11.1.2 Coccinellids

4.2.11.1.2.1 Fourth spray

The occurrence of coccinellids in different treatments after the fourth spray is presented in Table 32. Among the chemical treatments spinosad, ethofenprox and profenofos recorded comparatively higher coccinellid population while Citronella oil spray at weekly intervals and NSKE at fortnightly intervals recorded higher coccinellid population. Control recorded the highest coccinellid population. Fipronil and deltafos recorded low coccinellid population.

Discussion

5. DISCUSSION

Bittergourd is cultivated extensively in Kerala throughout the year. Large quantities of conventional pesticides are being used by farmers in controlling the pest complex of bittergourd. This leads to the accumulation of toxic residues in the fruits. New insecticide molecules with newer modes of action and which are required in small doses are to be included for pest management in bittergourd. Hence in an attempt to formulate an IPM package for bittergourd, five newer generation insecticides, few botanicals and one natural organic (woodash) was evaluated under laboratory and field conditions in the present investigation. The variety "Preethi" released by Kerala Agricultural University, having medium long and white fruits was used for the study. The detailed discussion on the results is presented under the following headings.

a) Laboratory evaluation on efficacy of synthetic insecticides, botanicals and natural organics against *H. septima, C. sexmaculata* and *A. cerana indica*.

b) Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against the key pests of bittergourd.

5.1 LABORATORY EVALUATION ON EFFICACY OF SYNTHETIC INSECTICIDES, BOTANICALS AND NATURAL ORGANIC AGAINST *H. septima, C. sexmaculata* AND *A. cerana indica.*

5.1.1 Laboratory evaluation on efficacy of synthetic insecticides, botanicals and a natural organic against the pest *H. septima*

The result of the present investigation revealed that the treatment profenofos at 0.1 per cent gave consistently good results by bringing high per cent mortality of 95.83 and cent per cent at one, three and five days after treatment (Table 2, Fig.1).

The result of the findings was in consonance with the findings of Mohan (1985) who reported that, spraying of profenofos at 0.5 kg a.i. ha^{-1} gave good results on coccinellid, *H. vignitiotopunctata* infesting brinjal in Karnataka.

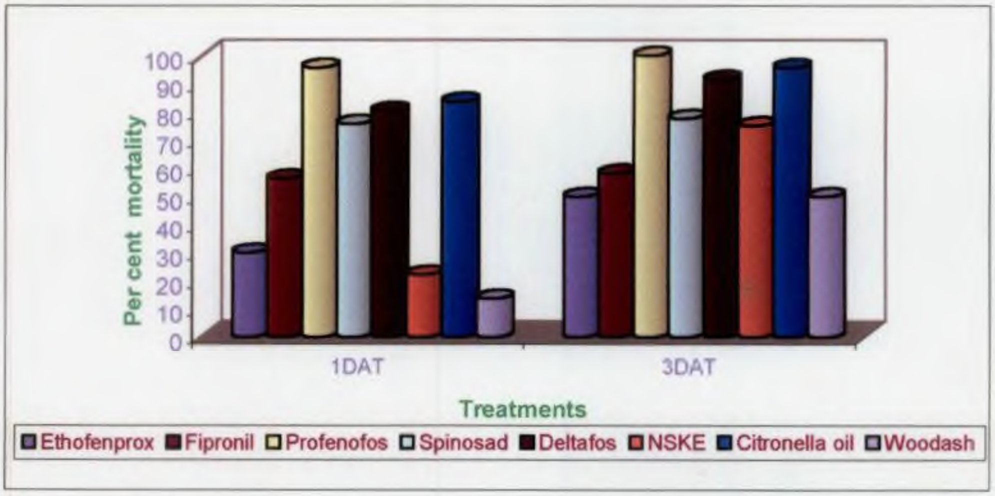

Fig. 1. Per cent mortality of adult epilachna beetle in different treatments (laboratory evaluation)

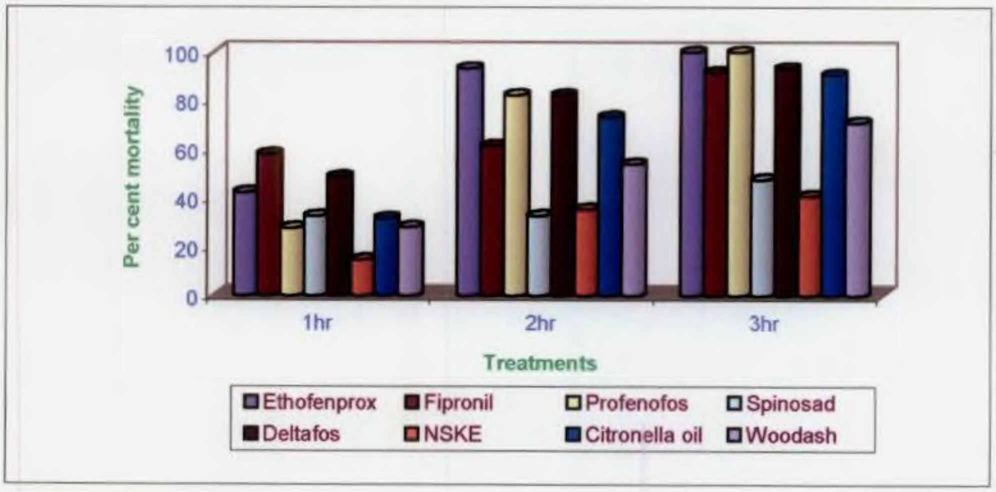

Fig. 2. Per cent mortality of honey bees in different treatments (laboratory evaluation)

Citronella oil, deltafos, spinosad and NSKE were also found to be very effective in controlling epilachna population. Sridevi *et al.* (2000) reported that spraying of citronella oil with piperonyl butoxide in 1:4 ratio showed very good additive effects against *T. castaneum.*

Spinosad was found to give 75.92 per cent mortality to *H. septima* on one DAT and 77.77 per cent at three DAT. Fang and Subramanyan (2003) reported that spinosad at 0.1 to 1 mg a.i. kg^{-1} of grain caused cent per cent mortality of *R. dominica* on wheat storage. Mane (1968) reported that NSKE had shown repellent action against chewing insect namely, pumpkin beetle *A. foeveicollis.*

Fipronil recorded low per cent mortality to *H.septima.* Evaluation of fipronil in two different places at Russia by Roslavsteva (2001) against Colarado potato beetle showed that 0.03 per cent fipronil gave reduction in Moscow, but the same concentration at another place resulted in greater than 20 per cent of beetles resistant to fipronil.

At five days after treatment, all the treatments including control showed cent per cent mortality.

5.1.2 Laboratory evaluation on efficacy of synthetic insecticides, botanicals and a natural organic against the Indian honeybee

NSKE recorded low per cent mortality (14.813) at one hour after treatment and found to be safe to honeybees. At two hour after treatment, spinosad and NSKE recorded the lower mortality rate of 32.933 and 35.553 per cent respectively.

Miles and Dutton (2000) reported that spraying of spinosad conserved beneficials like pollinators and predators, so it is a compatible product in IPM programme. According to Jones *et al.* (2002) spinosad had minimum impact on beneficials like *O. insidiosus and E. formosa* and could be used in IPM programme for greenhouse cucumber. Miles *et al.* (2003) reported that spinosad was safe to honeybees when applied on the flowering crops, during the periods of bee activity.

At three hours after treatment, citronella oil caused the highest per cent mortality to honeybees. Malerbo *et al.* (1998) who tested the effects of repellents and attractants on honeybees in *in vitro* condition observed that citronella oil was the most effective repellent. Patel and Kumar (1989) also recorded that citronella oil was the most effective repellent against honeybee at 0.5 to 1 per cent. The highest mortality was observed in ethofenprox and profenofos which might be due to the fact that, these two insecticides act as contact poison. The lowest per cent mortality was observed in NSKE and spinosad treatments at three hours after spray proving their safety to honeybees.

At four and six hours after spray, cent percent mortality was observed in all the treatments. At six hours after treatment there was cent per cent mortality in control also. This might be due to the separation of workers from the colony of honeybees, which is a social insect.

5.1.3 Laboratory evaluation of efficacy of synthetic insecticides, botanicals and a natural organic against the predator *C. sexmaculata*

The results obtained from the investigation revealed that the treatment spinosad had low per cent mortality at one hour after spray (Table 6, Fig.3). Miles and Dutton (2000) reported that spinosad was safe to predators in glass house IPM programme. According to Hendrix *et al.* (1997) spraying of spinosad conserved beneficials like ladybird beetles in Mississippi delta region. At different intervals of observation, spinosad recorded lowest per cent mortality of *M. sexmaculatus* ranging from 11.11 at two hours after spraying to 77.77 per cent at six hours after treatment.

The high per cent mortality (16.667) recorded by citronella oil and fipronil at one hour after spraying.

At seven hours after treatment there was complete mortality in all the treatments.At 36 hours after treatment, there was cent per cent mortality in all the treatments including control.

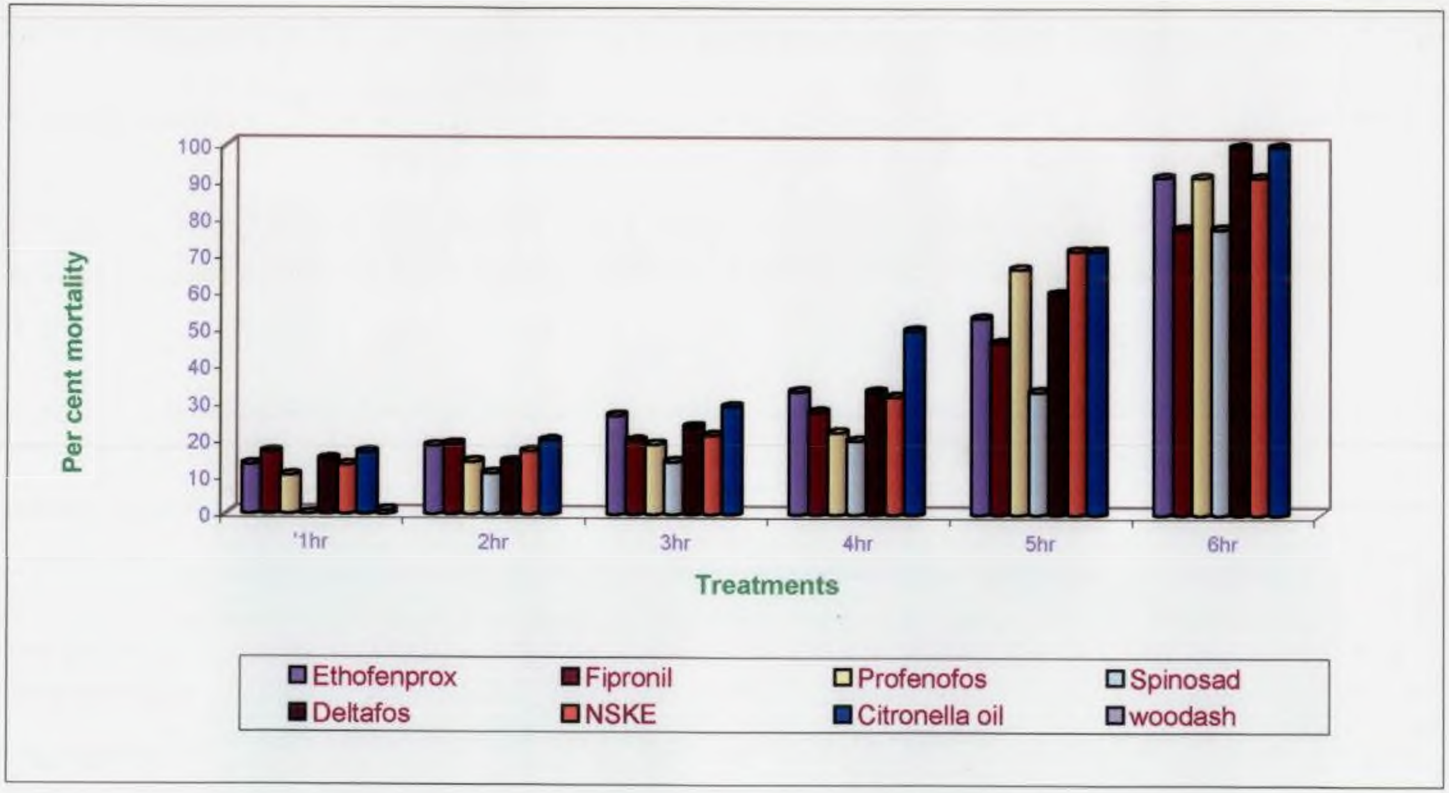

Fig. 3. Per cent mortality of adult *Cheilomenes sexmaculata* in different treatments

5.2 FIELD EVALUATION ON EFFICACY OF SYNTHETIC INSECTICIDES, BOTANICALS AND NATURAL ORGANICS AGAINST THE KEY PESTS OF BITTERGOURD

5.2.1 Evaluation of efficacy of synthetic insecticides, botanicals and natural organics against leafhoppers

The results of the present investigation revealed that the treatment ethofenprox 0.02 per cent gave consistently good results in bringing down the leafhopper population till 14 days after treatment (Tables 8, 10, 12 and 14, Fig.4, 5, 6 and 7). This was clear from the per cent reduction in the population observed during different intervals. The values were 68.19, 71.7, 67.5, 67.6, 57.2 and 53.75 per cent for the first spray, 78.92, 82.28, 78.48, 54.88, 43.8 and 43.80 per cent reduction for third spray and 44.46, 42.15, 42.76, 30.03, 33.70 and 31.93 per cent reduction respectively for the fourth spray.

The efficacy of ethofenprox in controlling leafhoppers was reported by various workers. Krishnaiah and Kalode (1993) reported that ethofenprox at 100g a.i. ha^{-1} gave good results against brown plant hopper, *N. lugens* infesting rice without detrimental effect to its natural enemies and hence it is preferred in IPM. Panda *et al.* (1995) reported ethofenprox at 0.075 kg a.i. ha^{-1} was very effective on Brown plant hopper and gave a higher grain of yield of 68.35 q ha^{-1} in rice. David and Kumarasamy (2001) also reported the effectiveness of spinosad in controlling the leafhoppers infesting vegetables.

Karthikeyan (2003) observed that ethofenprox was effective in controlling the leafhopper *E. (E.) motti* in bittergourd up to seven days after spray and it was found as effective as acetamiprid and imidacloprid.

The observations taken after the first spray showed that ethofenprox caused more than 50 per cent reduction in population over control for 14 days, while it was seven days during the second spray. During the third and fourth sprays the per cent reduction was less than 50 during all intervals observed.

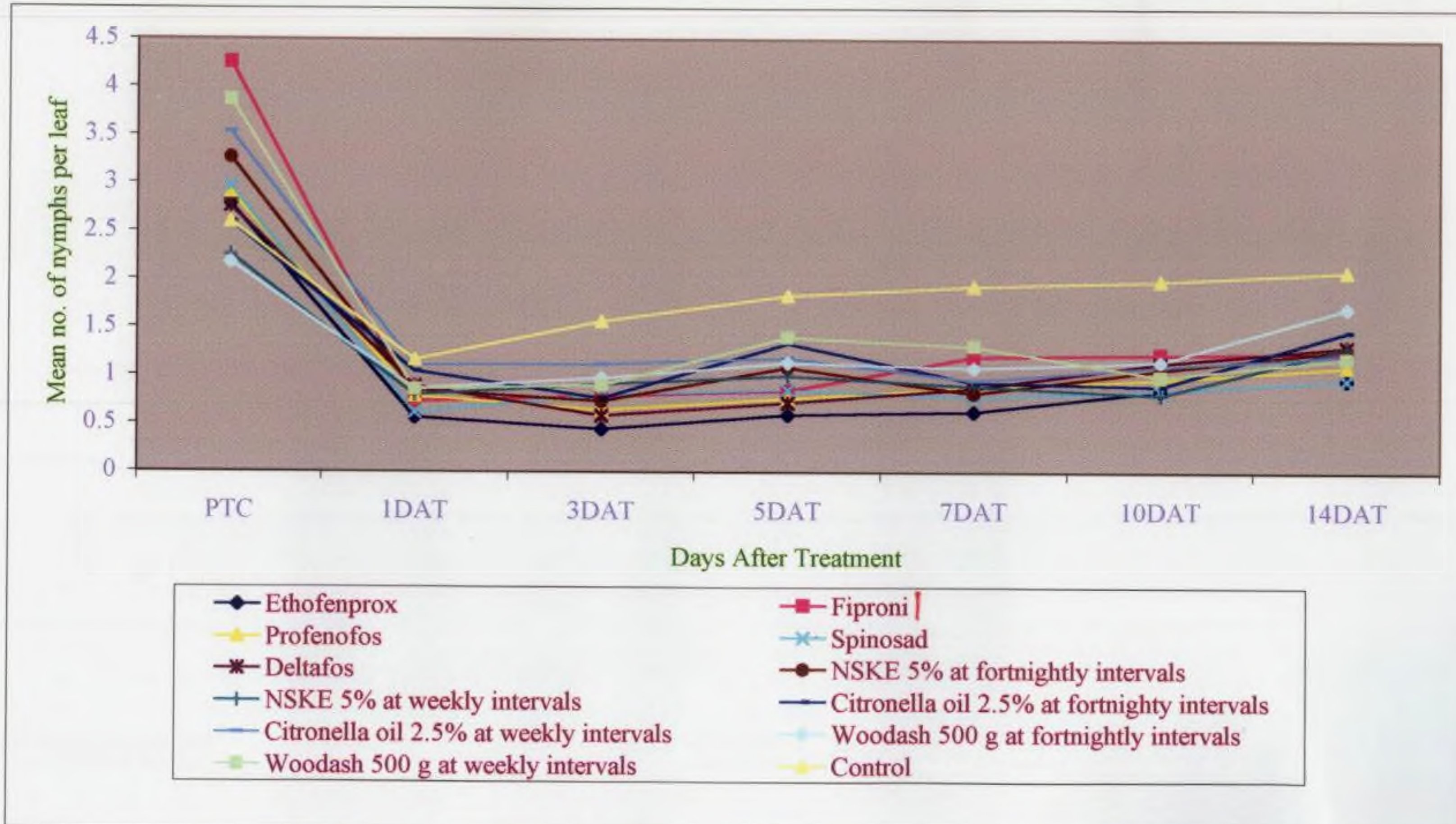

Fig. 4. Population density of leafhopper in different treatments after the first spray

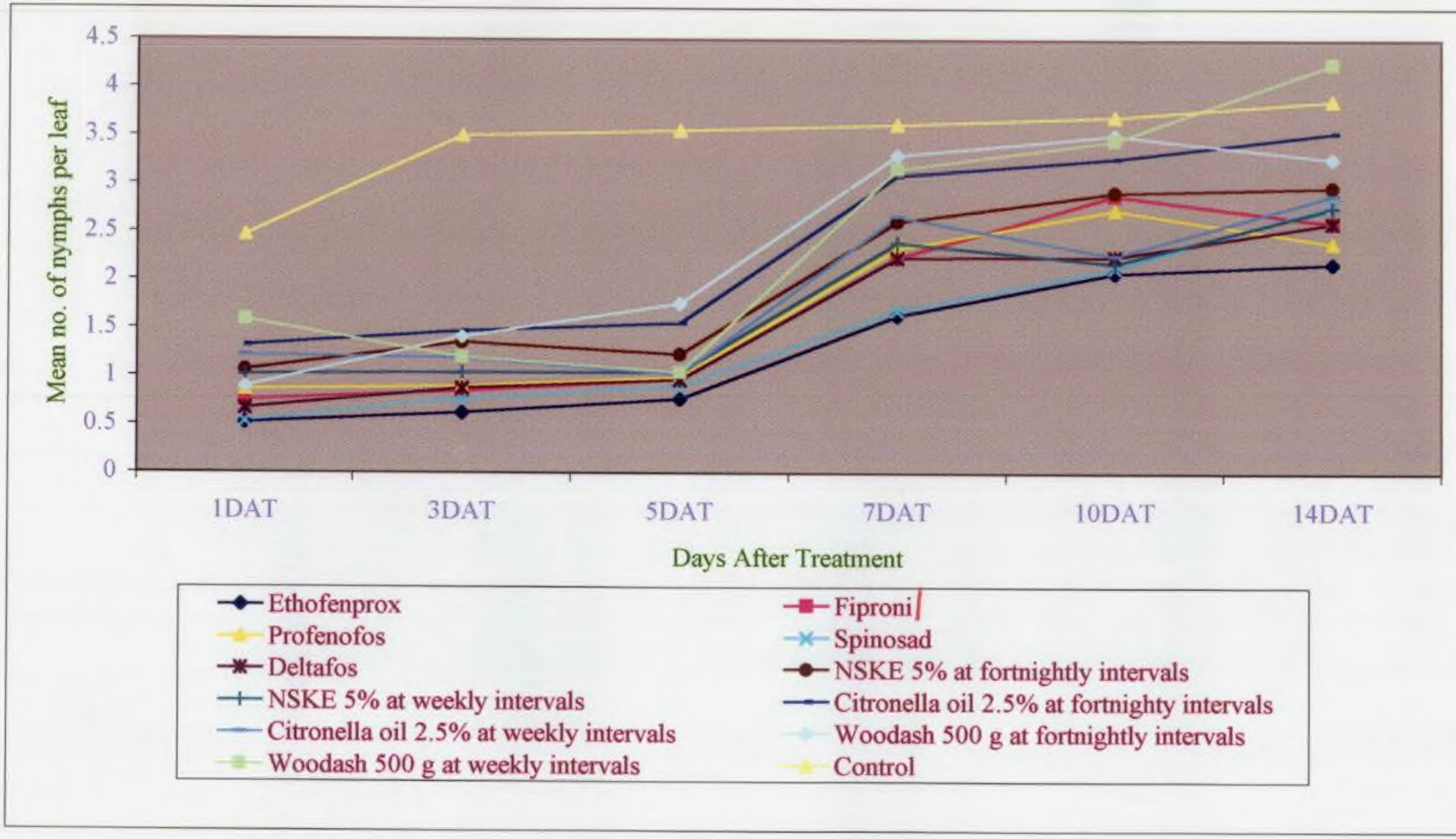

Fig. 5. Population density of leafhopper in different treatments after the second spray

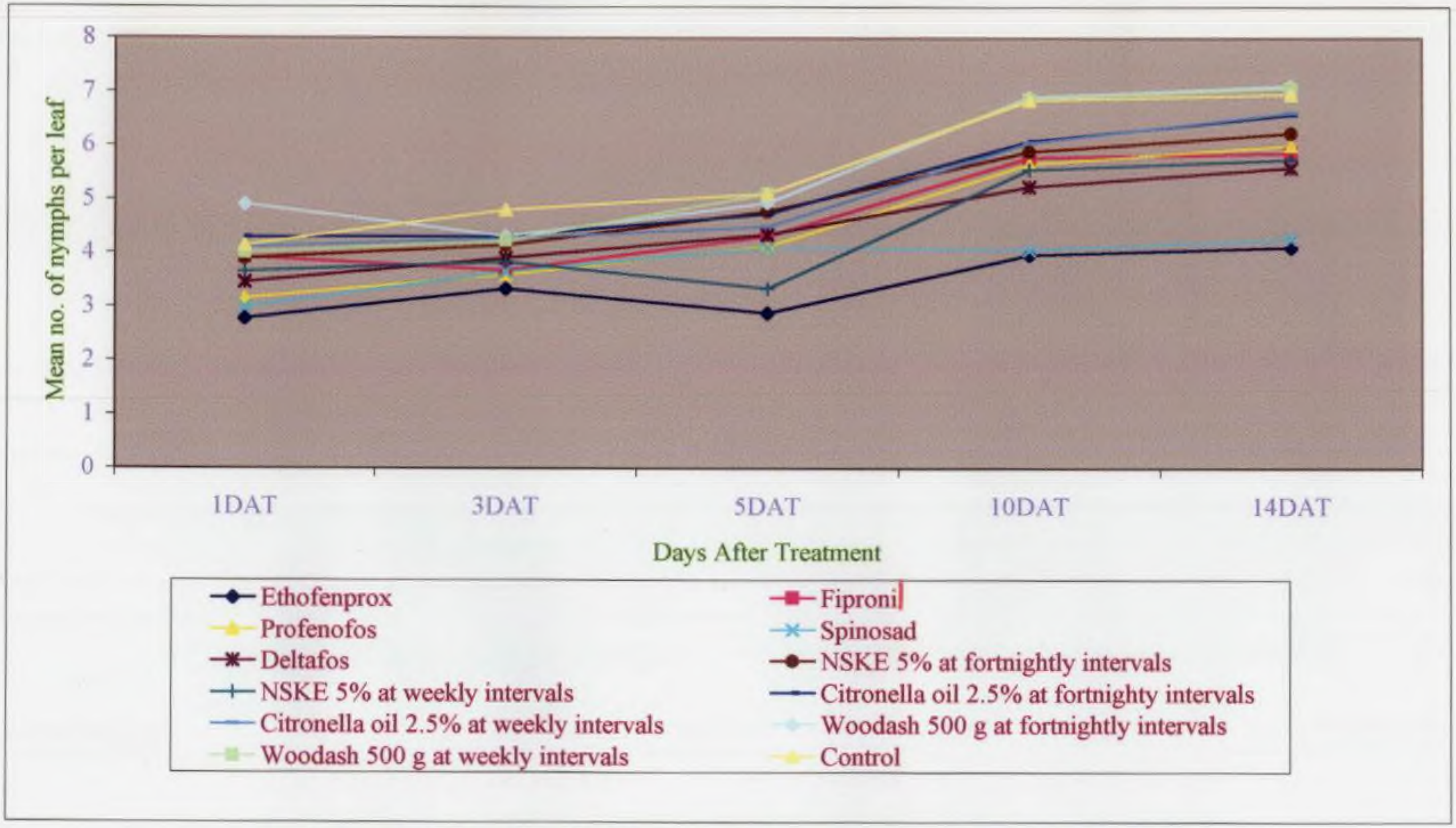

Fig. 6. Population density of leafhopper in different treatments after the third spray

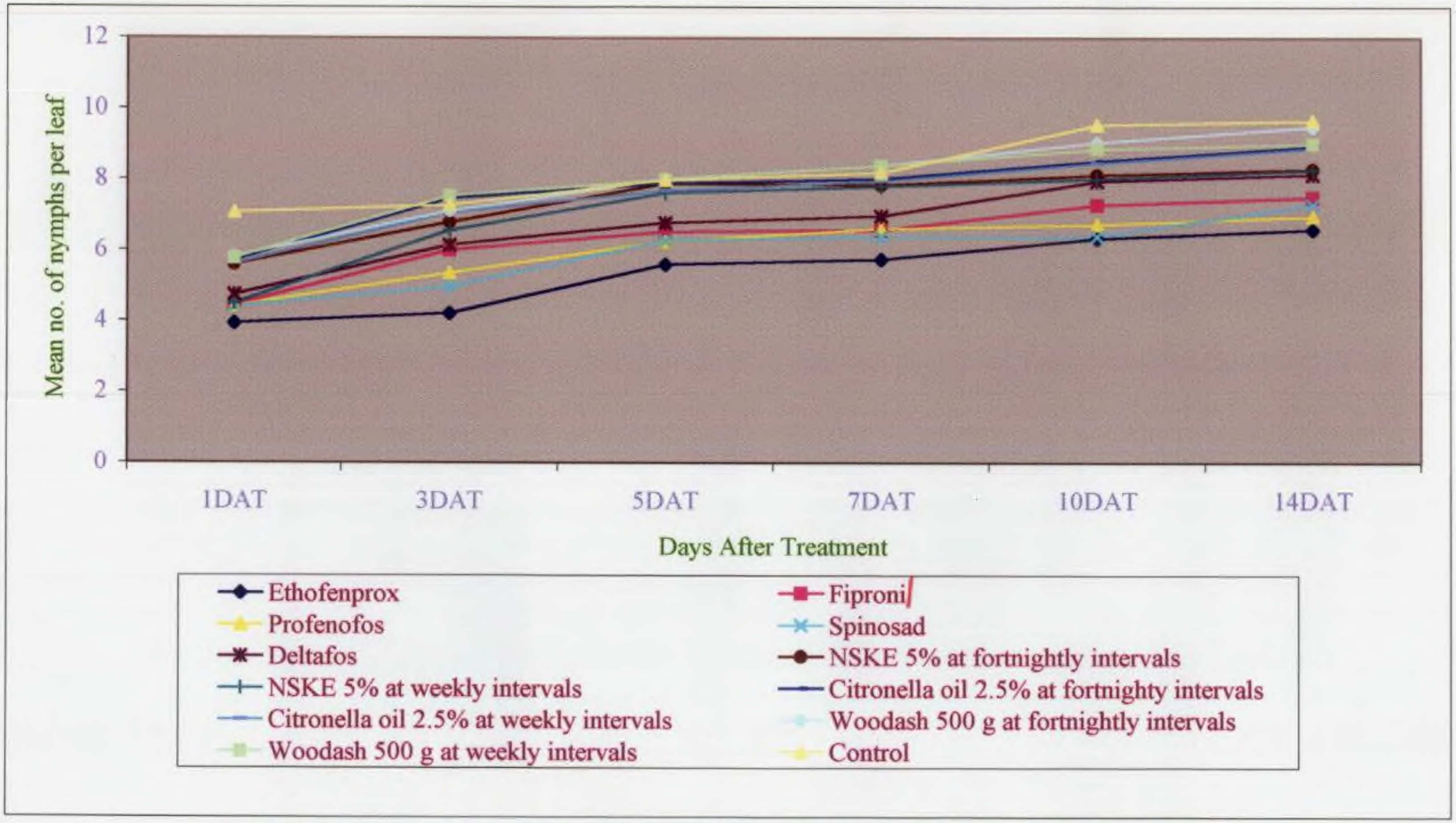

Fig. 7. Population density of leafhopper in different treatments after the fourth spray

Next to ethofenprox, spinosad at 75 g a.i. ha^{-1} gave good control of leafhoppers. During first spray, it causes more than 50 per cent reduction in population over control for 14 days and 7 days during second spray. Deltafos and profenofos were found to be effective against leafhopper for seven days after the first spray and five days after the second spray. Kumar *et al.* (2001) found that spark caused significant reduction in brinjal leafhopper over control. NSKE and Citronella oil were found to give good control upto seven DAT during the first spray and upto five DAT during second spray, NSKE at weekly intervals and citronella oil at weekly intervals gave about 70 per cent reduction in population at five DAT during second spray.

During the third and fourth spray the leafhopper population were very high in all the treatments and none of the treatments gave effective control of the leafhoppers. During both spray, ethofenprox was found to give comparatively good control of the leafhoppers.

Woodash alone caused reduction in population upto 45.82 per cent during first spray upto 70.66 per cent during second spray. During third and fourth sprays woodash recorded higher population than that of control.

Natural organic like wood ash is highly effective in controlling leafhopper when the population was in low level and when the population build up was high, it recorded leafhopper population higher than control.

5.2.2 Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against epilachna population

The infestation of the epilachna beetle was noticed only during the first two sprays. There after the population was nil. Profenofos was significantly superior to control but it was on par with all other treatments (Tables 16 and 18, Figs.8 and 9). Mohan (1985) reported that spraying of profenofos @ 0.5 kg a.i. ha^{-1} gave significant reduction in *H. vignitioctopunctata* infesting brinjal.

Next to profenofos, spinosad and deltafos also recorded lower infestation. Spinosad at 0.1 to 1 mg a.i. per kg of grain caused cent per cent mortality of *R. dominica* in wheat storage (Fang and Subramanyam, 2003).

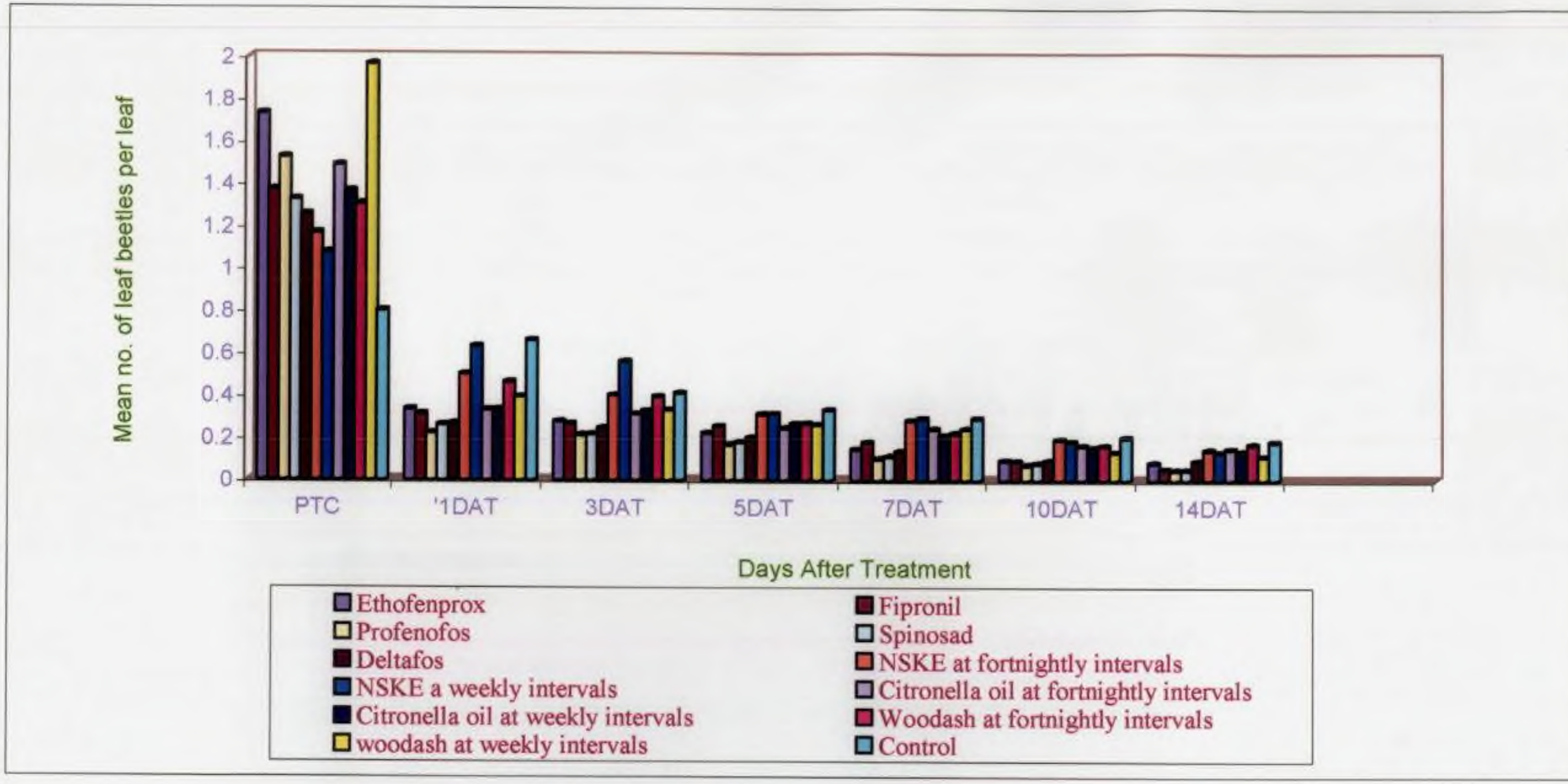

Fig. 8. Population density of epilachna beetles in different treatments after the first spray

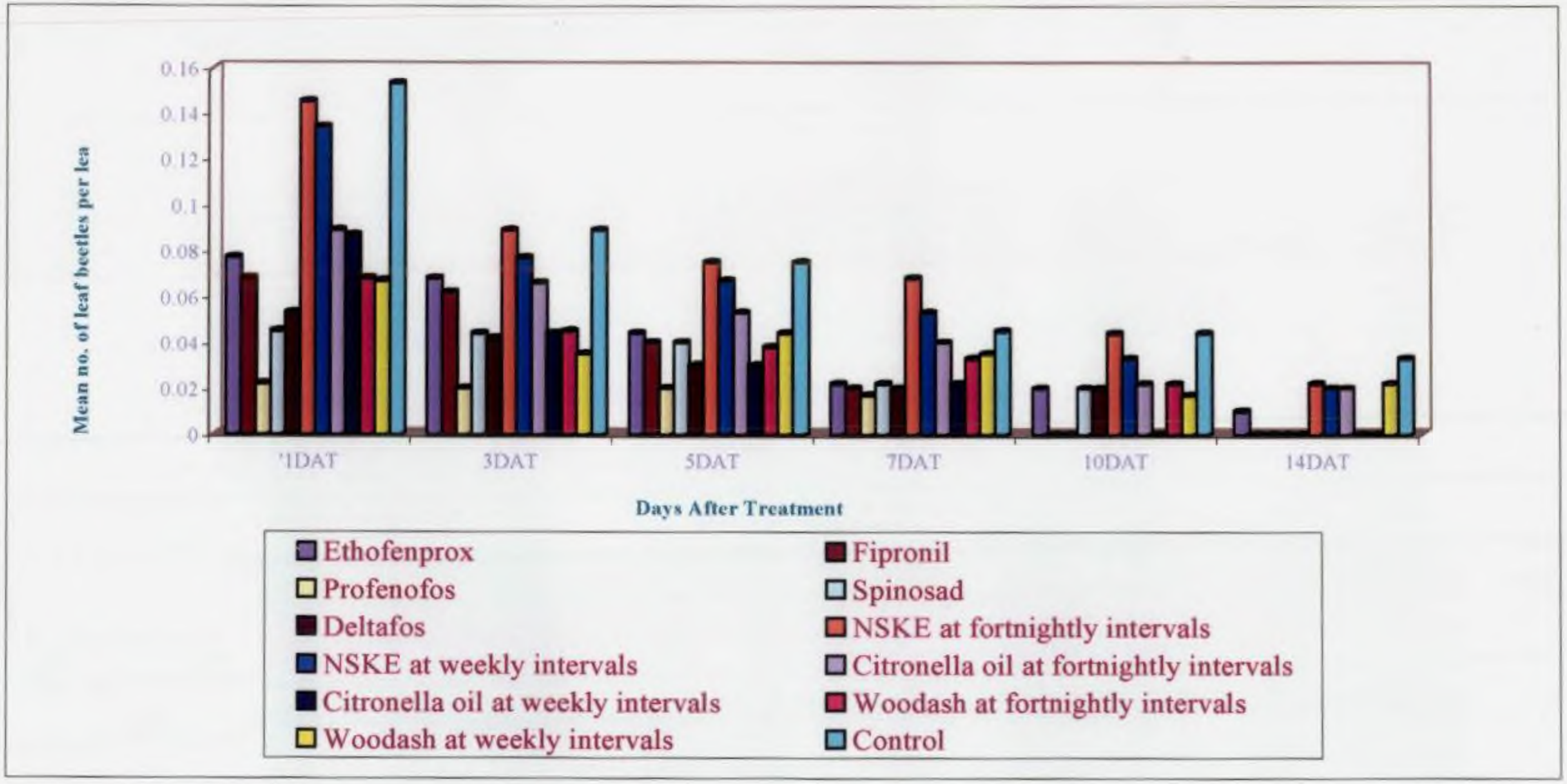

Fig. 9. Population density of epilachna beetles in different treatments after the second spray

In the first spray among botanicals and natural organics higher per cent reduction in population was observed in citronella oil and woodash treatments. Highest per cent reduction was observed at one DAT. However during the second spray, woodash at weekly intervals gave better control during first three days while citronella oil at weekly intervals gave good control of leaf beetle.

Cent per cent reduction in population was observed in citronella oil at weekly intervals from 10 DAT and wood ash and deltafos from 14 DAT, fipronil and profenofos from 10 DAT. The leaf extracts of *Polygonum hydropiper* (L.), *Eupatorium odoratum* (L.) and *A. indica* were compared with woodash and malathion against red pumpkin beetle *A. foveicollis* at Jorhat, India and found that malathion 0.1 per cent concentration was the most effective treatment followed by *A. indica* and woodash (Das and Ishaque, 1998).

5.2.3 Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against leaf miner population

The leafminer infestation was observed only during the first spray. In the subsequent sprays, the intensity of the pest population was very low.

The result revealed that all the chemical treatments and NSKE were very effective in controlling leafminer population (Table 20, Fig.10). Application of deltafos and profenofos resulted in excellent control of leafminer. Cent percent reduction in population was recorded at five DAt in deltafos and seven DAT in profenofos. Raid and Robinson (1994) reported that spraying of profenofos caused 60 to 70 per cent reduction in the mines per leaf.

Several workers reported the efficacy of spinosad in controlling the leaf miner population. Gahbiche and Aoun (1999) reported that spinosad resulted in a reduction of 54 per cent of larvae and 78 per cent pupae of *L.trifolii* with out adverse effects on larval parasitoids of leaf miner. Gahbiche (2001) reported cent per cent mortality of larval stadia of green bean leafminer due to spraying of spinosad. Gravena *et al.* (2002) also reported that spraying of spinosad in combination with

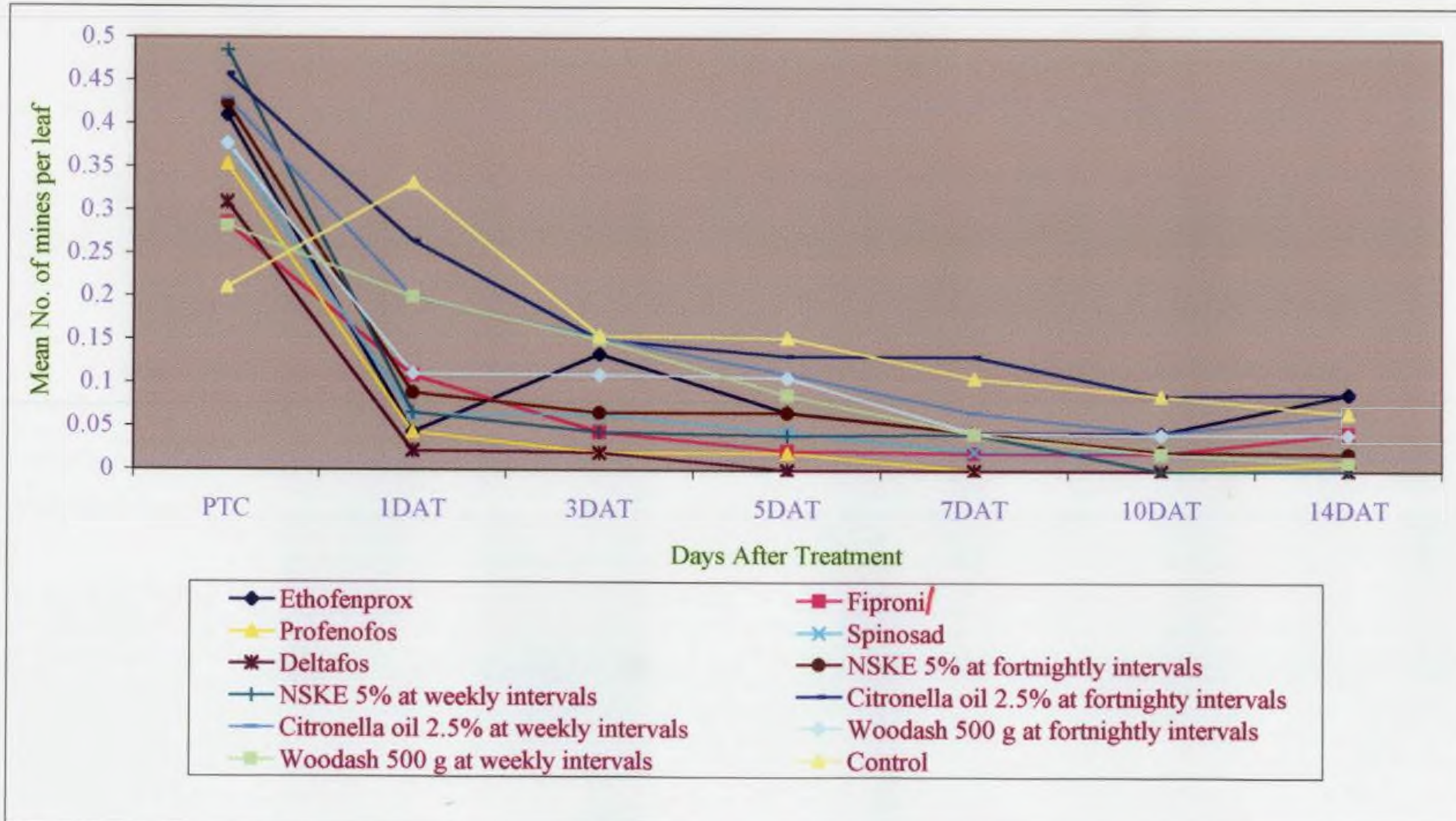

Fig. 10. Population density of leafminer in different treatments after the first spray

mineral oil at four different doses namely 7.5, 10, 12.5, 15 ml of commercial product per 100 litre of water reduced citrus leafminer upto ten days after spraying.

Fipronil resulted in 85.62 per cent reduction in leaf miner infestation at five DAT and was giving good control upto 10 DAT. Ethofenprox also gave good results in controlling leafminer population. The result obtained from the present findings was in consonance with the findings of Saito *et al.* (1992) who observed that spraying of ethofenprox had high adulticidal activity and reduced the number of feeding and oviposition punctures of *L. trifolii* affecting vegetables and ornamentals in Japan.

NSKE at weekly intervals gave good control of leafminer and NSKE at weekly intervals was found to be much better than spraying at fortnightly intervals. Regupathy *et al.*(1997) recommended NSKE at five per cent for the control of leaf miner infesting cucurbits.

5.2.4 Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against pumpkin caterpillar population

The population of pumpkin caterpillar was low during the crop period. The pre treatment count showed that the population ranged from 0.020 to 0.177 larvae per leaf in different treatments. Spinosad, citronella oil, NSKE, fipronil and deltafos recorded very low values at different intervals (Table 22 and Fig.11). The highest per cent reduction of pumpkin caterpillar over control was 92.12 and 91.33 in spinosad and citronella oil at weekly spraying at one DAT (Table 23). Spinosad, deltafos, citronella oil and NSKE recorded cent per cent reduction from three DAT and fipronil at five DAT.

Vadodaria *et al.* (2001) reported that the spraying of spinosad is highly effective against a number of pests viz., *P. xylostella* and *H. undalis* infesting cabbage. Arora *et al.* (2003) also reported that spraying of spinosad was highly effective against third instar larva of *P. xylostella* infesting cauliflower.

Citronella oil also gave good result in reducing the population of pumpkin caterpillar. Bosch (1971) reported that cent per cent control was observed against fruit sucking moth in apple orchard when treated with citronella oil.

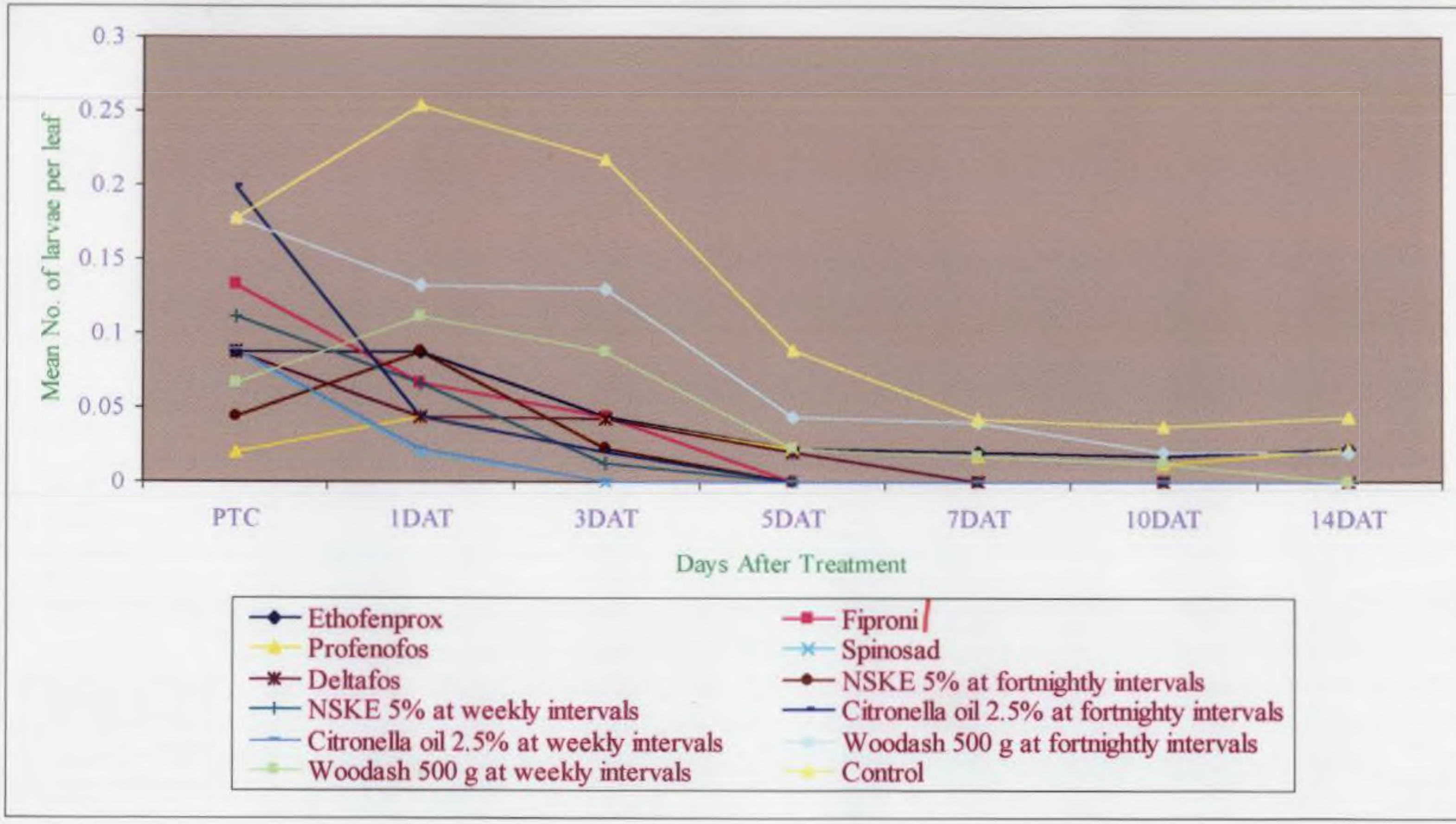

Fig. 11. Population density of pumpkin caterpillar in different treatments after the first spray

NSKE also caused cent per cent mortality of pumpkin caterpillar from third day after spraying. The result obtained was in consonance with the findings of Behera and Satapathy (1996) who reported that NSKE caused cent per cent mortality to the larvae of *S. littoralis* within 10 days after the treatment. Deltafos gave cent per cent mortality of pumpkin caterpillar from three days after spraying. Brar *et al.* (1998) reported that spray of deltafos caused cent per cent reduction of spotted bollworm *E. insulana* in cotton with in 72 hours after the spray.

Fipronil also gave 74 and 80 per cent control of pumpkin caterpillar at one DAT and three DAT respectively and cent per cent reduction at five DAT. Shi-zuhua *et al.* (1998) reported that spray of fipronil caused cent per cent mortality of third instar larvae of Diamond back moth in vegetable fields. Panda *et al.* (1999) conducted bioefficacy studies of fipronil in at 25, 40 and 50 g a.i. ha^{-1} caused 67.8 to 84.8 per cent reduction of *P.xylostella* infesting cabbage. Rao *et al.* (2003) also noted that granular application of fipronil at 75 g a.i. ha^{-1} recorded lowest leaf folder and *S. litura* damage in soyabean.

5.2.5 Field evaluation on efficacy of synthetic insecticides, botanicals and natural organics against gall fly population.

In the present investigation, the incidence of gall fly was observed only during the first spray and thereafter the incidence was nil. The post treatment count also showed that the treatment effect was not significant.

From the result obtained, it was evident that the treatment NSKE, fipronil, deltafos and spinosad were highly effective in controlling gall fly infestation (Table 24 and Fig.12). The result obtained was in agreement with the findings of Kumar *et al.* (1998) who reported NSKE four per cent controlled the gall midge, *Asphondylia* sp. infesting brinjal in Karnataka.

5.2.6 Field evaluation on efficacy of synthetic insecticides, botanicals and natural against aphid population

In the present investigation, the population was negligible upto third spray and mild infestation was noted during the fourth spray.

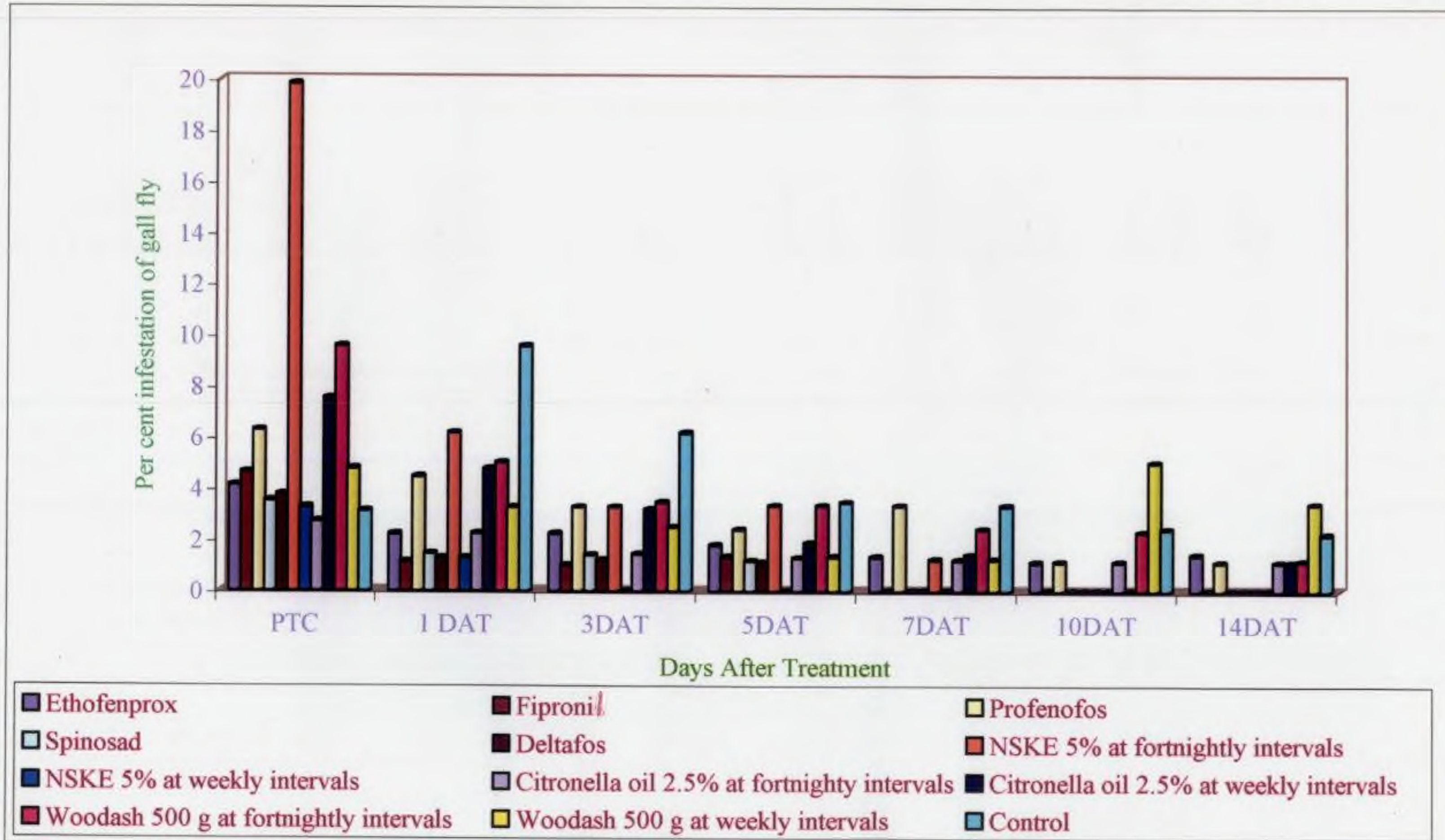

Fig. 12. Per cent infestation of gall fly in different treatments after the first spray

5.2.6.1 Fourth spray

The observation taken at different intervals showed that all the treatments recorded low values. All the treatments were statistically on par. The effectiveness of chemical treatments on aphids were reported by several workers; ethofenprox against mustard aphid (Arivudainambi and Prasad, 2003), profenofos against green peach aphid (Mc clahan and founk, 1983), profenofos against cowpea aphid (Sammour and El-Kabang, 1993) and NSKE against safflower aphid Dhembare *et al.*(2002).

5.2.7 Field evaluation on efficacy of synthetic insecticides botanical and natural organics against white fly population

The result obtained on the present investigation revealed that incidence of whitefly population was highly negligible at different intervals in different treatments. Habu (1991) reported that ethofenprox was most toxic to adults of sweet potato whitefly *B. tabaci.* Kinjo and Matsui (1994) also reported that ethofenprox reduced the longevity and fecundity of sweet potato white fly in green houses.

Rushtapakornchai *et al.* (1996) reported that fipronil was effective in reducing tomato whitefly in Thailand. Singh *et al.* (2002) carried out a field study in Hissar on brinjal and found that profenofos at 800 ml a.i. ha^{-1} was the most effective in controlling the brinjal white fly.

Rao *et al* . (1990) reported that a mixture of 0.05 per cent triazophos and 0.02 per cent deltamethrin were the most effective against whitefly infesting cotton. Kumar *et al.* (2001) also reported that spraying of Spark 0.1 per cent caused 48 to 65 per cent reduction of white fly in brinjal in Hyderabad.

Srinivasan and Babu (2001) reported that NSKE recorded lower mean population of white fly on brinjal followed by Nimbecidine and Neemgold.

5.2.8 Efficacy of synthetic insecticides, botanicals and natural organics against fruit fly, *B.cucurbitae*

Analysis of the data on fruit fly infestation in different treatments revealed that in the first harvest lowest per cent infestation (17.73) was recorded in citronella oil at fortnightly intervals followed by wood ash at weekly intervals (18.03) based on fruit number. Among the chemical treatments, lowest infestation was observed in deltafos (23.64).

Second to fourth harvest were made at 14,13 and 14 DAT respectively. Citronella oil and NSKE performed better than chemicals. Saradamma and Dale (1981) reported that citronella oil acts as an antifeedent or feeding deterrant in insects. Ragumoorthi *et al.* (1998) evaluated five different neem products against the moringa fruitfly and observed that NSKE was the most effective with high feeding deterrancy (43.75 to 62.75 per cent) low fecundity (51.90 to 74.26 per cent), high maggot mortality (18.50 to 24.75 per cent), high puparium mortality (24.75 to 31.5 per cent) and high adult malformation (7.75 to 18.25 per cent) at Chandigarh, India.

Deltafos resulted in low per cent infestation on fruit fly based on fruit weight than based on fruit number. Profenofos and ethofenprox recorded higher per cent infestation and were least efective in controlling fruit fly infestation.

5.2.9 Efficacy of synthetic insecticides, botanicals and natural organics against fruit borer, *D. indica and H. armigera*

The fruit infestation by both *H. armigera* and *D. indica* was noticed from first to fourth harvest. In the first harvest (4 DAT) the per cent infestation by number ranged from 1.833 to 17.50 in different treatments and ethofenprox and woodash applied at fortnightly intervals recorded lower infestation (1.83 and 2.20, respectively). Srinivas and Peter (1993) evaluated the efficacy of ethofenprox at 100 g a.i. ha^{-1} in Tamil Nadu and found that it gave significantly superior effects on brinjal shoot and fruit borer *Leucinodes orbonalis* (Guen.) compared to the conventional insecticides.

With respect to weight of fruits, it ranged from 6.67 to 19.68 and spinosad recorded the lowest infestation. Hasty *et al.* (1997) also reported that spraying of spinosad had high spectrum of activity against cotton bud worm and cotton boll worm in USA.

During second, third and fourth harvests spinosad, citronella oil and woodash application resulted in low fruit borer infestation by number as well as by weight. Perusal of literature did not show the effectiveness of citronella oil against fruit borers of vegetables. However, Ogbalu (1999) reported that woodash offered the highest percent of protection for most pepper cultivars against the pepper fruit fly, *Atherigona orientalis* (Schines) in Nigeria than the poultry manure and compost.

5.2.9.1 Total yield

The total yield recorded from different treatments revealed that deltafos recorded highest yield per plot of 12.69 kg followed by citronella oil spraying at weekly intervals with 11.57 kg per plot (Table 28 and Fig.13). NSKE spraying at weekly intervals recorded the highest number of fruits per plot (181.33) followed by citronella oil spraying at weekly intervals with 171 fruits and NSKE at fortightly intervals with 168 fruits.

5.2.9.2 Marketable yield

Deltafos recorded maximum marketable fruits 10.38 kg followed by citronella oil spraying at weekly intervals (9.66kg) and NSKE spraying at weekly intervals with 9.39 kg per plot. This three treatment recorded maximum per cent marketable yield by number.

Highest number of marketable fruits was recorded by NSKE spraying at weekly intervals followed by citronella oil spray at weekly intervals. Citronella oil spraying at weekly intervals and spinosad recorded higher per cent marketable yield while Woodash recorded the lowest marketable yield.

5.2.10 Benefit cost ratio

Among the different treatments deltafos, alone showed the BCR of above one (1.3 : 1). The expensive inputs and high labour cost resulted in high cost of cultivation and high wind prevailed during cropping period damaged the pandals and resulted in crop damage which inturn gave poor crop yields. This resulted in poor BCR ratio.

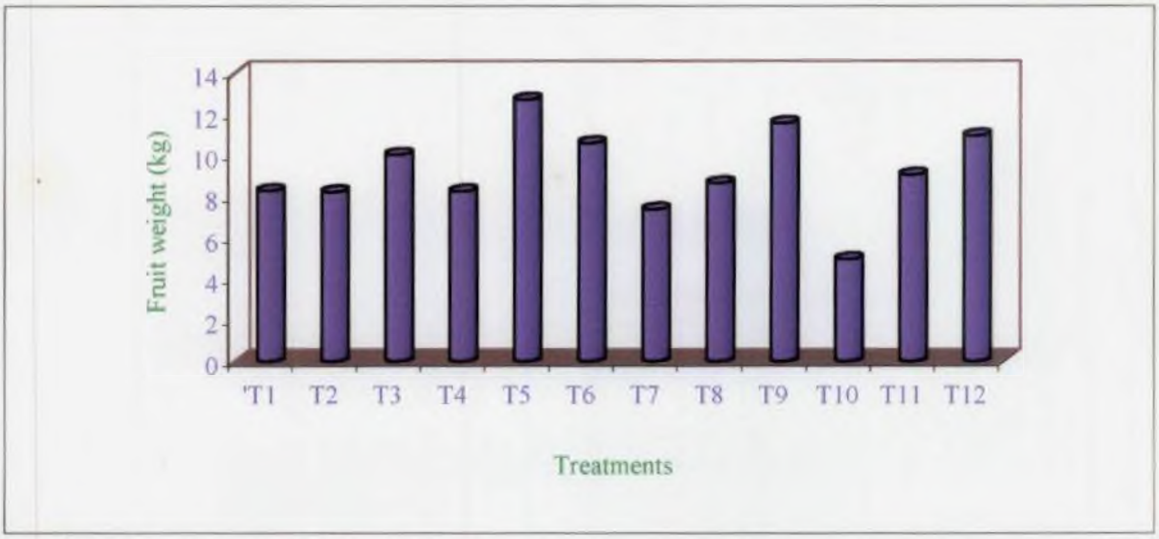

Fig. 13. Total yield by fruit weight in different treatments

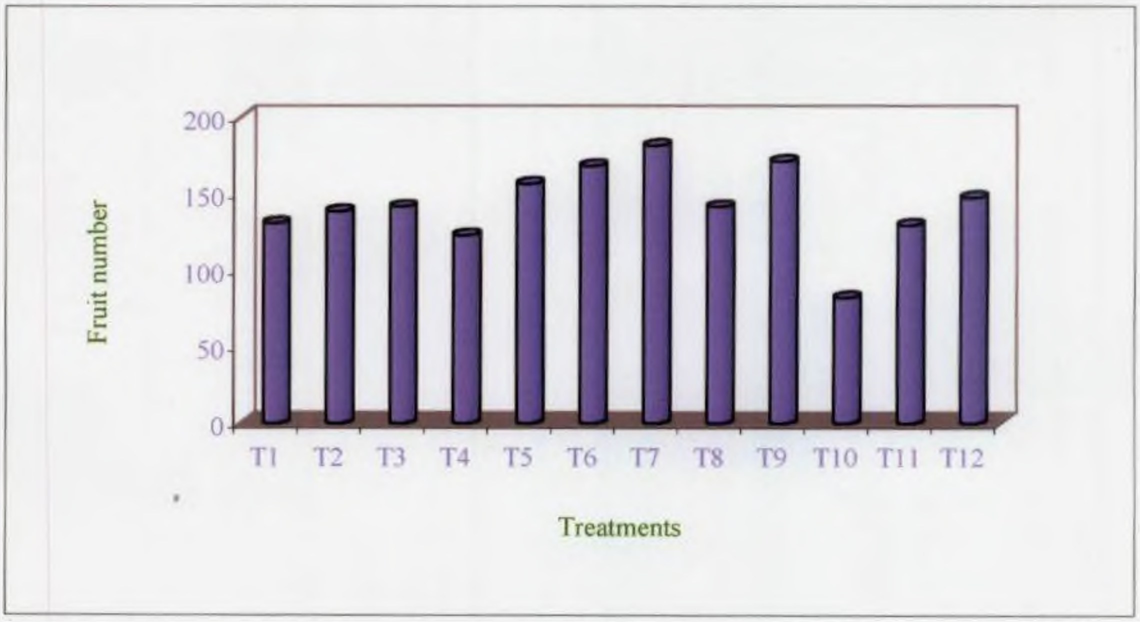

Fig. 14. Total yield by fruit number in different treatments

T_1 = Ethofenprox T_2 = Fipronil T_3 = Profenofos T_4 = Spinosad T_5 = Deltafos T_6 = NSKE at fortnightly intervals T_7 = NSKE at weekly intervals T_8 = Citronella oil at fortnightly intervals T_9 = Citronella oil at weekly intervals T_{10} = Woodash at fortnightly intervals T_{11} = Woodash at weekly intervals T_{12} = Control

5.2.11 Parasites and predators

5.2.11.1 Parasites

Parasites were observed only on the larvae of *D. indica* during the trial. After the first spray, parasitoids were observed only in citronella oil spraying at fornightly intervals, woodash dusting at fornightly intervals and control. Subsequent sprays showed that parasitoids were observed only in woodash dusting at fortnightly intervals upto seven DAT and in control upto 14 DAT.This shows that all the chemical treatments as well as botanicals were harmful to the parasitoids.

5.2.11.2 Predators

5.2.11.2.1 Spiders

In general analysis of data, revealed that all botanicals and natural organics recorded highest number of spiders when compared to chemical treatments. Among chemical treatment fipronil, profenofos and deltafos recorded significantly lower population at different intervals. This might be due to the fact the synthetic insecticides are highly toxic to spider population.

5.2.11.2.2 Coccinellids

The predatory coccinellid population was high in control plots with mean values ranging from 0.321 per leaf at one DAT to 0.067 at 14 DAT. Coccinellids were also observed in ethofenprox and spinosad. The result was in conformity with the findings of Vinuela *et al.* (2001) who reported that spinosad was safe for the pupae and adults of predator *C. carnea* at the maximum field dosage. Musser and Shelton (2003) also reported that spinosad were less toxic to abundant predator in sweetcorn namely *C. maculaata, H. axyresis* and *O. insidosus.* Kalode *et al.* (1993) reported ethofenprox at 100g a.i. ha^{-1} caused no detrimental effect to natural enemies in rice ecosystem. NSKE at fortnightly intervals and Citronella oil also recorded coccinellid upto 14 DAT.

5.3 CONCLUSION

The evaluation on the efficacy of newer insecticide molecules, botanicals and natural organics against major pests of bittergourd showed that the efficacy of these candidates to different pests varied greatly. Ethofenprox and spinosad were found very effective against leafhopper, *E. motti*; profenofos against leafbeetle, *H. septima*; deltafos, profenophos, spinosad, ethofenprox, fipronil and NSKE against leaf miner, *L. trifolii* and spinosad, citronella oil, NSKE, fipronil and deltafos against pumpkin caterpillar, *D. indica*. The gall fly, *N. falcate* was effectively controlled by NSKE, fipronil, deltafos and spinosad. Citronella oil and woodash interestingly gave lower fruit fly infestation. NSKE also was good against fruit fly infestation. Against fruit borers spinosad was observed to the best treatment.

Highest yield though not statistically significant was recorded in deltafos treatment followed by citronella oil spraying. NSKE gave highest number of fruits per plot. Marketable yield was also highest in deltafos.

Larvae of *Diphania indica* are attacked by braconid parasitoids. After the first spray,larval parasitoids were observed only in citronella oil, woodash and control. Botanicals and woodash recorded more number of spiders. The chemicals were harmful to spider predators. NSKE, citronella oil and control recorded predatory coccinellid population.

The above results clearly indicated that NSKE, citronella oil and woodash application should be encouraged during the initial infestation by pests. These botanicals encourage the activity of parasitoids and predators. Hit the pest with selected suitable chemical insecticides when the pest attains higher population.

Selected insecticides need to be evaluated on a large scale before finalizing the IPM module against insect pests of bittergourd.

Summary

6. SUMMARY

Bittergound is one of the important vegetable crops grown in Kerala. This crop is severely attacked by a few insect pests, namely, the fruit fly, *Bactrocera cucurbitae*, leafhopper, *Emposca* (E.) *motti*., fruit borers, *Diphania indica* and *Helicoverpa armigera* and gall fly, *Neolasioptera falcata*. Conventional inseciticdes are being used in a very large scale to manage these pests, which leave toxic insecticide residues in the fruits. Hence in order to reduce the pesticide load on this crop and to the environment, new molecules of insecticides, namely, ethofenprox, fipronil, spinosad, deltafos and profenofos were evaluated against the major pests of bittergourd. Botanicals like neem seed kernel extract, citronella oil and a natural organic, the woodash also were tested against the pests. The investigation on the "IPM strategy in bittergourd using new generation insecticides" was conducted at the laboratory in the Department of Entomology and also at the research fields at College of Horticulture, Vellanikkara during October 2003 to February 2004.

a) Laboratory evaluation of the toxicity of synthetic insecticides, few botanicals and one natural organic against the pest. *Henosepilachna septima,* the predator, *Chilomenus sexmaculatus* and the pollinator, *A. cerana indica*

b) Field evaluation on the efficacy of insecticides, botanicals and natural organics against the key pests of bittergourd

The salient findings of the present investigation are summarized below.

- The efficacy of different insecticides against epilachna beetle under laboratory conditions revealed that profenofos gave highest per cent mortality. Citronella oil and deltafos were found as the next best treatments.

- Spray application of NSKE and spinosad were found to be safe to the pollinator, Indian honey bees, ethofenprox, profenofos, deltafos, fipronil, citronella oil were highly toxic to honey bees under laboratory conditions.

- Spray application of spinosad were found to be safe to the predatory coccinellid beetle, whereas deltafos and citronella oil showed higher toxicity to predatory coccinellid beetle.

- Ethofenprox at 0.02 per cent concentration recorded lowest leaf hopper count and higher per cent reduction at the different intervals observed.

- Spray application of profenofos at 0.1 per cent concentration was effective in reducing epilachna beetle infestation followed by spinosad.

- All chemical treatments and NSKE were found to be effective in controlling leaf miner infestation.

- Spinosad, citronella oil, NSKE, fipronil and deltafos gave consistently good results in controlling pumpkin caterpillar infestation.

- NSKE, fipronil, deltafos and spinosad were found effective in controlling gall fly infestation.

- Dusting of woodash was found to be effective in reducing aphid infestation.

- Among botanicals, citronella oil and NSKE were found effective against fruit fly infestation and among chemicals, deltafos was found effective against fruit fly infestation.

- Spinosad, citronella oil and woodash gave consistently good results by reducing the fruit borer infestation.

- Citronella oil spraying at weekly intervals recorded the highest per cent marketable yield.

- Citronella oil and woodash treatments recorded parasitism by braconids on *D. indica* and these were found safe to the parasitoids.

- All botanicals and natural organics harboured spider population. Among chemicals, very low population of spiders was supported by spinosad.

- Citronella oil spraying at weekly intervals and NSKE at fortnightly intervals recorded higher predatory coccinellid population while fipronil and deltafos were harmful to population these predators.

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* Originals not seen

Appendix

Appendix - I

Meteorological Observation

Weekly weather data at Vellanikkara during the period of field experiment from (Oct. 22, 2003 to Feb. 10, 2004)

Standard week 2003	2003-2004 Date	Temperature		Relative humidity (%)		Sunshine hours	Rainfall (mm)	Wind speed (km hr^{-1})
		Maximum (°C)	Minimum (°C)	Morning	Evening			
43	Oct. 22 - Oct. 28	31.6	22.6	86	65	7.9	2.5	3.6
44	Oct. 29 - Nov. 4	32.2	23.4	83	60	8.1	2.0	4.8
45	Nov. 5 - Nov. 11	30.9	23.7	78	64	5.2	0.28	8.2
46	Nov. 12 - Nov. 18	32.1	24.6	71	54	8.6	0.0	8.1
47	Nov. 19 - Nov. 25	31.7	24.2	71	55	7.8	0.0	9.5
48	Nov. 26 - Dec. 2	31.1	23.4	72	58	7.2	0.0	8.8
49	Dec. 3 - Dec. 9	32.0	22.7	63	41	10.0	0.0	9.1
50	Dec. 10 - Dec. 16	31.9	22.0	68	50	8.1	0.0	5.4
51	Dec. 17 - Dec. 23	32.0	21.6	75	47	8.6	0.0	6.3
52	Dec. 2 - Dec. 31	32.9	22.9	78	48	9.3	0.0	9.1
2004 1	Jan. 1 - Jan. 7	32.5	22.8	72	43	9.5	0.0	8.7
2	Jan. 8 - Jan. 14	32.3	22.2	63	44	9.9	0.0	11.4
3	Jan. 15 - Jan. 21	33.9	21.0	71	42	9.9	0.0	6.7
4	Jan. 22 - Jan. 28	34.3	22.7	78	42	9.3	0.0	5.1
5	Jan. 29 - Feb. 4	34.5	22.8	78	41	9.4	0.0	5.1
6	Feb. 5 - Feb. 11	34.5	23.0	73	40	8.6	0.0	5.6

IPM STRATEGY IN BITTERGOURD USING NEW GENERATION INSECTICIDES AND BOTANICALS

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

The investigation on the "IPM strategy in bittergourd using new generation insecticides and botanicals" were carried out in the field as well as in the laboratory of Department of Entomology, College of Horticulture, Vellanikkara during October 2003 to February 2004. The present investigation revealed that profenofos gave high mortality to epilachna beetles, NSKE and spinosad were safe to honey bees and spinosad alone was found to be safe to predatory coccinellids under laboratory conditions.

Under field conditions ethofenprox was found as the most effective insecticide against leaf hoppers, profenofos against epilachna beetle and all chemical treatments and NSKE against leaf miner infestation. Spinosad, citronella oil, NSKE, fipronil and deltafos recorded lower pumpkin caterpillar infestation. NSKE, fipronil, deltafos and spinosad consistently effective in reducing the gall fly infestation. Citronella oil, NSKE and deltafos had registered the lower fruit fly infestation. The fruit borer infestation was less in the plots treated with spinosad, citronella oil and woodash.

All botanicals and woodash harboured spider predators and spinosad was comparatively safe to spiders. Citronella oil and NSKE recorded higher coccinellid predators.