INFESTATION OF THE PUMPKIN CATERPILLAR, *Diaphania indica* Saunders IN CUCURBITS AND ITS MANAGEMENT

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DECLARATION

I hereby declare that this thesis entitled "**Infestation of the pumpkin caterpillar, *Diaphania indica* Saunders in cucurbits and its management"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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11- 10-2011 (2009-11-135)

CERTIFICATE

Certified that this thesis entitled “**Infestation of the pumpkin caterpillar, *Diaphania indica* Saunders in cucurbits and its management**” is a record of research work done independently by Ms. Neena Lenin (2009-11-135) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to

My Loving parents and brothers

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Neena Lenin

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LIST OF ABBREVIATIONS

%	Per cent
$/m^2$	Per square metre
@	At the rate of
a.i	Active ingredient
CD	Critical difference
DAS	Days after sowing
DAT	Days after treatment
EC	Emulsifiable concentrate
et al.	And others
Fig.	Figure
g	Gram
h	Hour
ha^{-1}	Per hectare
kg	Kilogram
m	Metre
ml	Millilitre
SC	Suspension concentrate
SP	Soluble Powder
sp.	Species
viz.	Namely
WP	Wettable Powder

Introduction

1. INTRODUCTION

The ubiquitous insects are one of the dominant life forms on earth. The marvellously designed and fascinating arthropods comprise about 85 per cent of all known species. Among the different groups of insects, the order Lepidoptera constituting the butterflies and moths is one of the most successful taxon. It is the second most species rich order, with about 170,000 recognised species and perhaps 300,000 still undescribed (Benton, 1995). Presumed to have evolved around 200 million years ago, the host choice of the lepidopteran fauna often relate to plant chemistry and taxonomy. The order encompasses numerous pestiferous insects too. Of late, one relatively nondescript pest, the pumpkin caterpillar, *Diaphania indica* Saunders has emerged as a reckonable pest of cucurbits world over.

The pest is basically distributed in the tropics and subtropics, from the Caribbean and northern South America across sub Saharan Africa, Asia and the Pacific. It is seen in India, China, Japan, South Korea, Bangladesh, Saudi Arabia, Yemen, sub-Saharan Africa, Florida and Northern Territory of Australia. The synonyms of the pest include *Botys hyalinalis* Boisduval 1833, *Eudioptis indica* Saunders1851, *Eudioptis capensis* Zeller 1852, *Phakellura gazorialis* Guenee 1854, *Phakellura zygaenalis* Guenee 1854, *Phakellura curcubitalis* Guenee 1862, *Glyphodes intermedialis* Dognin 1904, *Glyphodes indica* Saunders, *Hedylepta indica* Saunders, *Margaronia indica* Saunders, *Palpita indica* Saunders, *Phacellura indica* Saunders (EPPO, 2005). Commonly known as the pumpkin caterpillar, the moth is also referred to as cotton caterpillar, gherkin fruit borer, melon worm, cucumber moth etc.

D. indica is chiefly an oligophagous pest of Cucurbitaceae (Ayyar, 1940). It infests most of the cucurbits including cucumber, melon, gherkin, bottle gourd, bitter gourd, snake gourd, Luffa, little cucumber, etc cultivated worldwide (EPPO, 2005). Though principally a leaf feeder, the pumpkin caterpillar is also known to infest flowers, new tender shoots and young and mature fruits. Attack on fruits reduces their commercial value, leading to colossal crop losses during outbreaks (Choi et al., 1990). Severe damage was observed in bitter gourd, cucumbers and melon in Japan (Shimizu, 2000). Several reports indicate that the damage by the pest in cucurbits is fast escalating (Namvar and Alipanah, 2002; Bacci et al., 2006). Apart from this, the pest also damages other plants like, beans, okra, passion fruit, pigeon pea and short staple cotton (Ba-Angood, 1979) and cowpea (Sankar, et al., 2005) enhancing its damage potential manifold.

Precise management measures against *D. indica* are lacking. Mostly, organophosphate, carbamate and pyrethroid insecticides have been used for the control of the pest. In the light of the problems associated with the incessant use of these conventional insecticides, suitable alternatives are being increasingly explored. Plant products like turpentine oil, citriodore oil and ageratochromene (Namvar and Alipanah, 2002) and neem oil + garlic (Sivakumar, 2001) were tested for their efficacy. The bacterium, *Bacillus thuringiensis* Berliner (Singh and Naik, 2006) and the fungus, *Beauveria bassiana* (Bals.) Vuill (Jiji, et al., 2008) too were exploited. The efficacy of the newer insecticide molecules *viz*., indoxacarb, methoxyfenozide, spinosad, emamectin benzoate and novaluron were established (Kay, 2007).

D. indica was first reported on cotton leaves from India (Hampson, 1896). On cucurbits the pest was recorded by Lefroy in 1906. Subsequently, Ayyar (1923) reported the pyralid as one of the major pests causing substantial damage to cucurbits in the country. A number of cucurbits cultivated in India were recorded as hosts of *D. indica* (Segeren, 1983; Viraktamath et al., 2003). Its attack on fruits has resulted in marketable loss (Ravi, 1998). The adults are present year round with the highest populations between April and September and lowest between November and February, in India. Commensurate with the change in its pest status globally, the pumpkin caterpillar has become an important pest in India too, recently. An outbreak of the pest was observed in cucurbit gardens in Anand district of Gujarat, causing 60 and 90 per cent fruit damage in bitter gourd and little gourd, respectively during 2003 and 2004 (Jhala et al., 2004).

Though an array of pests is associated with cucurbitaceous vegetables in Kerala, *D. indica* is found to cause severe damage, presently. Moreover, its occurrence on crops in other plant families, notably Leguminosae and Malvaceae (Ba-Angood, 1979) documented elsewhere assumes significance in a state like Kerala where the vegetable cultivation pattern includes a diverse range of crops. Despite its prevalence in appreciable densities in the State, information on the pest is meagre. Obviously, a precise study is needed to establish the present status of the pest in cucurbits. Knowledge of other host plants is also required to gauge the magnitude of the problem.

Currently, no specific control measures are directed against *D. indica*. However, in the changing pest scenario, effective measures are vital to contain the pest. Information on the intensity of damage, host range and effective management measures are needed for evolving a sustainable integrated pest management module against the pumpkin caterpillar. The present study is envisaged to address the above issues with the following objectives.

- To study the incidence and extent of damage caused in cucurbits
- To record other host plants of the pest
- To identify effective botanical, microbial and safer chemical insecticides for its management

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Review of literature

2. REVIEW OF LITERATURE

The literature related to the serious incidence of *D. indica*, extent of damage caused, host range, natural enemies and management is reviewed.

2.1 INCIDENCE

Substantial damage by the pumpkin caterpillar was recorded in green house cucumbers and melons in Japan (Shimizu, 2000, Kinjo and Arakaki, 2002). The damage inflicted by the pest surged with the increasing cultivation of cucurbitaceous vegetables in Korea (Ministry of Agriculture and Forestry, 2001). Severe incidence of the pest was noted in the Northern Territory of Australia (Morgan and Midmore, 2002), Asia and Africa (EPPO, 2005).

In India, an outbreak of the pest was observed in cucurbit gardens in Anand district of Gujarat during July 2003 and 2004 (Jhala et al., 2004).

2.1.1 Extent of Damage

Studies conducted in Gaum indicated that the yield loss due to infestation of the pest was approximately 10 per cent with one larva per leaf. The loss increased linearly as population exceeded above one larva per leaf (Schreiner, 1991).

Investigations on the damage and control threshold of the cotton caterpillar in a cucumber greenhouse in Korea revealed that the consumption quantity of the second, third, fourth and fifth instars was 21.5, 706.5, 753.5 and 124.0 mm^2, respectively. The plant height did not differ at 44 days after the larval release, but was significantly different at 73 days. The leaf damage ratio was significantly different from 15 to 73 days after the larval release. The fruit yield was 48.2 kg for one larva, 42.7 kg for 2 larvae, 33.7 kg for 4 larvae, 29.8 kg for 6 larvae, 17.3 kg for 8 larvae, 14.5 kg for 10 larvae, and 13.7 kg for 12 larvae when the 2nd-3rd instars were released at different densities. The fruit damage when observed at 44 days after release of the pest was 0, 0, 0, 3.0, 4.8 7.4, 8.3 for one, 2, 4, 6, 8, 10 and 12 larvae, respectively. There was a positive relationship between leaf area and degree of damage by the caterpillar (Jeon et al., 2006).

In India, the damage by the pest to the fruits of little gourd and bitter gourd was recorded to be 90 and 60 per cent, respectively from Gujarat. In pointed gourd, the damage by the larvae was restricted to the leaves only and it was 25-30 per cent (Jhala et al., 2004). An experiment conducted in Bhubaneswar, Orissa, India, during January-April 2004 to study the seasonal incidence of *D. indica* revealed that the population varied from 5- 23 per 100 fruits, which was lower in January and increased in subsequent days. The pest population showed a positive correlation with the maximum temperature and negative correlation with humidity. The highest number of larvae was observed in March, when harvesting was at its peak. Fruit infestation ranged between 3 and 14 per cent (Singh and Naik, 2006).

Field trials conducted for two seasons on the pest complex of snake gourd in Kerala revealed the prevalence of *D. indica* during two seasons and in all stages of the crop with mean value ranging from 1.67 larvae per plant in the vegetative stage during the second season to 3.67 larvae per plant during the flowering stage of the first season. The number of larvae increased as the plant matured (Sivakumar, 2001).

2.1.2 Nature of Damage

The pumpkin caterpillar is mainly a leaf feeder. However, it was also observed to feed on tender stems, flowers and fruits of cucurbitaceous vegetables (Namvar and Alipanah, 2002).

On hatching, the young larvae clustered around the main veins, and fed on the chlorophyll, skeletonizing the leaves. Early symptoms of infestation were the development of lace-like patches of networks of intact small leaf veins. Later the larvae bound together the leaves and fed on them. The young and older larvae also bored into the ovaries of flowers and new tender shoots, thus damaging them. The pest also targeted young and developing fruits. Damage was most serious in the early stages of fruit formation, when the pests punctured the skin of young fruits, particularly where they touched leaves or the soil (Nair, 1970; Jhala et al., 2004). Well developed fruits with hard rinds often escaped attack (Patel and Kulkarny, 1956). Early instar larvae were found more on fruits than on leaves. On fruits they scraped the epicarp in early instars but bored near fruit base in later instars (Singh and Naik, 2006).

2.1.3 Host Range

D. indica preferentially attacks cucurbitaceous plants. However, literature updates indicate its penchant for other plant families.

Cucurbits

Almost all cucurbitaceous vegetables have been recorded as hosts of the pest. The growth and reproduction of *D. indica* varies depending on the kind of host plants. Studies on the oviposition and feeding preference of *D. indica* indicated that the caterpillars showed their preferences in the following order - cucumber (*Cucumis sativus* L.), gourd (*Lagenaria siceraria* (Mol.) Standley), water melon (*Citrullus lanatus* (Thunb.)), oriental melon (*Cucumis melo* var. makuwa), wax gourd (*Benincasa hispida* Thunb.), melon (*Cucumis melo* L.), star cucumber (*Sicyos angulatus* L.), sponge cucumber (*Luffa cylindrical* Mill.) and cotton(*Gossypium indicum* Medik.). The feeding and oviposition preferences towards cucumber and pumpkin (*Cucurbita moschata* Duchesne ex Poir.) were greater than those towards water melon, oriental melon and melon There was a positive relationship between the leaf area and the degree of damage by the cotton caterpillar (Choi et al., 2003). Life table studies revealed that cucumber and pumpkin were the most preferred host plants of cotton caterpillar. The adults laid eggs more on mature leaves than on aged and developing leaves. They laid more on leaves than on petiole and stem, and more on the adaxial than on the abaxial surface side of the leaves. The developmental periods of egg and larva fed on oriental melon, melon and pumpkin were longer than those on water melon and cucumber. The hatchability rate was the highest on cucumber (87.2 per cent) and lowest on melon (72.8 per cent) where as the average number of eggs per female was the highest on cucumber (281.8) and least on oriental melon (96.6).The survival rate from hatching to emergence on water melon (76.00 per cent) was the highest, and the lowest on cucumber (50.00 per cent) (Shin et al., 2002).

Varietal differences in the preference were noticed in the three snake gourd varieties *viz*., Kaumudi, TA-19 and a local cultivar. Kaumudi showed the lowest incidence of the pest as the plant matured (Sivakumar and Jiji, 2002).

Other host plants

The pest was recorded from other plant families, notably Leguminosae and Malvaceae (EPPO, 2005). It damaged plants like beans (*Phaseolus* spp.), Indian mustard (*Brassica juncea* var. *juncea* (L.)) and pigeon pea (*Cajanus cajan* (L.) Millsp.), okra (*Abelmoschus esculentus* (L.) moench.), passion fruit (*Passiflora edulis* Sims), short staple cotton (*Gossypium* spp.) (Yasui, 2002) and cowpea (*Vigna unguiculata* (L.)) (Sankar, et al., 2005). *Murrraya* sp., *Oscimum basilicum* (L.), *Sechium edule* (Jacq.) Swartz and *Thymus vulgaris* L. were also recorded as the host plants of *D. indica*. (Solis, 2006).

In a study conducted at Hisar, Haryana, India, during the kharif of 2001, cowpea (cultivars CS 88, Pusa Phalguni and HFC 42-1) grown under protected and unprotected conditions, was observed to be a host plant of *D. indica* (Sankar et al., 2005)

2.1.4 Natural Enemies of *D. indica*.

Natural enemies constitute the first line of defense against pests in any ecosystem. Both predators and parasitoids flourish in the field. However, only a few natural enemies have been recorded for this pest.

Predators

In a survey conducted for the natural enemies associated with the pumpkin caterpillar in India, 20 species of parasitoids, predators and pathogens were recorded. Ants and spiders comprised the predators identified (Peter and David, 1991 b). Common mynah (*Acridotheres tristis* Linnaeus.) and cattle egret (*Bubulcus ibis* Linnaeus.) were found predating on larvae of *D. indica* (Jhala etal., 2004).

Parasitoids

Two years systematic sampling from 1985 to 1986 in the vegetable fields of a Hangzhou suburb of China showed that, *Trichogramma confusum* Viggiani was a major natural enemy of the melon worm. Each year, the eggs of the pests were heavily parasitized by the parasitoid during late August, September and October. The rates of parasitization at their peaks reached nearly 100 per cent for periods of more than ten days. An analysis based on both field and laboratory data indicated that temperature was the major meteorological factor determining the abundance and rates of parasitisation of *T. confusum* in the field (Liu and Li, 1988). Two species of braconid endoparasitoids (*Elasmus indicus* Rohwer and *Apanteles taragamae* Viereck) and an unidentified ichneumonid endoparasitoid were found to parasitize larvae of *D. indica* in the field in Sri Lanka. Due to the high level of parasitism by *E. indicus* (58.5 per cent) the damage to snake gourd was not severe (Ganehiarachchi, 1997).

Sixteen parasitoids were reported specific for *D. indica*. Most of them belonged to the families Braconidae, Ichneumonidae, Bethylidae, Elasmidae and Chalcididae (Peter and David, 1991 b). *Goniozus sensorius* Gordh (Hymenoptera : Bethylidae) a gregarious ectoparasitoid of *D. indica* parasitized 7.26 hosts on an average (Peter and David, 1991 a). *Aphanogmus fijiensis* (Ferriere) (Hymenoptera: Ceraphronidae) was recorded as a hyperparasitoid through *G.sensorius* *A. taragamae* was reported as a gregarious endo parasitoid. The mean number of adults emerging from each host was 14.61. *Tetrastichus pantnagarensis* Khan (Hymenoptera : Eulophidae) was noted as a hyper parasite of *D. indica* through *A. taragamae* (Hymenoptera : Braconidae) (Peter and David, 1990).

Studies on the population dynamics of *D. indica* revealed that April-September was the peak period of incidence of the pest while November-February was the lowest. The biotic mortality factors recorded were parasitism by *A. taragamae, A. machaeralis* Wilkinson (Hymenoptera: Braconidae), *G. sensorius, Trathala flavoorbitalis* (Cam.) (Hymenoptera: Ichneumonidae), *Elasmus brevicornis* Gahan (Hymenoptera: Elasmidae) and *Phanerotoma hendecasisella* Cam. (Hymenoptera: Braconidae). Among these, *A. taragamae* was the key mortality factor of *D. indica.* The study also revealed that only two of the six parasites exercised an important role in the population dynamics of *D. indica.* The combined action of these two parasites from January to March and October to December was significant in keeping the population index lower than during the months when these parasites were absent (Peter and David, 1991 c).

Four natural enemies *viz*, *Trichogramma chilonis* Ishii., *Dolichogenidea stantoni* (Ashmead), larval pupal parasitoid *Xanthopimpla punctata* (Fabricius) and the entomopathogen *Nomuraea rileyi* (Farlow) Samson were recorded from the eggs and larval stages of the pest in pickling cucumber (*Cucumis anguria* L.) from Karnataka, India (Visalakshy, 2005).

2. 2 MANAGEMENT

Suitable management options are the key to sustainable pest management. Various tactics like chemical, botanical and biological methods have been explored for the effective management of *D. indica*.

2.2.1 Botanical Insecticides

The efficacy of plant products in managing the pest has been documented. Turpentine oil, citriodore oil from *Eucalyptus citriodora* (Hook.) and ageratochromene from *Ageratum conyzoides* L. showed antifeedant activity against caterpillars of *D. indica* at the concentration of 1000 mg kg^{-1}. The selective anti-feeding rates of the oils, within 24 hours were 61.78, 66.58 and 86.39 per cent respectively. Their non-selective anti-feeding rates after 24 hours decreased by 37.7, 42.76, and 75.03 per cent .The residual effect of ageratochromene was the greatest, but that of turpentine oil and citriodore oil was only about one day due to the high volatility of the oils (Qin et al., 2001)

Spraying with acetone extract of *Vitex negundo* Linn 0.05% leaves resulted in 100 per cent mortality of *D. indica* (Kalavathi et al., 1991). Application of neem oil 2.5% + garlic 20g l^{-1} was effective against the pest in snake gourd (Sivakumar, 2001). Contrarily, neem cake extract and multineem could not reduce the damage of *D. indica* when applied in farmer’s field (Singh and Naik, 2006).

Azadirachtin extracted from neem seeds by conventional and CO2 supercritical fluid extraction methods, at a concentration of 20 ìg ml^{-1}

displayed very high anti-feeding effects on the third and fifth instar larvae. The anti-feeding effects were significantly higher on the third instar larvae than on the fifth instar larvae (He et al., 2007).

2.2.2 Chemical Insecticides

Dicarzol 1lbs/ 100 Gals, mesurol 0.5 lbs/100 Gals, sevin 0.2%, sumicidin 0.05% and thiodan 0.05% were equally toxic to the fourth instar larva of *D. indica*, the extent of mortality being 16.66 per cent after 24 hours and 71.30 per cent after 48 hours (Banasihan, 1983). Treatments with carbaryl 0.2% and dimethoate 0.05% were effective in reducing larval population of *D. indica* on cucumbers in the field (Schreiner, 1991). Several insecticides including methomyl 750- 1125 g/ml , endosulfan 400 g/ ml, synthetic pyrethoids (cypermethrin 550- 760 g/ml, deltamethrin 400 – 500 g/ml and fenvalerate 375- 500 g/ml) carbaryl 1000 g/ml and dimethoate 660 g/ml were recommended for application on leaves and young fruits against the pest (Kim et al., 1993).

Twenty one per cent malathion EC 2000 times, the mixture of 40.7 % chlorpyrifos EC 1000 times and B-V WC 1000 times had the best control effects to *D. indica*, the control effects being 100 per cent even after five days of spray (Cheng, 1999). The efficacy of 98.45% dimethoate, 2.5 % and 98 % rotenone and 95 % tea saponin alone or in combination when tested on third and fourth instar larvae of *D. indica*, revealed that the mortality was greatest with dimethoate (16.39 per cent) applied with Potter's method. Mortality with topically applied pesticides was lower than with Potter’s methods. (Wang and Huang, 1999).

Small plot field tests of insecticides indicated that chlorpyrifos 1000 g/ml, fenvalerate 375- 500 g/ml, chlorfluazuron 750 g/ml and *B. thuringiensis* (Bt) had high toxicity to young instar larvae of the melon worm, but the effects of chlorfluazuron and Bt were relatively slow. The laboratory bioassay showed that chlorpyrifos was highly toxic to *Trichogramma* wasp, an egg parasitoid of the melon worm, while Bt was non-toxic. Repeated applications of chlorpyrifos or Bt for the control of the melon worm in different plots of autumn cucumber demonstrated that in the early stage of the crop, the melon worm was under effective control in all plots. As the season progressed, egg parasitism by parasitoids was low in plots treated with chlorpyrifos, while those in plots treated with Bt steadily increased, reaching over 70 per cent. Twelve days after insecticide application, the melon worm caused significant damage in plots which had been treated with chlorpyrifos, while the pest inflicted little damage in plots treated with Bt. Strategic application of selective insecticides can effectively conserve and enhance natural enemies, and thereby help to bring the melon worm under effective control (Yang, 2005).

Indoxacarb, methoxyfenozide, spinosad, emamectin benzoate and novaluron effectively controlled larvae of *D. indica* in the zucchini flowers (Kay, 2007). Bistrifluron exerted no effects on the eggs of *D. indica*. However, the larvae hatching from the eggs evidenced 100 per cent mortality within 24 hours. The insecticide was toxic to all the larval stages. When applied to the pupal stage, the chemical significantly affected the longevity and fecundity of the normally emerging adults. The application of high concentrations of bistrifluron (50 ppm) to young adults delayed their pre-oviposition periods. In addition, the longevity, fecundity and hatching rate were attenuated (Kim et al., 2007)

Indoxacarb at 30-40 g a.i. ha^{-1} was able to effectively protect both leaves and fruits of bitter gourd from the feeding damage of *D. indica* after five to six sprays at an interval of seven days. The protection offered by the treatment resulted in yields significantly higher than that from plots treated with lambdacyhalothrin at the rate of 250 g a.i. ha^{-1}. During peak infestation, indoxacarb application at the rate of 30 g a.i. ha^{-1} (3 g product/16) resulted in about 90 per cent larval control. The insecticide was superior to lambda-cyhalothrin 2.5 EC applied at the rate of 250 g a.i. ha^{-1} (16 ml product/16) which resulted in about 15 per cent control. Plants treated with indoxacarb at 3 g 16 l^{-1} of spray solution had 10-20 per cent damaged fruits. This did not differ significantly from the 13-18 per cent damaged fruits when 4 g of the same product was used. Lambdacyhalothrin applied at 16 g 16 l^{-1} resulted in 30-55 per cent damaged fruits. When no pesticide was applied, 73-74 per cent of fruits developed insect damage. Marketable yield was directly related to the pest control treatments. Unprotected, the crop produced 0.21 to 1.32 t ha^{-1} but when sprayed with indoxacarb at 3 g 16 l^{-1}, yield increased to 1.5 to 6.5 t ha^{-1}. Increasing the rate to 4 g 16 l^{-1} the yield obtained was 1.7 to 6.4 t of marketable fruits per hectare. These two yield levels from the treated plots were significantly better than 1.5-2.3 t ha^{-1} from the crop treated with lambda-cyhalothrin at the rate of 16 ml 16 l^{-1} spray solution (Dupo et al., 2006).

The effect of synthetic pyrethroids on pests of bitter gourd and snake gourd were studied using deltamethrin and fenvalerate at 15 g a.i ha^{-1} in Kerala. These compounds could superiorly control the pumpkin caterpillar (Sivakumar and Jiji, 2001).

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2.2.3 Biological Control

Spore suspension containing 6.25 x 10^9 spores of Bt per 100cc controlled *D. indica* (Thomas, 1965). Mortality with 12, 000 IU mg^{-1} of Bt insecticide was highest at 31.52 per cent on 3rd-instar larvae and 20 per cent on 4th-instar larvae (Wang and Huang, 1999). Entomophilic nematodes were effective in the control of the cotton caterpillar, *D. indica*. *Steinernema carpocapsae* Pocheon strain was more effective against *D. indica*. When *S. carpocapsae* was treated at the rate of >20 infective juveniles (ijs)/larva, mortality was approximately 100 per cent at the first to fourth instars of *D. indica* in 72 hours (Kim et al., 2001).

A nuclear polyhedrosis virus (NPV) infecting *D. indica* infesting gherkins (*Cucumis anguria* L.) was reported for the first time from India. The pathogenicity of this NPV was shown through leaf surface contamination technique at a rate of $1x10^6$ polyhedral occlusion bodies ha^{-1} (Narayanan and Veenakumari, 2003).

2.2.4 Other Methods

Hand picking and destroying the larvae was recommended for the control of the pest (Nair, 1970).

Frequency vibration type trap lamp could control *D. indica* (Guang et al., 2000). For the monitoring of the cotton caterpillar adults using sex pheromone compounds, different mixture ratios of the pheromones (E)-11-hexadecenal and (E, E)-10, 12-hexadecadienal when tested showed that 7:3 ratio of (E)-11-hexadecenal and (E, E)-10, 12-hexadecadienal was more attractive than any other ratio, followed by 6:4, 8:2, 9:1, and 5:5 mixtures(Choi et al., 2009). The Delta trap was the most sensitive trap to *D. indica.* Two traps per hectare (2 traps / ha) for small holdings and in field of uneven topography was observed to be the effective trap density (Russel, 2007).

A field experiment was conducted to determine the effect of mulching and earwig as biological control agent against cucurbit worm on musk melon. Two population rates of 30,000 earwig ha^{-1} and 20,000 earwig ha^{-1} were compared. The earwigs were released twice on plots mulched with either silver plastic or rice straw. Unmulched and with no earwigs released were also provided as control plants. The number of cucurbit worms was reduced on plants grown with rice straw mulch and released with 30,000 earwig ha^{-1} but the difference was found not significant with rate of 20,000 earwig ha^{-1}. Mulching and release of earwig also reduced population of other insects. Those plants grown with mulch and released with earwigs had significantly less cucurbit beetles and whiteflies. The highest number and weight of marketable fruits were recorded on silver plastic mulched-plants with earwigs released at 30,000 individuals ha^{-1} (Patricio et al., 2009).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Survey was conducted in the Kalliyoor panchayath, an important vegetable growing tract of Thiruvananthapuram district during 2009-2010 to document the incidence and damage of the pumpkin caterpillar on the major cucurbitaceous vegetables. Laboratory trials on the evaluation of botanical and newer molecules of insecticides were done in the Department of Entomology, College of Agriculture, Vellayani and the field trial at the Instructional Farm, Vellayani. The materials used and methods followed are described.

3.1 DOCUMENTATION OF INCIDENCE AND DAMAGE OF THE PUMPKIN CATERPILLAR

Vallamcode ward of Kalliyoor panchayath, where cucurbitaceous vegetables were extensively cultivated was selected for recording the incidence of *D. indica*. A preliminary survey was conducted in the ward and the occurrence of the pest in bitter gourd, snake gourd, cucumber and coccinia, the four common cucurbits of the State was noted. Other pests infesting the crops too were recorded. Ten plots (more than 25 cents) of each of the cucurbitaceous vegetables were identified at random for documenting the extent and nature of damage caused by the pest. The crops were observed during the vegetative, flowering & fruiting stages. Ten plants were selected at random and the extent of damage caused by the pumpkin caterpillar scored. The following scale (0-4) was adopted for cataloguing the damage.

Score	Per cent infestation
0	0
1	1-25
2	26-50
3	51-75
4	>76

The infestation index was calculated as

$$\text{Infestation Index} = \frac{\text{Sum of all scores}}{\text{Number of scores x Maximum score}} \times 100$$

The plant parts damaged by the caterpillar, other plants in the vicinity including crop plants and weeds infested by the pest, natural enemies, cultural practices adopted and plant protection measures practiced too were recorded.

3.2 ASSESSMENT OF EFFICACY OF BOTANICAL, CHEMICAL AND MICROBIAL INSECTICIDES

Six botanicals including two plant extracts, one plant oil and three commercial formulations and six newer molecules of insecticides and two microbials (Table1) were tested for their efficacy against the pest.

3.2.1 Rearing of *D. indica*

The pest was reared on bitter gourd leaves. Different larval instars of *D. indica* were collected from unsprayed fields and released on bitter gourd leaves kept in glass troughs (15 x 20 cm). The petioles of the leaves were wrapped with moist cotton to keep the leaves turgid. Caterpillars were released on to fresh leaves once in two days. The pupae were collected and kept in separate glass troughs. The emerging adults were again transferred to troughs (17 x 30 cm) containing bitter gourd twigs dipped in water contained in conical flasks for mating and egg laying. Cotton soaked in 10 per cent sugar solution was kept inside the trough for the adults to feed. The neonate larvae were transferred to bitter gourd leaves and reared as detailed above.

Table 1. Botanical, chemical and microbial insecticides evaluated for their efficacy against *Diaphania indica*

Trade name	Common name	Dose	Manufacturers
Botanicals			
Annona seed extract		5%	Preparation
Neem seed kernel extract		5%	Preparation
Neem oil emulsion		2%	Preparation
Anosom 1% EC	Anonin	2ml l^{-1}	Agrilife, (Hyderabad) AP
Derisom 2% EC	Karinjin	2ml l^{-1}	Agrilife, (Hyderabad) AP
NeemAzal T/S 1%EC	Azadirachtin	2ml l^{-1}	EID Parry (India) Ltd
Chemicals			
Success 480 SC	Spinosad	0.015 %	Dow AgroSciences India
Fame 480 SC	Flubendiamide	0.004%	Bayer crop science
Curacron 50 EC	Profenofos	0.05%	Syngenta India Ltd.
Pegasus 50WP	Diafenthiuron	0.02%	Syngenta India Ltd.
Hostathion 40 EC	Triazophos	0.05%	Bayer crop science
Hilhunter 55 EC	Chlorpyrifos 50% + Cypermethrin5%	0.05%	Hindustan insecticides Ltd.
Microbials			
Lipel - SP	*Bacillus thuringiensis. kurstaki*	2 g l^{-1}	Agrilife, (Hyderabad) AP
Racer BB	*Beauveria bassiana*	2 g l^{-1}	Agrilife, (Hyderabad) AP

3.2.2 Raising of Bitter Gourd Plants

Seeds of bitter gourd (var. Preethi) were sown in clay pots (15 cm diameter) filled with potting mixture (soil, sand and cowdung in 1:1:1 ratio) at the rate of three seeds per plot. The plants were watered daily. One- month- old plants were used for the various studies.

3.2.3 Preparation of Spray Solutions

Annona seed extract 5%

Annona seeds were ground into a coarse powder in a mixie. Fifty grams of the powder was steeped in 500 ml of water for 48 hours and filtered. Ordinary bar soap (5g) was sliced and dissolved in 500 ml of water to prepare soap solution. The filtered seed extract was added to the soap solution and stirred well to prepare annona seed extract.

Neem Seed Kernel Extract 5%

Neem seed kernels were ground into a coarse powder in a mixie and 50 g of the powder was taken in a small muslin cloth bag and dipped in 500 ml of water for 12 hours. The cloth bag was then squeezed repeatedly till the out flowing fluid turned light brownish. Sliced bar soap (5g) was dissolved in 500ml of water to prepare soap solution and the kernel extract was added to it and stirred well.

Neem Oil - Garlic Emulsion 2%

Soap solution was prepared by dissolving 5g sliced soap in 500 ml of luke warm water. Twenty ml of neem oil was added to it and mixed thoroughly to form an emulsion. Twenty gram of garlic was ground in 500 ml water, filled through muslin cloth and the extract was mixed with neem oil emulsion to get one litre of 2 per cent neem oil - garlic emulsion.

Commercial formulations

The required quantities of the botanical (Anosom, Derisom and NeemAzal T/S) and chemical insecticides (spinosad, flubendiamide, triazophos, diafenthiuron, hostathion and chlorpyriphos 50% + cypermethrin 5%) were pipetted out / weighed and mixed with 100ml of water. The solution was then mixed with the needed volume of water to prepare the spray solution.

3.2.4 Testing of efficacy

Topical application and release on sprayed leaf techniques were followed for testing the efficacy of the botanical and chemical insecticides.

3.2.4.1 Topical application

Ten third instar larvae of the pumpkin caterpillar were taken in a clean petri dish and the insecticide solutions sprayed directly on them with an atomizer. Larvae sprayed with water served as control. The treated larvae were kept exposed under a fan for the spray fluid to evaporate. The caterpillars were then carefully transferred to bitter gourd leaves kept in glass troughs as described in 3.1.1. Three replications were maintained for each treatment. Mortality of the caterpillars was recorded every 24 hours.

3.2.4.2 Release on sprayed leaves

Potted plants of bitter gourd maintained as described in 3.2.2 were sprayed with the botanical and chemical insecticides. Leaves of almost equal size were collected from each of the treated plants one, three, five, seven, nine, eleven, thirteen and fifteen days after treatment and placed in petri dishes. Five third instar larvae of *D. indica* were placed on each of the treated leaves. Two such leaves served as one treatment. Three replications were maintained for each treatment. The mortality of the caterpillars was recorded one day after exposure.

3.2.4.3. Testing on infested plants in the field

The promising botanical and chemical insecticides identified in the laboratory screening were further tested for their efficacy on pest infested bitter gourd plants in the field. A bitter gourd plant was selected at random from a bitter gourd crop and one square metre area was demarcated around the plant and sprayed with the chemical. Five replications were maintained for each treatment. Observations on the number of caterpillars were recorded on alternate days from one day after spraying to 15 days after spraying.

3.2.5 Field Evaluation

A field trial was conducted in bitter gourd to evaluate the effective botanical and chemical insecticides identified in the laboratory trial and two microbial insecticides in comparison with carbaryl.

3.2.5.1 Preparation of the field

Seeds of bitter gourd (variety – Preethi) obtained from the Department of Olericulture, College of Agriculture, Vellayani were used for the trial. The details of the trial were as follows.

Design	:RBD
Treatments	:8
Replications	:3
Plot size	:6 ×2 m
Spacing	:2 ×2 m

T_1- Annona seed extract 5%

T_2- Anosom 2ml l^{-1}

T_3- Flubendiamide 0.004%

T_4- Spinosad 0.015%

T_5- *Bacillus thuringiensis* 2g l^{-1}

T_6- *Beuveria bassiana* 2g l^{-1}

T_7- Carbaryl 0.15%

T_8- Untreated check

The crop was raised and maintained as per the package of practices recommendation of KAU (2007) except for the plant protection measures which were given according to the treatments fixed.

3.2.5.2 Preparation of spray solution

Spray solutions of the respective botanical, microbial and chemical insecticides were prepared as described in 3.2.3. The first application of the treatments was done eight weeks after sowing, when the pumpkin caterpillar was noticed. The second spray was given three weeks after the first spray.

3.2.5.3 Assessment of pest incidence

Observations on the incidence of pests were recorded daily. One square metre area was demarcated around the central plant in each plot and the number of caterpillars both on the fruits and leaves were counted. Harvesting of the fruits was done once in two days. The number and weight of fruits and the number of fruits damaged by *D. indica* and other pests were also recorded.

3.3. STATISTICAL ANALYSIS

Data of each experiment were analysed, applying suitable methods of analysis (Panse and Sukhatme, 1967). The data on mortality of the pest recorded under 3.2.4 were statistically analyzed after adjusting for mortality in the controls using Abbott’s formula (Abbott, 1925)

RESULTS

4. RESULTS

The pumpkin caterpillar, *D. indica* is proving to be an important pest of cucurbitaceous vegetables, posing serious threat to various cucurbits. Results of the studies conducted on the incidence and damage of the pest in four popular cucurbits of Kerala and the efficacy of botanical, microbial and newer molecules of insecticides in managing the pest are presented in Tables 2 to 13.

4.1 INCIDENCE OF PUMPKIN CATERPILLAR

The incidence of *D. indica* in bitter gourd, snake gourd, cucumber and coccinia, the four major cucurbits of Kerala during the different growth stages of the crops in the Kalliyoor panchayat of Thiruvanathapuram district is presented in Table 2A. The other important pests infesting the vegetables during the period too are depicted in Table 2B.

The pumpkin caterpillar was recorded from all the four cucurbits in varying intensities throughout the cropping period. The occurrence of the pest was noted during the active vegetative stage, flowering and early fruiting stages of the crops. In bitter gourd, incidence of the pyralid was moderate during the vegetative stage. Subsequently, the population increased causing high damage during the flowering and fruiting stages, incurring economic loss. In snake gourd and cucumber, the pest occurred in high densities in all the growth stages. On the other hand, incidence of the pest was low during the vegetative and flowering stages in coccinia and moderate during the fruiting stage.

The other important pests of bitter gourd recorded during the survey included the tobacco caterpillar *Spodoptera litura* Fabricius (Lepidoptera : Noctuidae); aphid, *Aphis gossypii* Glover (Hemiptera : Aphididae); epilachna beetle, *Epilachna septima* (F.)(Coleoptera : Coccinellidae); pumpkin beetle, *Aulacophora foveicollis* Lucas

Table 2 . Incidence of *Diaphania indica* and other pests in cucurbitaceous vegetable in Kalliyoor panchayat of Thiruvanathapuram district, 2010

A. *Diaphania indica*

Crop	Stage of occurrence	Pest density
Bitter gourd	Vegetative Flowering, Fruiting	Moderate High
Snake gourd	Vegetative , Flowering, Fruiting	High
Cucumber	Vegetative, Flowering Fruiting	High Moderate
Coccinia	Vegetative, Flowering Fruiting	Low Moderate

B. Other pests

Crop	Pest		Order	Family	Stage affected	Pest status
	Common name	Scientific name				
Bitter gourd	Tobacco caterpillar	*Spodoptera litura*	Lepidoptera	Noctuidae	V	Low
	Aphid	*Aphis gossypii*	Hemiptera	Aphididae	V, Fl	Low
	Epilachna beetle	*Epilachna septima*	Coleoptera	Coccinellidae	V, Fl	Low
	Pumpkin beetle	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	V, Fl	Low
	Leaf footed bug	*Leptoglossus australis*	Hemiptera	Coreidae	Fr	Low
	Fruit fly	*Bactrocera cucurbitae*	Diptera	Tephritidae	Fr	High
Snake gourd	Tobacco caterpillar	*Spodoptera litura*	Lepidoptera	Noctuidae	V	Low
	Epilachna beetle	*Epilachna septima*	Coleoptera	Coccinellidae	V	Low
	Pumpkin beetle	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	V, Fl	Low
	Snake gourd caterpillar	*Anadevidia peponis*	Lepidoptera	Noctuidae	V, Fl Fr	Moderate Low
	Fruit fly	*Bactrocera cucurbitae*	Diptera	Tephritidae	Fr	High
Cucumber	Pumpkin beetle	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	V, Fl, Fr	Moderate
	Fruit fly	*Bactrocera cucurbitae*	Diptera	Tephritidae	Fr	High
Coccinia	Pumpkin beetle	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	V	Low
	Leaf footed bug	*Leptoglossus australis*	Hemiptera	Coreidae	Fr	Low
	Fruit fly	*Bactrocera cucurbitae*	Diptera	Tephritidae	Fr	Low

V : Vegetative Fl : Flowering Fr : Fruiting

(Coleoptera : Chrysomelidae); leaf footed bug, *Leptoglossus australis* (Fabr.) (Hemiptera : Coreidae) and *Bactrocera cucurbitae* Coq. (Hemiptera : Tephritidae). The tobacco caterpillar occurred in low density during the vegetative stage. The aphid, epilachna beetle and pumpkin beetle were seen both in the vegetative and flowering stages in low populations. The major pests seen in the fruiting stage were the leaf footed bug and the fruit fly. While the attack of the fruit fly was very high, the leaf footed bug occurred in low density.

The important pests of snake gourd noted were *S. litura*, *E. septima*, *A. foveicollis*, *Anadevidia peponis* (Fb.) (Lepidoptera : Noctuidae) and *B. cucurbitae*. The tobacco caterpillar and the epilachna beetle were seen in low densities during the vegetative stage of the crop. The pumpkin beetle occurred in low densities during the vegetative and flowering stages. The snake gourd caterpillar was seen throughout the three growth stages. The population of the pest was moderate during the vegetative and flowering stages and low during the fruiting stage. The only important pest noted during the fruiting stage was the fruit fly which caused heavy damage.

The pumpkin beetle and the fruit fly were the other pests observed infesting cucumber during the survey. Only moderate damage of the leaves by the pumpkin beetle was recorded during the vegetative, flowering and fruiting stages. Fruit fly caused high damage during the fruiting stage.

The other pests observed infesting coccinia included *A. foveicollis* in the vegetative stage and *L. australis* and *B. cucurbitae* during the fruiting stage. All the pests occurred only in low densities in the crop.

4.1.1 Damage by *D.indica*

Apart from the fruit fly, the pumpkin caterpillar was also observed to cause economic damage to the crops. The extent of damage caused by the pest in bitter gourd, snake gourd, cucumber and coccinia during vegetative, flowering and fruiting stages of the crops in the Kalliyoor panchayat of Thiruvananthapuram district is presented in Table 3. The nature of damage in the various vegetables too is described.

Extent of damage

Among the vegetables surveyed, damage by the pest was significantly higher in bitter gourd, cucumber and snake gourd, the infestation index in the crops being 64.75, 63.47 and 61.27 per cent, respectively (Table 3). The extent of damage on all the three vegetables was on par. The extent of damage was significantly low in coccinia, the infestation index in the crop being 28.00 per cent. Between the three stages of the crops, damage was significantly higher during the fruiting stage (61.97 per cent), followed by the flowering stage (54.51 per cent). The attack of the pest was low in the vegetative stage of the crops (46.62 per cent).

Regarding the damage in the various cucurbits, significantly higher damage was recorded during the fruiting (67.50 to 100.00 per cent) and flowering (56.66 to 90.00 per cent) stages in bitter gourd, the mean infestation index being 74.75 and 70.49 per cent, respectively. The extent of damage during both the stages was at par. Comparatively, lower damage was seen in the vegetative stage (30.00 to 70.00 per cent), the mean infestation index computed being 49.00 per cent. All the crop stages *viz*., flowering (50.00 to 66.66 per cent), fruiting (46.66 to 75.00 per cent) and vegetative (55.00 to 70.00 per cent) were equally susceptible to the pest in snake gourd, the mean infestation index being 61.50, 57.99 and 64.33 per cent, respectively. In cucumber, high damage of the pest was seen both during the fruiting (53.30 to 85.00 per cent) and flowering (60.00 to 73.00 per cent) stages, the mean infestation index being 69.83 and 64.58 per cent, respectively. The extent of damage in the vegetative stage ranged from 50.00 to 63.33 per cent with a mean

Table 3. Extent of damage caused by *Diaphania indica* in cucurbitaceous vegetables in Kalliyoor panchayat of Thiruvanathapuram district, 2010

Crop	Infestation index (per cent)			
	Vegetative	Flowering	Fruiting	Mean
Bitter gourd	49.00 (30.00 -70.00)	70.49 (56.66 – 90.00)	74.75 (67.50 – 100.00)	64.75
Snake gourd	61.50 (55.00 - 70.00)	57.99 (50.00 – 66.66)	64.33 (46.66 – 75.00)	61.27
Cucumber	55.99 (50.00 –63.33)	64.58 (60.00 – 73.00)	69.83 (53.30 – 85.00)	63.47
Coccinia	20.00 (20.00)	25.00 (20.00 – 30.00)	39.00 (20.00 – 50.00)	28.00
Mean	46.62	54.51	61.97	

Figures in parentheses are range values.

CD Crop 4.22
CD Stage 3.65
CD (Crop x Stage) 7.31

infestation index of 55.99 per cent. Contrarily, in coccinia maximum damage was seen in the fruiting stage (20.00 to 50.00 per cent), the mean index being 39.00 per cent which differed significantly from that in the other stages. The extent of damage during the flowering (20.00 to 30.00 per cent) and vegetative (20.00 per cent) stages was at par, the mean infestation index being 25.00 and 20.00 per cent, respectively.

Concerning the damage in the different crop stages, during the vegetative stage, significantly higher damage was observed in snake gourd and cucumber followed by bitter gourd. Lower damage was seen in coccinia. During the flowering stage maximum damage was observed in bitter gourd followed by cucumber both being on par. It was followed by snake gourd. Least damage was recorded in coccinia. The damage was equally severe in bitter gourd, cucumber and snake gourd during the fruiting stages. Again the damage was lower in coccinia during the fruiting stage.

Nature of damage

The type of damage caused by the pumpkin caterpillar in the four vegetables is described herewith.

Bitter gourd

The leaves, fruits, flowers and tender stems were attacked by the pest. On the leaves, the first instar larvae clustered near the petiole end on the under surface on either side of the main vein and scraped the green matter. Consequently, the infested part turned transparent and leathery. Later, the skeletonised area dried up and dropped off, leaving holes on the leaves. The actively feeding third instar caterpillars moved to other leaves and cut and fed on them. Towards the pupation stage, the caterpillars folded the leaves and fed from within. Pupation was within the leaf folds (Plate 1). On the fruits, the early instar larvae aggregated

Plate 1. Leaves of bitter gourd damaged by *Diaphania indica*

in between the ridges and scraped the rind. Later, the larvae tunnelled into the fruits, leaving bored holes. When the attack was severe, the whole rind was destroyed, giving a shaved appearance to the fruits. At times, the damaged fruits turned yellow due to secondary infection by microbes, causing the fruits to rot and drop (Plate 2). On the flowers, the caterpillars bored into the ovaries and fed within turning them into a powdery mass.

Snake gourd

Both the leaves and fruits of snake gourd were attacked by *D. indica*. The mode of infestation on leaves was almost similar to that in bitter gourd. The young caterpillars clustered near the main vein on the under surface of the leaves and scraped the green matter, turning them leathery (Plate 3). At times the larvae skeletonised the entire leaf, reducing its photosynthetic efficiency. Pupation was within the leaf folds. On the fruit, the caterpillars scraped the outer skin (Plate 4). Honey dew like secretions exuded from the damaged part paving the way for secondary infection by fungus, leading to rotting of the fruits. The caterpillars also bored into the fruits and fed on the internal contents.

Cucumber

In cucumber, the pest mainly attacked the leaves. As in bitter gourd and snake gourd, the caterpillars clustered on the under surface of leaves and scraped the green matter. White leathery spots appeared intially on the upper surface of the leaves which later coalesced forming a membraneous area. Pupation was within leaf folds formed by the caterpillars (Plate 5).

Coccinia

Both fruits and leaves of coccinia were damaged by the pumpkin caterpillar. The early instar caterpillars congregated on the under surface

Plate 2. Fruits of bitter gourd damaged by *Diaphania indica*

Plate 3. Leaves of snake gourd damaged by *Diaphania indica*

Plate 4. Fruits of snake gourd damaged by *Diaphania indica*

Plate 5. Leaves of cucumber damaged by *Diaphania indica*

of the leaves feeding on the green matter and skeletonising the leaves. The later instars folded the leaves and pupated within. On the fruits, the caterpillars intially scraped the epicarp, rendering the fruits vulnerable to secondary infection. The caterpillars also bore into the fruits and fed on the internal contents (Plate 6).

4.1.2 Influence of Cultivation Practices on Pest Infestation

Certain cultivation practices like the spacing, cultural operations, fertilizers applied, plant protection measures adopted are seen to influence the attack of pests in crops. The effect of the fertilizers applied and insecticides used on infestation of *D. indica* in the different vegetables is presented in Tables 4 to 5.

4.1.2.1 Fertilizer application

The mode of fertilizer application varied among the farmers selected for the study. Some of them applied organic manures as basal dose and subsequently only fertilizers at various stages of the crop (more fertilizers). Others applied fertilizers only twice i.e. at the vegetative and flowering stages. Manures were given at frequent intervals during the fruiting stage (more manures).

Among the farmers selected for the study, 30 per cent applied more fertilizers and 70 per cent more manures in bitter gourd. Fifty per cent of the snake gourd farmers depended purely on fertilizers where as 50 per cent included more of manures. Sixty per cent of the cucumber and coccinia growers depended mostly on fertilizers where as 40 per cent applied more manures (Fig. 1).

Of the selected farmers, none applied the fertilizers at the dose recommended in the Package of Practices of Kerala Agricultural University (KAU, 2007) for any of the four crops. Sixty per cent of the bitter gourd farmers applied a higher dose whereas 40 per cent applied a lower dose than that recommended. All the snake gourd farmers applied

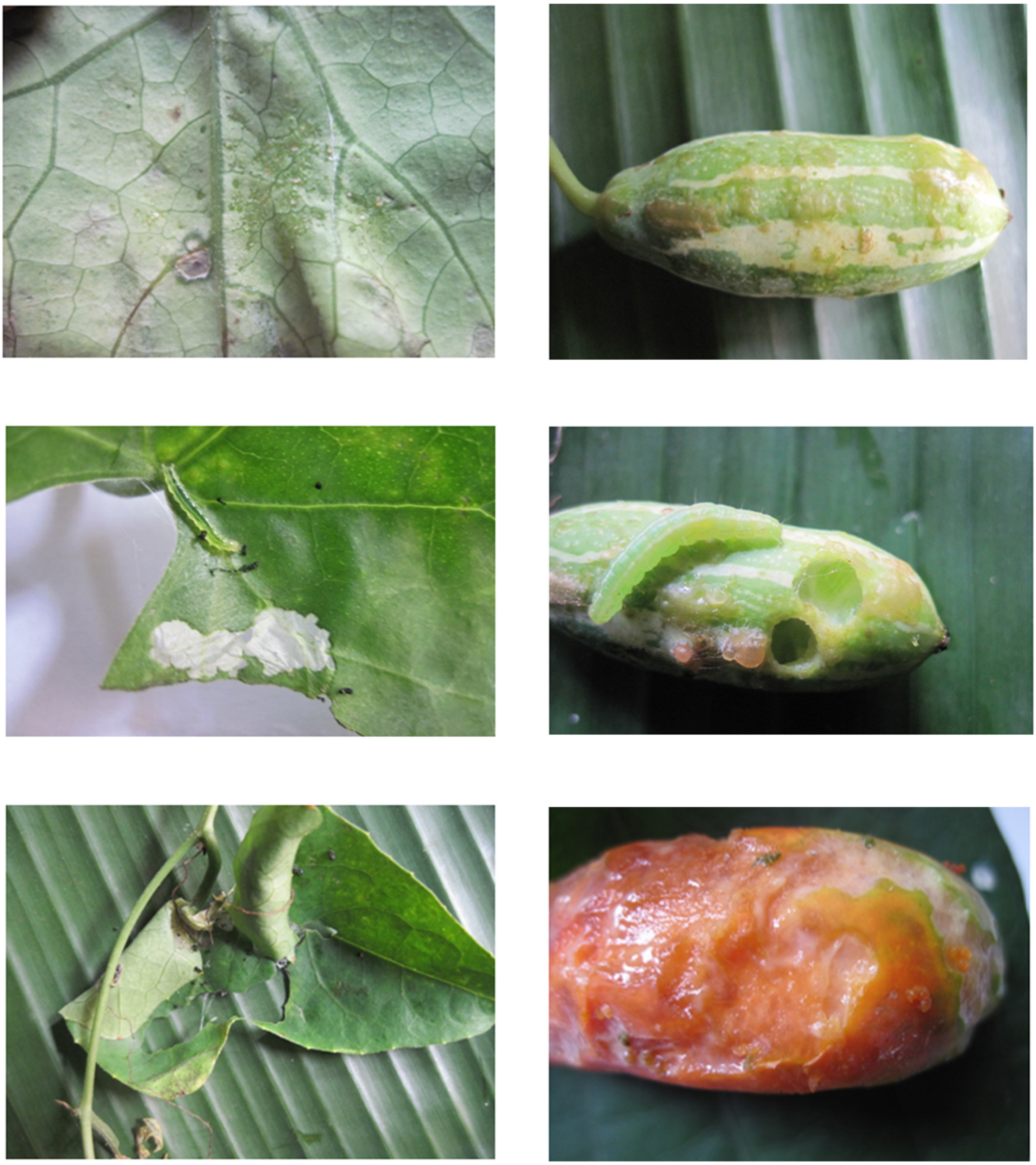


Plate 6. Leaves and fruits of coccinia damaged by *Diaphania indica*

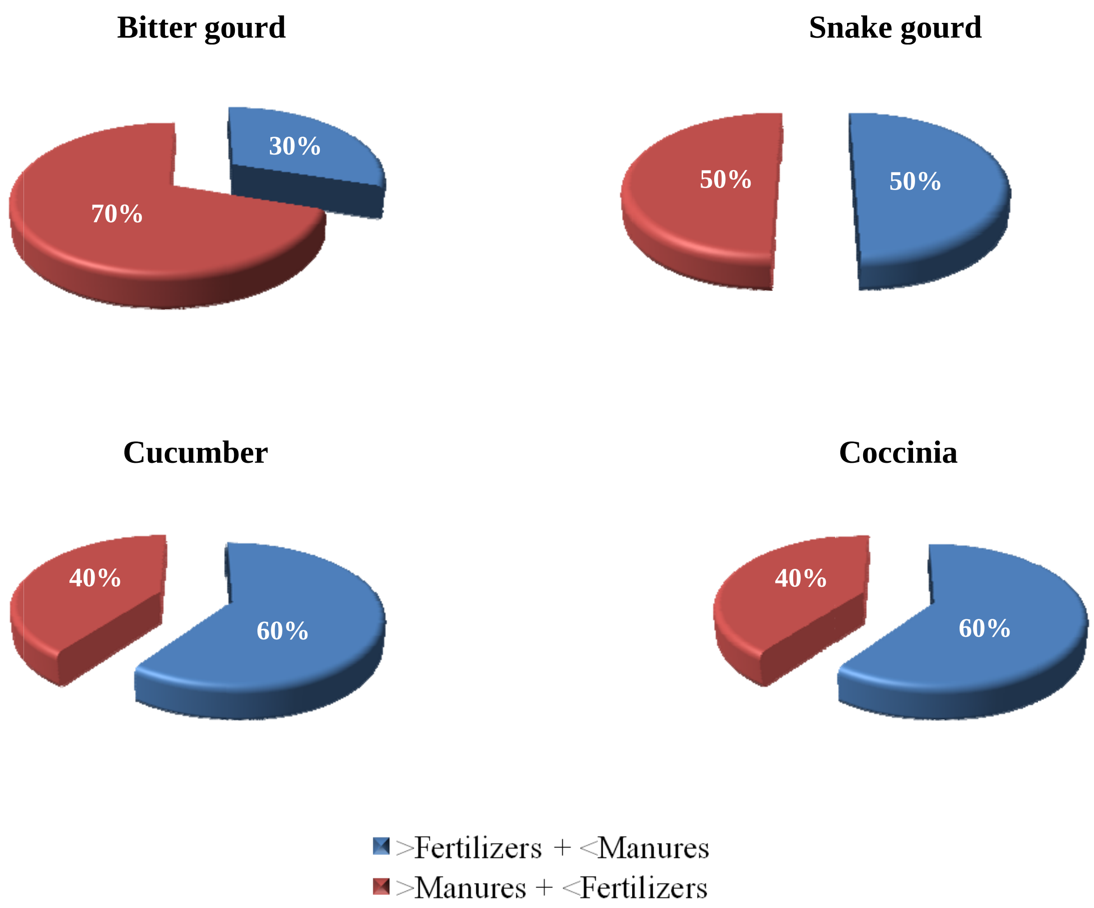


Fig. 1. Extent of application of fertilizers and manures in cucurbitaceous vegetables

a higher dose of fertilizers. In cucumber, 70 per cent of the farmers followed doses of fertilizers at a level higher than the package of practices where as 30 per cent followed a lower dose. In coccinia, 80 per cent of the farmers gave a higher level of fertilizer than the recommended level and 20 per cent a lower dose (Fig.2.)

The extent of infestation by the pest in the different vegetables did not show any noteworthy difference when more fertilizers or more manures were applied (Table 4). The mean infestation index ranged from 47.14 to 75.36 and 53.33 to 73.33 per cent in bitter gourd, 57.99 to 66.33 and 57.99 to 62.33 per cent in snake gourd, 54.17 to 72.50 and 57.22 to 68.05 per cent in cucumber and 20.00 to 42.50 and 20.00 to 36.67 per cent in coccinia when more manures and more fertilizers were applied, respectively. Similarly, the doses too did not significantly influence the extent of infestation. While the mean infestation index ranged from 41.66 to 76.25 and 45.00 to 72.50 per cent in bitter gourd, 57.99 to 64.33 per cent in snake gourd, 55.70 to 68.33 and 56.66 to 73.33 per cent in cucumber and 20.00 to 40.00 and 20.00 to 35.00 per cent in coccinia when fertilizers were applied at doses above and below that recommended in the Package of Practices (KAU, 2007), respectively.

4.1.2.2 Plant protection measures adopted

Seventy per cent of the bitter gourd farmers used insecticides alone to control the different pests of the crop where as 30 per cent combined insecticides and organic measures. Ninety per cent of the snake gourd growers and cucumber growing farmers used insecticides for plant protection. Only ten per cent used other measures. All the coccinia cultivators used only insecticides for pest management. Quinalphos, malathion, monocrotophos and dimethoate were the organophosphate insecticides used by the farmers. Carbaryl was the only carbamate insecticide used. The neonictinoid and synthetic pyrethroid applied were imidacloprid and fenvalerate, respectively (Fig. 3)

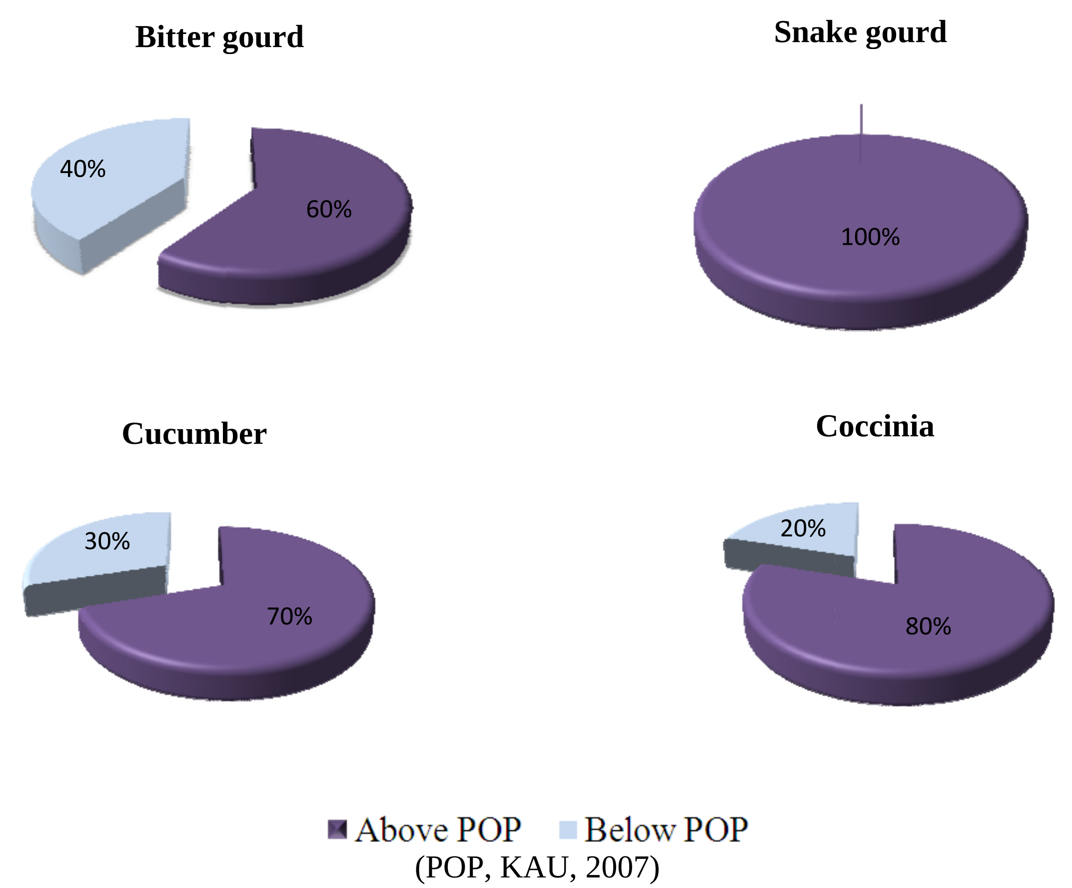


Fig. 2. Extent of application of different doses of fertilizers in cucurbitaceous vegetables

Table 6: Other host plants of *Diaphania indica*

Common name	Scientific name	Family
Red amarnath (*Cheera**)	*Amaranthus tricolor* Linn.	Amaranthaceae
Green amaranth (*Pachacheera**)	*Amaranthus dubius* Mart.ex.Thell	Amaranthaceae
Slender amaranth (*Kuppacheera* *)	*Amaranthus viridis* L.	Amaranthaceae
Bristly starbur (*Kaatu njerinjil* *)	*Acanthospermum hispidum* DC.	Compositae

*Vernacular name

Table 7. Effect of botanical insecticides on *Diaphania indica*

Treatments	Percentage mortality			
	1 DAT	3 DAT	5 DAT	7 DAT
Annona seed extract 5%	100.00 (10.04)	100.00 (10.04)	50.00 (7.14)	0.00
Neem oil garlic emulsion 2%	98.33 (9.88)	58.33 (7.59)	16.66 (4.20)	0.00
Neem seed kernel extract 5%	85.00 (9.15)	41.66 (6.45)	8.33 (3.05)	0.00
Anosom 2ml l^{-1}	100.00 (10.04)	100.00 (10.04)	100.00 (10.04)	100.00
Derisom 2ml l^{-1}	100.00 (10.04)	100.00 (10.04)	83.00 (9.16)	0.00
NeemAzal T/S 2ml l^{-1}	98.33 (9.72)	65.00 (8.10)	66.66 (8.22)	0.00
CD (0.05)	(0.36)	(0.45)	(3.03)	NA

Figures in parentheses are $\sqrt{x+1}$ transformed values

DAT : Days after treatment

NA : Not statistically analysed

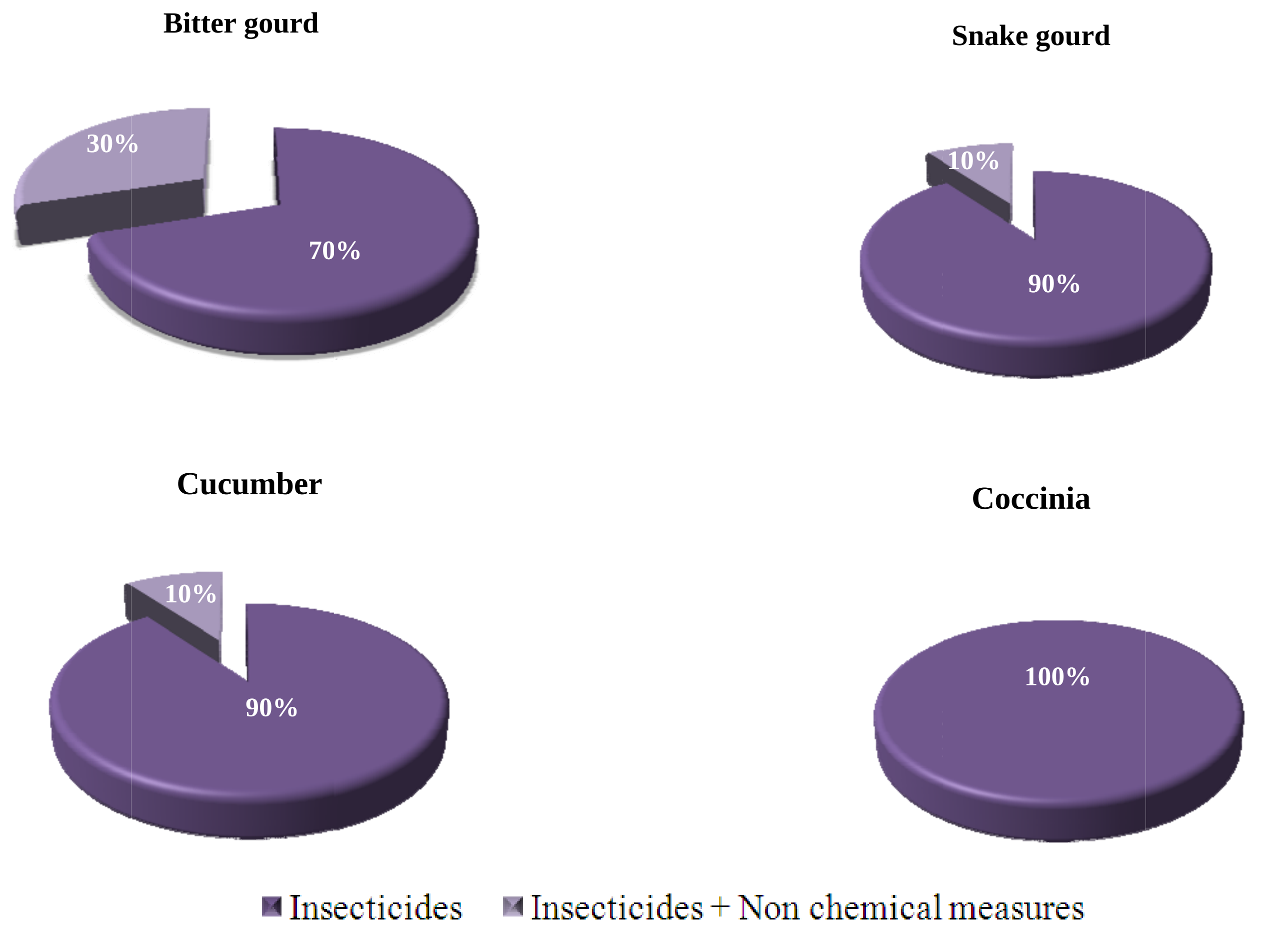


Fig. 3. Extent of adoption of different pest management measures in cucurbitaceous vegetables

Among the bitter gourd farmers using chemical insecticides, 57.14 per cent used organophosphates alone for pest management. 28.57 per cent used a combination of organophosphates and neonicotinoid and 14.28 per cent organophosphates + carbamate. Of the snake gourd farmers who applied insecticides, 33.33 per cent used synthetic pyrethroid alone, 33.33 per cent of organophosphates alone, 22.22 per cent organophosphates + carbamate and 11.11 per cent organophosphates + neonicotinoid. Among the cucumber cultivators, 55.55 per cent used synthetic pyrethroid and 22.22 per cent each of organophosphates and a combination of organophosphates + carbamate. In coccinia, 50 per cent of the farmers used synthetic pyrethroid, 30 per cent organophosphates + neonecotinoid and 20 per cent organophosphates + carbamate (Fig.4.).

The extent of infestation by the pest in the different vegetables did not show any noteworthy difference when insecticides + non chemical measures or insecticides alone were applied (Table 5). The mean infestation index ranged from 53.33 to 73.33 and 47.14 to 75.35 per cent in bitter gourd, 66.66 to 75.00 and 57.03 to 63.14 per cent in snake gourd, 53.33 to 73.33 and 56.29 to 70.92 per cent in cucumber when insecticides + non chemical measures or insecticides alone were applied, respectively. In coccinia, where only chemical insecticides were used for pest control the infestation index ranged from 20.00 to 39.00 per cent.

Marked differences were seen when different groups of insecticides were used for pest control. While the extent of infestation in fields where organophosphate insecticides alone were used ranged from 42.86 to 50.00 per cent, it was 14.29 and 21.43 per cent in organophosphates + carbamate and organophosphates + neonicotinoid applied plots, respectively. Similarly in snake gourd too, the extent of infestation was higher when organophosphates alone (25.93 to 33.33 per cent) and synthetic pyrethroid alone (22.22 to 33.33 per cent) were used than when organophosphates + carbamate (16.66 to 18.52 per cent) and organophosphates + neonicotinoid (9.11 per cent) were used. In

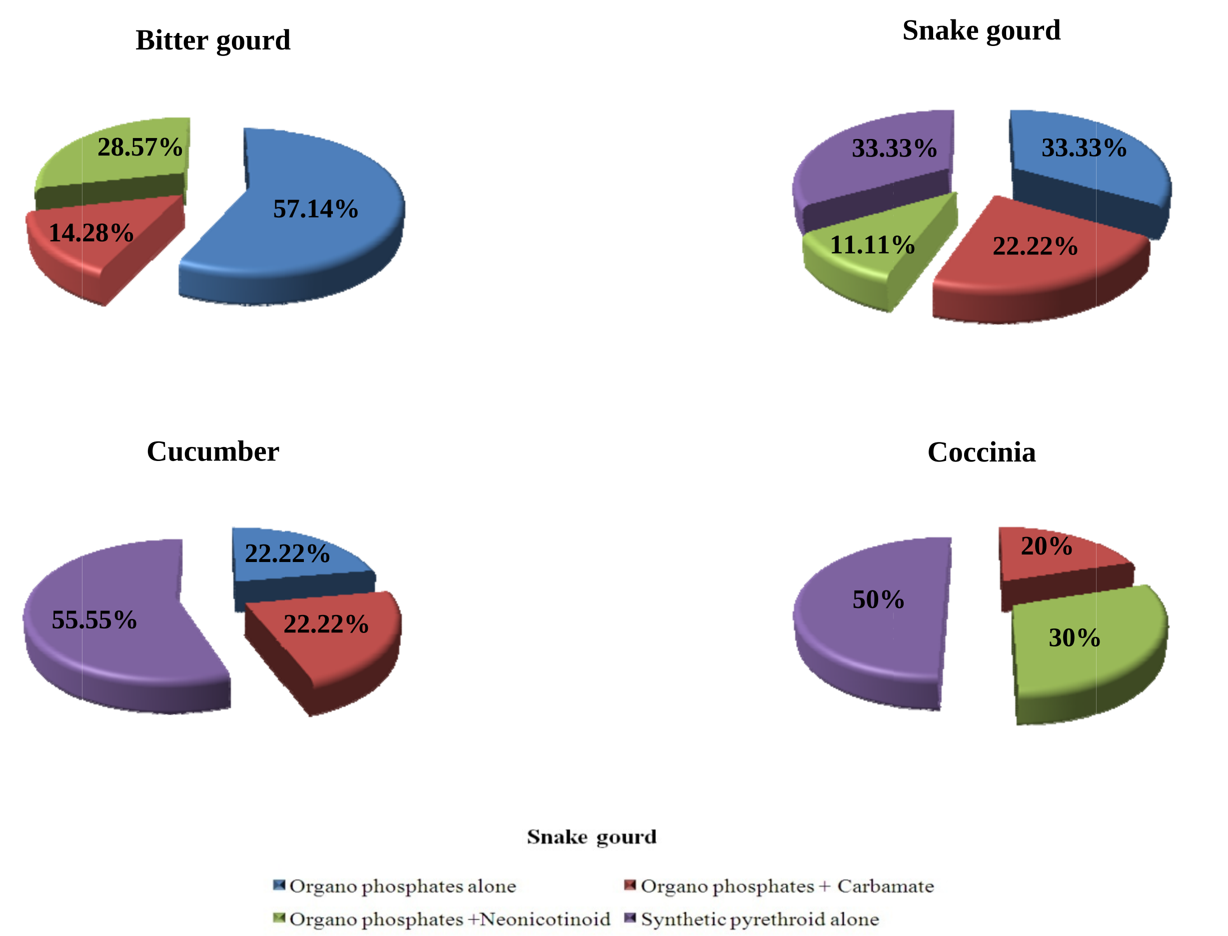


Fig. 4 Extent of application of different groups of insecticides in cucurbitaceous vegetables

cucumber, the extent of infestation was high in plots treated with synthetic pyrethroid (44.44 to 51.85 per cent). Comparatively the infestation was lower in organophosphates (16.66 to 22.22 per cent) and organophosphate + carbamate (14.81to 19.44 per cent) sprayed plots. In coccinia, when organophosphates + carbamate and organophosphates + neonicotinoid were sprayed, the extent of infestation recorded was 20 and 30 per cent, respectively.

4.1.3 Other Plants Infested by *D. indica*

Four plants found in the vicinity of the cucurbitaceous vegetables were found to be attacked by *D. indica* (Table 6). The plants noted were the red amaranth, *Amaranthus tricolor* Linn. (Amaranthaceae) and green amaranth, *Amaranthus dubius* Mart.ex.Thell. (Amaranthaceae); and the weed plants viz. slender amaranth, *Amaranthus viridis* L. (Amaranthaceae) and bristly starbur *Acanthospermum hispidum* DC. (Compositae).

The red and green amaranths were substantially damaged by the pest (Plate 7). The young caterpillars initially scraped the leaves, feeding on the chlorophyll. The infested area dried and dropped off. Later instars cut and fed on the leaves. Pupation was within leaf folds. High damage was also recorded in *A. viridis* and *A. hispidium* (Plate 8).

4.1.4 Natural Enemies

The parasitoid *Apanteles* sp. (Hymenoptera : Braconidae) was recorded parasitising the caterpillars during the survey.

4.2 MANAGEMENT

The results of the laboratory and field trials conducted on the relative efficacy of various botanical, chemical and microbial insecticides against the pumpkin caterpillar are presented in Tables 7 to 13.

Amaranthus tricolor

Amaranthus dubius

Plate 7. Leaves of *Amaranthus tricolor* and *Amaranthus dubius* damaged by *Diaphania indica*

Amaranthus viridis *Acanthospermum hispidum*

Plate 8. Leaves of *Amaranthus viridis* and *Acanthospermum hispidum* damaged by *Diaphania indica*

4.2.1 Laboratory Evaluation

The results of the laboratory trials conducted on the efficacy of various botanical and chemical insecticides against the pumpkin caterpillar are presented in Tables 7 and 8.

4.2.1.1 Effect of botanical insecticides

Topical application of annona seed extract 5%, neem oil garlic emulsion 2%, neem seed kernel extract 5%, Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and NeemAzal T/S 2ml l^{-1} resulted in 100 per cent mortality of the caterpillars three days after spraying.

When the caterpillars were released on leaves sprayed with the botanicals at different intervals, with the exception of neem seed kernel extract 5% which resulted in 85.00 per cent mortality of the larvae, all the other treatments were on par in their effect when the caterpillars were released one day after treatment (Table 7). Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and annona seed extract 5% resulted in 100 per cent mortality of the pest. NeemAzal T/S 2ml l^{-1} and neem oil garlic emulsion 2% recorded 98.33 per cent mortality.

Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and annona seed extract 5% resulted in 100 per cent mortality of the larvae on the third day after treatment. Release on leaves treated with NeemAzal T/S 2ml l^{-1} resulted in 65 per cent mortality followed by neem oil garlic emulsion 2% (58.33 per cent). The least effective treatment was neem seed kernel extract 5% (41.66 per cent) on the third day after treatment.

On the fifth day after treatment, again Anosom 2ml l^{-1} registered 100 per cent mortality and was on par with Derisom 2ml l^{-1} (83.33 per cent) and NeemAzal T/S 2ml l^{-1} (66.66 per cent). Derisom 2ml $l^{-1}$was also found to be on par with NeemAzal T/S 2ml l^{-1} and annona seed extract 5% (50.00 per cent) in its efficacy. Low mortality was noted in neem oil garlic emulsion 2% (16.66 per cent) and neem seed kernel

Table 6: Other host plants of *Diaphania indica*

Common name	Scientific name	Family
Red amarnath (*Cheera**)	*Amaranthus tricolor* Linn.	Amaranthaceae
Green amaranth (*Pachacheera**)	*Amaranthus dubius* Mart.ex.Thell	Amaranthaceae
Slender amaranth (*Kuppacheera* *)	*Amaranthus viridis* L.	Amaranthaceae
Bristly starbur (*Kaatu njerinjil* *)	*Acanthospermum hispidum* DC.	Compositae

*Vernacular name

Table 7. Effect of botanical insecticides on *Diaphania indica*

Treatments	Percentage mortality			
	1 DAT	3 DAT	5 DAT	7 DAT
Annona seed extract 5%	100.00 (10.04)	100.00 (10.04)	50.00 (7.14)	0.00
Neem oil garlic emulsion 2%	98.33 (9.88)	58.33 (7.59)	16.66 (4.20)	0.00
Neem seed kernel extract 5%	85.00 (9.15)	41.66 (6.45)	8.33 (3.05)	0.00
Anosom 2ml l^{-1}	100.00 (10.04)	100.00 (10.04)	100.00 (10.04)	100.00
Derisom 2ml l^{-1}	100.00 (10.04)	100.00 (10.04)	83.00 (9.16)	0.00
NeemAzal T/S 2ml l^{-1}	98.33 (9.72)	65.00 (8.10)	66.66 (8.22)	0.00
CD (0.05)	(0.36)	(0.45)	(3.03)	NA

Figures in parentheses are $\sqrt{x+1}$ transformed values

DAT : Days after treatment

NA : Not statistically analysed

extract 5% (8.33 per cent) and they were on par in their effect. Even on the seventh day after treatment, Anosom 2ml l^{-1} gave 100 per cent mortality and was the best treatment. No mortality of the pest was recorded in all the other botanicals.

4.2.1.2 Effect of chemical insecticides

Topical application of spinosad 0.015%, flubendiamide 0.004%, profenophos 0.05%, diafenthiuron 0.02%, triazophos 0.05% and chlorpyriphos 50%+ cypermethrin 5% 0.05% resulted in 100 per cent mortality of the caterpillars one day after treatment.

The chemical insecticides killed the larvae of *D. indica* to varying extent when released on the treated leaves (Table 8). All the insecticides gave 100 per cent mortality on the first day after release. On the third day after treatment, spinosad 0.015%, flubendiamide 0.004%, and diafenthiuron 0.02% and profenophos 0.05%, registered 100 per cent mortality. Triazophos 0.05% and chlorpyriphos 50%+ cypermethrin 5% 0.05% recorded 86.66 and 73.33 per cent mortality. On the fifth day, flubendimaide 0.004% and spinosad 0.015% gave 100 per cent larval mortality which was on par with profenophos 0.05% (86.66 per cent). These were followed by diafenthiuron 0.02% (60.00 per cent). Triazophos 0.05 % (26.66 per cent) and chlorpyriphos 50% + cypermethrin 5% 0.05% (33.33 per cent) were on par and they were the least persistent. Observations recorded on the seventh day after treatment showed that flubendiamide 0.004% and spinosad 0.015% gave 100 per cent mortality and were on par and differed significantly from all other treatments. Profenophos 0.05% (33.33 per cent) was closely followed by diafenthiuron 0.002% (26.66 per cent) and both the treatments were on par. No mortality of the caterpillars was recorded in triazophos 0.05% and chlorpyriphos 50%+ cypermethrin 5% 0.05%

On the ninth day too 100 per cent mortality of the caterpillars was registered in flubendiamide 0.004% treatment. Spinosad 0.015% also

Table 8. Toxicity of chemical insecticides to *Diaphania indica*

Treatments	Percentage mortality							
	1 DAT	3 DAT	5 DAT	7 DAT	9 DAT	11 DAT	13 DAT	15 DAT
Spinosad 0.015%	100.00	100.00	100.00 (10.04)	100.00 (10.04)	73.33	33.33	20.00	10.00
Flubendiamide 0.004%	100.00	100.00	100.00 (10.04)	100.00 (10.04)	100.00	80.00	73.33	33.33
Profenofos 0.05%	100.00	100.00	86.66 (9.36)	33.33 (5.79)	20.00	0.00	0.00	0.00
Diafenthiuron 0.02%	100.00	100.00	60.00 (7.73)	26.66 (5.18)	0.00	0.00	0.00	0.00
Triazophos 0.05%	100.00	86.66	26.66 (5.18)	0.00 (1.00)	0.00	0.00	0.00	0.00
Chlorpyrifos 50% + Cypermethrin5% (0.05%)	100.00	73.33	33.33 (5.85)	0.00 (1.00)	0.00	0.00	0.00	0.00
CD (0.05)	NA	NA	(1.23)	(1.04)	NA	NA	NA	NA

Figures in parentheses are $\sqrt{x+1}$ transformed values

DAT : Days after treatment

NA : Not statistically analysed

gave 73.33 per cent mortality of the pest. While 20 per cent mortality was observed in profenophos 0.05%, diafenthiuron 0.02%, triazophos 0.05% and chlorpyriphos 50% + cypermethrin 5% 0.05% did not show any mortality. Likewise on the eleventh and thirteenth days, flubendiamide 0.004% gave high mortality of the pest, the percentage mortality recorded in the treatments being 80 and 73.33, respectively. Spinosad 0.015% recorded only 33.33 and 20.00 per cent mortality during the period. No mortality was seen in all other treatments.

However, on the fifteenth day after treatment, low mortality was recorded in flubendiamide 0.004% (33.33 per cent) and spinosad 0.015% (10.00 per cent).

4.2.1.3 Testing on infested crop

The results on the efficacy of the two effective botanicals *viz*., Anosom 2ml l^{-1} and annona seed extract 5% and the newer molecules of insecticides *viz*. flubendamide 0.004% and spinosad 0.015% when tested under field conditions on bitter gourd plants infested with the pumpkin caterpillar are presented in Table 9 .

Both the insecticides, flubendamide 0.004% and spinosad 0.015% and the botanicals, Anosom 2ml l^{-1} and annona seed extract 5% reduced the population of the caterpillars significantly, the number of caterpillars recorded in the treatments being 0.00, 4.60, 2.60 and 6.60 per m^2, respectively as against 15.6 caterpillars per m^2 in the control plot, one day after spraying. Similarly, on the third, fifth and seventh day after spraying, no caterpillars were seen in the plots sprayed with the botanical and chemical insecticides.

However, on the ninth day after spraying, though all the treatments were superior to control, flubendamide 0.004% and spinosad 0.015%, differed significantly from the botanicals in their effect. While no pests was recorded from the treatments, 4.00 and 5.40 caterpillars per m^2 were seen in the Anosom 2ml l^{-1} and annona seed extract 5% treated

Table 9 . Population of *Diaphania indica* on bitter gourd plants treated with botanical and chemical insecticides

Treatments	Number of caterpillars / m^2							
	1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	11 DAS	13 DAS	15 DAS
Annona seed extract 5%	6.60 (2.75)	0.20 (1.09)	0.00 (1.00)	0.00 (1.00)	5.40 (2.52)	6.80 (2.79)	8.60 (3.09)	9.40 (3.22)
Anosom 2ml l^{-1}	2.60 (1.89)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.00 (2.23)	6.60 (2.75)	8.00 (3.00)	8.60 (3.09)
Spinosad 0.015%	4.60 (2.36)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Flubendiamide 0.004%	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Untreated	15.60 (4.07)	14.20 (3.89)	15.20 (4.02)	15.80 (4.09)	15.20 (4.02)	16.80 (4.21)	16.00 (4.12)	16.60 (4.19)
CD (0.05)	(0.31)	(0.18)	(0.21)	(0.10)	(0.18)	(0.18)	(0.16)	(0.22)

Figures in parentheses are $\sqrt{x+1}$ transformation

DAS : Days after spraying

plots, respectively. A similar trend was seen on the eleventh and thirteenth days after spraying. Again, no pests were seen in the insecticide treated plots. However, 6.60 and 8.00 and 6.80 and 8.60 caterpillars per m^2 were noted in the plots sprayed with Anosom 2ml $l^{-1}$and annona seed extract 5%, respectively. No pest was seen in the plots sprayed with chemical insecticides on the fifteenth day after spraying too. The botanicals were on par with control, the number of caterpillars recorded in Anosom 2ml l^{-1} and annona seed extract 5% being 8.60 and 9.40 per m^2, respectively.

4.2.2 Field Trial

The results of the field trial on the efficacy of the effective botanical, chemical and microbial insecticides in reducing the population of the pest and consequently increasing the yield of the plants is presented in Tables 10 to13.

4.2.2.1 Effect on pest population

First spray

Observations recorded after the first spray indicated that all the treatments reduced the population of the pumpkin caterpillar significantly (Table 10). Among the treatments, the insecticide flubendiamide 0.004% was the most effective, the mean number of caterpillars observed in the plot being 9.29 per m^2 as compared to 24.66 caterpillars per m^2 in the control plot. This was followed by spinosad 0.015% (12.79 caterpillars per m^2) which was on par with Anosom2ml l^{-1} (13.79 caterpillars per m^2). Application of annona seed extract 5% (14.54 caterpillars per m^2) was equally effective as Anosom 2ml l^{-1} in its efficacy in reducing the population of the pest. Annona seed extract 5% was also on par with carbaryl 0.15% (15.54 caterpillars per m^2) which in turn was on par with *B. bassiana* 2g l^{-1} (15.91 caterpillars per m^2) and *B. thuringiensis* 2g l^{-1} (16.29 caterpillars per m^2) in its efficacy.

Table 10. Relative efficacy of botanical, microbial and chemical insecticides in reducing the population of *Diaphania indica* on bitter gourd (after first spray)

Treatment	Number of caterpillars / m^2								
	1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	11 DAS	13 DAS	15 DAS	Mean
Annona seed extract 5%	11.33	7.00	8.00	10.00	14.66	18.00	21.66	25.66	14.54
Anosom 2ml l^{-1}	8.33	6.33	7.66	10.00	13.66	18.00	22.00	24.00	13.75
Bacillus thuringiensis 2g l^{-1}	23.33	12.33	5.66	8.33	13.66	19.00	22.66	25.33	16.29
Beauveria bassiana 2g l^{-1}	20.66	11.00	6.66	11.33	13.66	18.00	22.00	24.00	15.91
Spinosad 0.015%	8.33	7.66	8.66	9.00	11.33	14.00	21.33	22.00	12.79
Flubendiamide 0.004%	5.66	5.66	7.33	9.00	10.00	11.00	12.00	13.66	9.29
Carbaryl 0.15%	10.00	9.00	11.33	13.00	14.00	19.00	23.00	25.00	15.54
Untreated	24.33	26.00	27.00	23.00	22.00	24.00	25.00	26.00	24.66

CD Treatments 1.00
CD Days 0.66
CD (Treatments x Days) 1.87
DAS : Days after spraying

Considering the relative efficacy of the various treatments on the first day after spraying, flubendamide 0.004% with the least number of caterpillars (5.66 caterpillars per m^2) was the best treatment and the insecticide was superior to all other treatments. It was followed by spinosad 0.015% and Anosom 2ml l^{-1} which were on par with carbaryl 0.15% in reducing the pest population, the number of caterpillars recorded in the treatments being 8.33, 8.33 and 10.00 per m^2, respectively. Annona seed extract 5% (11.33 caterpillars per m^2), *B. bassiana* 2g l^{-1} (20.66 caterpillars per sq.m), *B. thuringiensis* 2g l^{-1} (23.33 caterpillars per m^2) also reduced the population of the pest significantly when compared to the control plot (24.33 caterpillars per m^2).

On the third day after spraying flubendiamide 0.004%, Anosom 2ml l^{-1} and annona seed extract 5% reduced the pest population significantly, the number of caterpillars recorded per m^2 in the treatments being 5.66, 6.33 and 7.00, respectively as against 26.00 per m^2 in the control plot. The three treatments were on par in their effect. Significant reduction in the number of caterpillars was also observed in spinosad 0.015% (7.66 per m^2), its efficacy being on par with Anosom 2ml l^{-1}, annona seed extract 5% and carbaryl 0.15% (9.00 per m^2). Compared to the untreated plot, significant reduction in the population of the pest was seen in the plots sprayed with the microbial insecticides *B. bassiana* 2g l^{-1} (11.00 caterpillars per m^2) and *B. thuringiensis* 2g l^{-1} (12.33 caterpillars per m^2)

The microbial insecticides *B. thuringiensis* 2g l^{-1} and *B. bassiana* 2g l^{-1} and the chemical insecticide flubendiamide 0.004% proved superior in reducing the pest population, the number of caterpillars recorded being 5.66, 6.66 and 7.33 per m^2, respectively on the fifth day after spraying. The treatments were closely followed by the botanicals Anosom 2ml l^{-1} (7.66 caterpillars per m^2) and annona seed extract 5%

(8.00 caterpillars per m^2) which were on par with spinosad 0.015% (8.66 caterpillars per m^2). Carbaryl 0.15% recorded 11.33 caterpillars per m^2 and was superior to untreated control (27.00 caterpillars per m^2).

Observations recorded on the seventh day after spraying indicated that the population of the pest was significantly reduced in *B. thuringiensis* 2g l^{-1} (8.33 caterpillars per m^2), flubendiamide 0.004% (9.00 caterpillars per m^2), spinosad 0.015% (9.00 caterpillars per m^2) Anosom 2ml l^{-1} (10.00 caterpillars per m^2) and annona seed extract 5% (10.00 caterpillars per m^2) treatments and the treatments were on par in their efficacy. *B. bassiana* 2g l^{-1} (11.33 caterpillars per m^2) too registered lower population of the pest and was on par with Anosom 2ml l^{-1} and annona seed extract 5% and carbaryl 0.15% (13.00 caterpillars per m^2) as against 23.00 caterpillars per m^2 in the control plot.

A significant reduction in the number of caterpillars per m^2 was seen in all the treated plots on the ninth day after spraying, compared to the control plot (22.00). Flubendiamide 0.004% (10.00 caterpillars per m^2) and spinosad 0.015% (11.33 caterpillars per m^2) were on par in their efficacy. Anosom 2ml/l (13.66 caterpillars per m^2), *B. thuringiensis* 2g l^{-1} (13.66 caterpillars per m^2), *B. bassiana* 2g l^{-1} (13.66 caterpillars per m^2), carbaryl 0.15% (14.00 caterpillars per m^2) and annona seed extract 5% (15.66 caterpillars per m^2) were on par and differed significantly from the control plot (22.00 caterpillars per m^2).

On the eleventh day after spraying, again lower number of caterpillars was recorded in flubendiamide 0.004% (11.00 caterpillars per m^2) treatment and the insecticide was superior to all the treatments. Spinosad 0.015% (14.00 caterpillars per m^2) too recorded lower population of the pest. Anosom 2ml l^{-1} (18.00 caterpillars per m^2), annona seed extract 5% (18.00 caterpillars per m^2) *B. bassiana* 2g l^{-1} (18.00 caterpillars per m^2) *B. thuringiensis* 2g l^{-1} (19.00 caterpillars per m^2) and carbaryl 0.15% (19.00 caterpillars per m^2) were at par in their efficacy. All the treatments reduced the population of the pumpkin caterpillar significantly when compared to the control plot (24.00 caterpillars per m^2).

Flubendiamide 0.004% sprayed plots (12.00 caterpillars per m^2) recorded significantly lower number of caterpillars on the thirteenth day after spraying too. Spinosad 0.015%, annona seed extract 5%, Anosom 2ml l^{-1}, *B. bassiana* 2g l^{-1}, *B. thuringiensis* 2g l^{-1} and carbaryl 0.15% treated plots with 21.33, 21.66, 22.00, 22.00, 22.66, 23.00 caterpillars per m^2 , respectively were on par. The number of caterpillars seen in the control plot was 25.00 per m^2.

On the fifteenth day too flubendiamide 0.004% with 15.66 caterpillars per m^2 proved superior in its efficacy against the pumpkin caterpillar followed by spinosad 0.015% (22.00 caterpillars per m^2). Higher numbers of caterpillars were recorded in all the other treatments (24.00 to 25.66 caterpillars per m^2).

Considering the relative residual toxicity of the botanicals, microbials and the insecticides, low population of the pest (6.33 to 11.33 caterpillars per m^2) was seen up to seven days in the plots treated with the botanicals. Thereafter, an increase in the population of the pest was seen in the plots which ranged from 13.66 to 25.66 caterpillars per m^2. In the microbial insecticide treated plots too, the decline in the population was seen from the third day after spraying which persisted up to seven days after spraying. Subsequently the population of the pest increased (13.66 to 25.33 caterpillars per m^2). Regarding the residual toxicity of the insecticides, the efficacy of flubendiamide 0.004% persisted up to 15 days as indicated by the low population in the treatment (5.66 to 13.66 caterpillars per m^2). Low population of the pest was recorded up to 11 days in spinosad 0.015% (7.66 to 14.00 caterpillars per m^2). In carbaryl 0.15% it was seen up to nine days after spraying (9.00 to 19.00 caterpillars per m^2).

Second spray

A similar trend in the efficacy of the treatments was noticed after the second spray too (Table 11). Again all the treatments reduced the population of the pest significantly when compared to the untreated plot (26.66 caterpillars per m^2). Flubendiamide 0.004% (11.41 caterpillars per m^2) was the most effective treatment and it differed significantly in its effect from all other treatments. Spinosad 0.015% (14.87 caterpillars per m^2) and Anosom 2ml l^{-1} (15.58 caterpillars per m^2) were on par in the effect. Annona seed extract 5% (16.50 caterpillars per m^2) too was equally effective as Anosom 2ml l^{-1} in reducing the pest population. Similarly, the microbials *B. bassiana* 2g l^{-1} (17.62 caterpillars per m^2) and *B. thuringinesis* 2g l^{-1} (18.33 caterpillars per m^2) were on par with the insecticide check *viz*. carbaryl 0.15% (17.62 caterpillars per m^2) in their efficacy.

One day after treatment, lowest population of the pest was recorded in the plot sprayed with flubendiamide 0.004% (8.00 caterpillars per m^2), the treatment being significantly superior to all other treatments. Spinosad 0.015% (10.00 caterpillars per m^2), Anosom 2ml l^{-1} (10.00 caterpillars per m^2) and carbaryl 0.15% (11.00 caterpillars per m^2) closely followed the treatment and were on par in their efficacy. A significant reduction in the population of the caterpillar was also recorded in carbaryl 0.15% and annona seed extract 5% (13.33 caterpillars per m^2) treatments when compared to the control plot (27.00 caterpillars per m^2). Comparatively, higher population of the pest was seen in the plots sprayed with the microbial insecticides *viz*. *B. bassiana* 2g l^{-1} (23.00 caterpillars per m^2) and *B. thuringiensis* 2g l^{-1} (25.00 caterpillars per m^2).

On the third day after spraying significant reduction in the pest population was observed in both flubendiamide 0.004% (7.33 caterpillars per m^2) and Anosom 2ml l^{-1} (8.66 caterpillars per m^2). It was closely

Table 11. Relative efficacy of botanical, microbial and chemical insecticides in reducing the population of *Diaphania indica* on bitter gourd (after second spray)

Treatments	Number of caterpillars / m^2								
	1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	11 DAS	13 DAS	15 DAS	Mean
Annona seed extract 5%	13.33	9.33	10.33	12.33	15.66	19.66	23.66	27.66	16.50
Anosom 2 ml l^{-1}	10.00	8.66	10.00	12.33	16.00	19.00	22.66	26.00	15.58
Bacillus thuringiensis 2g l^{-1}	25.00	14.00	8.00	10.66	15.33	21.33	25.00	27.33	18.33
Beauveria bassiana 2g l^{-1}	23.00	13.00	8.33	12.66	14.66	19.33	24.00	26.00	17.62
Spinosad 0.015%	10.00	9.33	10.33	11.33	13.66	16.33	23.66	24.33	14.87
Flubendiamide 0.004%	8.00	7.33	9.00	11.33	12.33	13.33	14.33	15.66	11.41
Carbaryl 0.15%	11.00	10.00	12.00	16.00	17.00	22.00	26.00	27.00	17.62
Control	27.00	27.33	27.00	24.66	25.00	26.00	28.00	28.33	26.66

CD (0.05) Treatments 0.89
CD (0.05) (Treatments x Days) 1.79

DAS : Days after spraying

followed by annona seed extract 5% (9.33 caterpillars per m^2), spinosad 0.015% (9.33 caterpillars per m^2) and carbaryl 0.15% (10.00 caterpillars per m^2). All the three treatments were on par with Anosom 2ml l^{-1} in their efficacy. Significant reduction in the population of the caterpillar was also seen in the microbial insecticides *B. bassiana* 2g l^{-1} (13.00 caterpillars per m^2) and *B. thuringiensis* 2g l^{-1} (14.00 caterpillars per m^2) when compared to the control plot (27.33 caterpillars per m^2).

Significant reduction in the number of caterpillars was observed in *B. thuringiensis* 2g l^{-1} (8.00 caterpillars per m^2), *B. bassiana* 2g l^{-1} (8.33 caterpillars per m^2) and flubendiamide 0.004% (9.00 caterpillars per m^2), the three treatments being on par in their efficacy on the fifth day after spraying. The population of the pest was substantially low in the plots sprayed with the botanical pesticides *viz*. Anosom 2ml l^{-1} (10.00 caterpillars per m^2) and annona seed extract 5% (10.33 caterpillars per m^2) and the treatments were on par with flubendiamide 0.004% in their efficacy. Compared to the control plot, (27.00 caterpillars per m^2) significant reduction in the number of caterpillars was also recorded in the plots prayed with carbaryl 0.15% (12.00 caterpillars per m^2).

On the seventh day after treatment significant reduction in the population of the pest was recorded in *B. thuringiensis* 2g l^{-1} (10.66 caterpillars per m^2), flubendiamide 0.004% (11.33 caterpillars per m^2), spinosad 0.015% (11.33 caterpillars per m^2), Anosom 2ml l^{-1} (12.33 caterpillars per m^2) and annona seed extract 5% (12.33 caterpillars per m^2) treatments. The treatments were on par in their effect. *B. bassiana* 2g l^{-1} too registered lower population of the pest and was on par with flubendiamide 0.004%, spinosad 0.015%, Anosom 2ml l^{-1} and annona seed extract 5%. The number of caterpillar recorded in carbaryl 0.15% was 16.00 caterpillars per m^2 as against 24.66 caterpillars per m^2 in the control plot.

Compared to the control plot (25.00 caterpillars per m^2), high reduction in the number of caterpillars was seen in all the treated plots on the ninth day after spraying. While flubendiamide 0.004% (12.33 caterpillars per m^2) and spinosad 0.015% (13.66 caterpillars per m^2) were on par in their efficacy, *B. bassiana* 2g l^{-1} (14.66 caterpillars per m^2) and *B. thuringiensis* 2g l^{-1} (15.33 caterpillars per m^2) were on par with spinosad 0.015%. The botanicals annona seed extract 5% (15.66 caterpillars per m^2) and Anosom 2ml l^{-1} (16.00 caterpillars per m^2) and carbaryl 0.15% (17.00 caterpillars per m^2) too registered significantly lower number of caterpillars and were at par with the microbial insecticides.

Eleven days after spraying again lower number of caterpillars were recorded in flubendiamide 0.004% (13.33 caterpillars per m^2) treatment and the insecticide was superior to all the treatments. Spinosad 0.015% (16.33 caterpillars per m^2) too recorded lower population while Anosom 2ml l^{-1} (19.00 caterpillars per m^2), *B. bassiana* 2g l^{-1} (19.33 caterpillars per m^2) and annona seed extract 5% (19.66 caterpillars per m^2) were on par. *B. thuringiensis* 2g l^{-1} (21.33 caterpillars per m^2) and carbaryl 0.15% (22.00 caterpillars per m^2) were at par in their efficacy. All the treatments reduced the population of the pumpkin caterpillar significantly when compared to the control plot (26.00 caterpillars per m^2).

On the thirteenth day too significantly lower number of caterpillars was seen in flubendiamide 0.004% sprayed plots (14.33 caterpillars per m^2). The number of caterpillars seen in Anosom 2ml l^{-1}, annona seed extracts 5%, spinosad 0.015% and *B. bassiana* 2g l^{-1} were 22.66, 23.66, 23.66 and 24.00 caterpillars per m^2, respectively and the treatments were on par. The number of caterpillars seen in *B. thuringiensis* 2g l^{-1} and carbaryl 0.15% treated plots were 25.00 and

26.00 caterpillars per m^2, respectively as against 28.00 caterpillars per m^2in the control plot.

On the fifteenth day too flubendiamide 0.004% with 15.66 caterpillars per m^2 proved superior in its efficacy against the pumpkin caterpillar. Though higher number of caterpillars was recorded in all the other treatments, spinosad 0.015% (24.33 caterpillars per m^2) and *B. bassiana* 2g l^{-1} (26.00 caterpillars per m^2) were significantly superior to control (28.33 caterpillars per m^2). Carbaryl 0.15% (27.00 caterpillars per m^2), *B. thuringiensis* 2g l^{-1} (27.33 caterpillars per m^2), annona seed extract 5% (27.66 caterpillars per m^2) and Anosom 2ml l^{-1} (26.00 caterpillars per m^2) were on par with control.

Considering the residual toxicity of the botanicals, microbials and the insecticides, low population of the pest (8.66 to 12.33 caterpillars per m^2) was seen up to seven days in the plots treated with the botanicals. Thereafter, an increase in the population of the pest was seen in the plots (15.66 to 27.66 caterpillars per m^2). Similarly in the microbial treated plots too the decline in the population was seen from the third day after spraying which persisted up to seven days after spraying (8.33 to14.00 caterpillars per m^2). Subsequently the population of the pest increased (14.66 to 27.33 caterpillars per m^2). Regarding the residual toxicity of the insecticides, the efficacy of the flubendiamide 0.004% persisted up to 15 days as indicated by the low population in the treatment (7.33 to 15.66 caterpillars per m^2). While low population of the pest was recorded up to 11 days in spinosad 0.015% (9.33 to 16.33 caterpillars per m^2), in carbaryl 0.15% it was seen up to nine days after spraying (10.00 to 17.00 caterpillars per m^2).

4.2.2.2 Effect on fruit damage

D. indica and *B. cucurbitae* were the important pests observed damaging the fruits of bitter gourd. Damage due to *D. indica* was significantly lower in all the treatments, when compared to the untreated plot. The extent of fruit damage was significantly low in *B. bassiana* 2g l^{-1}, flubendiamide 0.004% *B. thuringiensis* 2g l^{-1} and spinosad 0.015% treated plants, the percentage of fruits damaged in the treatments being 8.43, 9.86, 10.70 and 11.59, respectively as against 23.49 per cent on the untreated plot. The treatments were on par in their effect. Anosom 2ml l^{-1} (12.36 per cent), annona seed extract 5% (13.13) and carbaryl 0.15% (14.23 per cent) also resulted in significant reduction in the fruit damage and were on par in their effect. (Table 12).

There was no significant difference in the infestation of fruit fly in the various treatments, the percentage of fruits damaged ranging from 7.08 to 10.65 per plot in the different treatments as against 7.76 per cent in the untreated plot.

4.2.2.3 Yield

The data on the yield assessed in terms of number and weight of fruits are presented in Table 13. The maximum number of fruits was obtained from Anosom 2ml l^{-1} (347.66 per plot), followed by spinosad 0.015% (332.66 per plot), *B. thuringiensis* 2g l^{-1} (326.66 per plot), *B. bassiana* 2g l^{-1} (325.00 per plot), flubendiamide 0.004% (307.33 per plot), carbaryl 0.15% (301.00 per plot). Annona seed extract 5% differed significantly from all other treatments with the least number of fruits (280.33 per plot) and was on par with the control treatment (224.00 per plot).

Compared to 11.29 kg fruits per plot in the control plot, significantly higher yield was obtained from all the treated plots. All the

Table 12. Extent of fruit damage in bitter gourd plots treated with botanical, microbial and chemical insecticides

Treatments	Total number of fruits harvested	Number of fruits damaged /12 m^2			
		Diaphania indica		*Bactrocera cucurbitae*	
		Number	Per cent	Number	Per cent
Annona seed extract 5%	367.00	48.33	13.13	38.33	10.41
Anosom 2ml l^{-1}	441.66	55.33	12.36	38.66	8.72
Bacillus thuringiensis 2g l^{-1}	397.66	42.00	10.76	45.33	7.08
Beauveria bassiana 2g l^{-1}	396.33	33.33	8.43	35.33	9.56
Spinosad 0.015%	427.66	49.66	11.60	29.00	10.65
Flubendiamide 0.004%	379.66	37.00	9.86	28.00	9.21
Carbaryl 0.15%	386.33	55.00	14.23	30.33	7.85
Control	325.66	76.00	23.49	25.66	7.76
CD (0.05)	NA	14.82	3.78	NS	NS

NA: Not statistically analysed

NS : Not significant

Table 13 . Yield of bitter gourd in plots treated with botanical, microbial and chemical insecticide

Treatments	Marketable fruits		
	Number of fruits (per 12 m^2)	Weight of fruits	
		kg/12 m^2	t ha^{-1}
Annona seed extract 5%	280.33	15.72	13.10
Anosom 2ml l^{-1}	347.66	15.95	13.29
Bacillus thuringiensis 2g l^{-1}	326.66	15.66	13.05
Beauveria bassiana 2g l^{-1}	325.00	14.24	11.87
Spinosad 0.015%	332.66	15.08	12.56
Flubendiamide 0.004%	307.33	15.31	12.76
Carbaryl 0.15%	301.00	16.28	13.56
Control	224.00	11.29	9.41
CD (0.05)	58.31	2.61	2.17

treatments were on par in their effect, the yield obtained from the different treatments being 16.28, 15.95, 15.72, 15.66, 15.31, 15.08 and 14.24 kg per plot, respectively in carbaryl 0.15%, Anosom 2ml l^{-1}, annona seed extract 5%, *B. thuringiensis* 2g l^{-1}, flubendiamide 0.004%, spinosad 0.015% and *B. bassiana* 2g l^{-1}. While the tons ha^{-1} yield in the untreated plot was 9.41tons, it was 13.56, 13.29, 13.10, 13.05, 12.76, 12.56 and 11.87, in carbaryl 0.15%, Anosom 2ml l^{-1}, annona seed extract 5%, *B. thuringiensis* 2g l^{-1}, flubendiamide 0.004%, spinosad 0.015% and *B. bassiana* 2g l^{-1}, respectively.

DISCUSSION

5. DISCUSSION

The destiny of any agroecosystem at large is determined by the insect communities prevailing in it in time and space. Over the years, certain pests had established themselves indisputably in agro ecosystems as irrefutable major pests of the crops. However, the climatic swings and sophisticated cultivation practices, have fostered profound changes in the pest status in various crop fields. Several traditional major pests have been displaced and seemingly innocuous ones have surged forth, taking a heavy toll of the crops. World over, a similar phenomenon has occurred in cucurbitaceous vegetables recently. Hitherto a minor pest, the pumpkin caterpillar, *D. indica* has emerged as a serious threat to the cucurbits. The changing pest scenario warrants a thorough knowledge on the economic significance of the pest in terms of its population dynamics, extent of injury and consequent loss to the crop.

Reports on the incidence of the pest and consequent ravages on Cucurbitaceae have been trickling in from Kerala too. Considering the economic status of the crops, especially bitter gourd in the State, containment of the pest is imminent. Data on the incidence of the pest, extent of damage caused and other relevant information being pre requisites for formulating management schedules, a survey was conducted in the Kalliyoor panchayath, of Thiruvananthapuram district during 2009-2010 to document the incidence and damage wrought by the pumpkin caterpillar on the major cucurbitaceous vegetables of the State. Attempts were also made to identify botanical, microbial and chemical insecticides with novel action as a tool for confronting the pest.

5.1 PEST INCIDENCE

Incidence of the pumpkin caterpillar was recorded on bitter gourd, snake gourd, cucumber and coccinia in varying intensities throughout the cropping period. The occurrence of the pest was more during the active vegetative stage, flowering and early fruiting stages of the crops. In bitter gourd, incidence of the pyralid was moderate during the vegetative stage and high during the flowering and fruiting stages (Fig. 5a). Contrarily, the pest occurred in high densities in all the growth stages in snake gourd (Fig. 5b) and cucumber (Fig.5c). On the other hand, incidence of the pest was low during the vegetative and flowering stages in coccinia and moderate during the fruiting stage (Fig.5d). The observations corroborate earlier reports. The pest was observed to be a serious problem in cucurbits in the Northern Territory of Australia (Morgan and Midmore, 2002) and Asia and Africa (EPPO, 2005). Significant damage of the pest was recorded in *C. sativus*, *L. siceraria*, *C. lanatus*, *C. melo*, *B. hispida*, *S. angulatus* and *L. cylindrica* in Korea (Choi et al., 2003). Damage of the pest in snake gourd was reported from Kerala too. Infestation by the pest was found to increase as the plant matured (Sivakumar and Jiji, 2002).

The other pests of bitter gourd recorded included the tobacco caterpillar, *S. litura*; aphid, *A. gossypii*; epilachna beetle, *E. septima*; pumpkin beetle, *A. foveicollis*; leaf footed bug, *L. australis* and *B. cucurbitae*. Tobacco caterpillar, epilachna beetle, pumpkin beetle, snake gourd caterpillar, *A. peponis* and fruit fly were the pests seen associated with snake gourd. Pumpkin beetle and fruit fly were the important pests of cucumber observed. Only the pumpkin beetle and the fruit fly were observed infesting coccinia in low densities. With the exception of the fruit fly, all the other pests were seen either in low or moderate densities in these crops. Consequent to the dominance of the pumpkin caterpillar in the different vegetables, several of the other leaf feeders like epilachna beetle in bitter gourd, snake gourd caterpillar in snake gourd

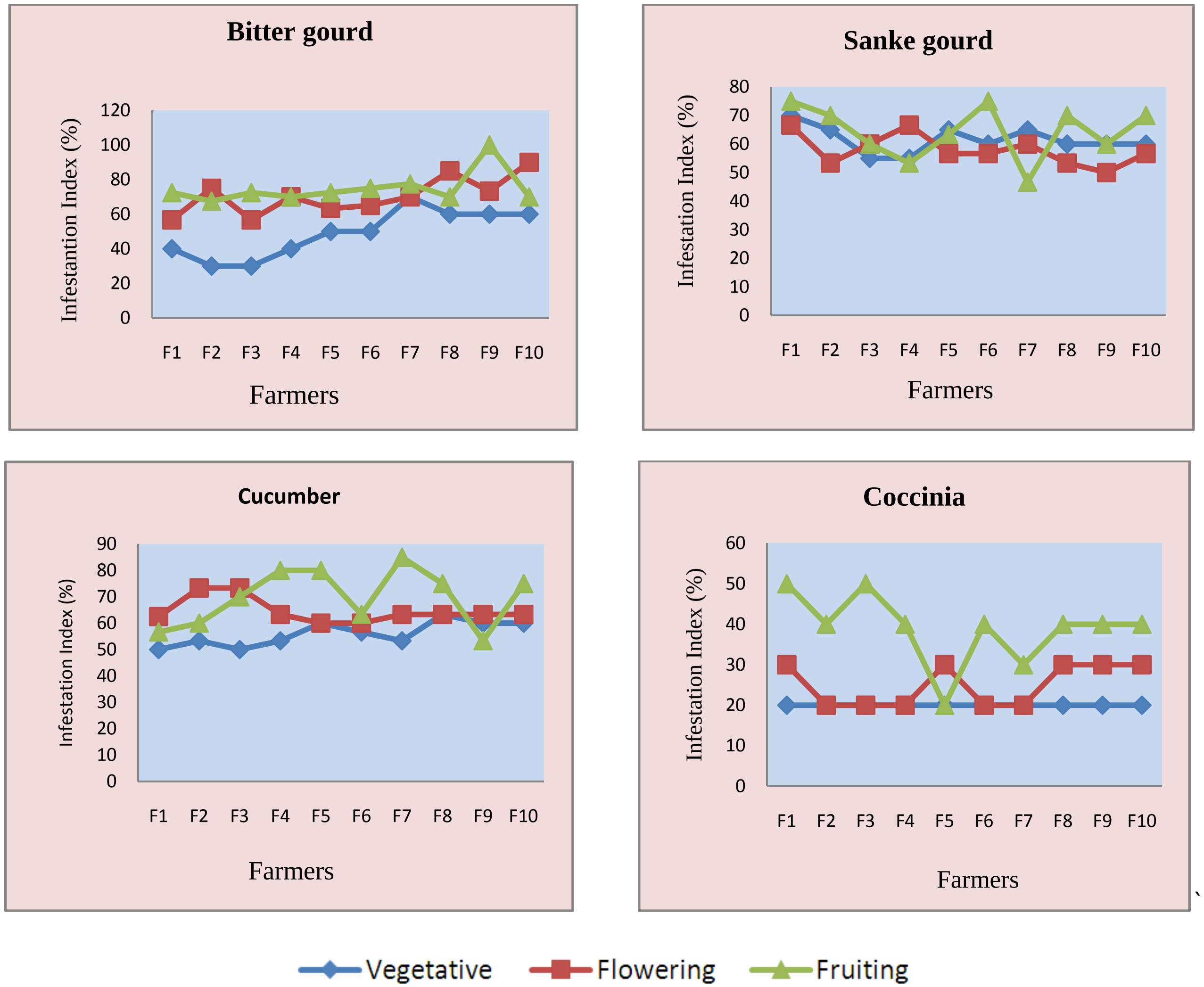


Fig.5. Infestation of *Diaphania indica* in cucurbitaceous vegetables in various farmers' fields

and pumpkin beetle in cucumber which are often seen in high densities were seen to maintain a low profile in the crops. Probably, this may be due to the competitive exclusion principle, which states that two species competing for the same resources cannot coexist if other ecological factors are constant. When one species has even the slightest advantage or edge over another, then the one with the advantage will dominate. This might have accounted for the comparatively lower population of the 'conventional' leaf feeders of bitter gourd, snake gourd and cucumber.

5.1.1 Damage

Information on the extent of damage a pest is capable of inflicting in a crop is highly essential. Concerning the extent of infestation by *D. indica* in the different vegetables, it was significantly higher in bitter gourd, cucumber and snake gourd (para 4.1.1). Lesser infestation was noted in coccinia. The damage in bitter gourd was significantly higher during the fruiting and flowering stages and low in the vegetative stage. All the crop stages *viz*., flowering, fruiting and vegetative were equally susceptible to the pest in snake gourd. High damage of the pest was seen both during the fruiting and flowering stages in cucumber. Contrarily, in coccinia maximum damage was seen in the fruiting stage. The extent of damage during the flowering and vegetative stages was low.

Literature on the relative damage of the pest in the various crop stages of cucurbitaceous vegetables is meagre. In a field study conducted at Anand district of Gujarat during July 2003 and 2004, the damage to the fruits of little gourd and bitter gourd was recorded as 90 and 60 per cent, respectively (Jhala et al., 2004). The extent of infestation recorded in bitter gourd (64.75 per cent) in the present study agrees with the report. However, with regard to the damage in little gourd (coccinia), only lower damage (28.00 per cent) was seen in the fruiting stage. Since the present study was confined to only one ward in a single panchayat of Thiruvananthapuram district, definite conclusions cannot be drawn from the data. Further studies are needed for confirmation of the results. The observations on the high infestation during the fruiting stage in bitter gourd conform to that of Singh and Naik (2006) who recorded the highest number of larvae and high fruit infestation in bitter gourd when harvesting was at its peak. Occurrence of *D. indica* in all stages of snake gourd was reported earlier from Kerala (Sivakumar, 2001) and the observations made in the present study are in agreement with the findings.

Regarding the nature of damage, the pest was seen infesting the leaves, fruits, and flowers of bitter gourd; leaves and fruits of snake gourd; leaves of cucumber and leaves and fruits of coccinia. The observations made conform to that of Namvar and Alipanah (2002) who reported that though primarily a leaf feeder, the pest also feeds on stems, flowers and fruits of cucurbitaceous vegetables.

The mode of infestation on the leaves and the symptoms manifested was almost the same in all the four vegetables. The early instar larvae congregated on the under surface of leaves on either side of the main vein, scraped the green matter, skeletonising the leaves. Later, the skeletonised part dried up and was shed off, leaving holes on the leaves. The actively feeding third instar caterpillars moved to other leaves and fed on them. Towards the pupation stage, the caterpillars folded the leaves and fed from within. Variations were seen in the feeding on fruits. On bitter gourd fruits, the caterpillars scraped the ridges giving it a shaved appearance in case of severe attack. In snake gourd, scraping on the fruit surfaces resulted in ‘honey dew’ like secretions which enhanced rotting of the fruit. No damage was noted on cucumber fruits. In coccinia, the caterpillars fed on the epicarp of the fruit. Subsequent to the surface feeding the caterpillars bored into the fruits of the vegetables and fed internally. Similar descriptions of the young larvae clustering around the main veins, skeletonizing the leaf, folding of leaves prior to pupation, feeding on flowers, new tender shoots and young and developing fruits have been made earlier (Patel and Kulkarny, 1956: Nair, 1970: Jhala et al., 2004: Singh and Naik, 2006).

5.1.2 Influence of Cultivation Practices on Pest Infestation

Crop husbandry practices like the spacing, cultural operations, fertilizers applied and plant protection measures adopted are seen to influence the attack of pests in crops especially the type and dose of fertilizer and plant protection measures (Reji, 2002). The effect of the type and quantity of fertilizers applied and insecticides used on infestation of *D. indica* in the different vegetables was studied. The type of fertilizer preferred by the farmers for the different cucurbits varied. While the bitter gourd growers used mostly organic manures (70 per cent), the snake gourd farmers depended on fertilizers (50 per cent) and organic manures (50 per cent) equally (Fig. 6). However, cucumber and coccinia growers depended mostly on fertilizers (60 per cent). Considering the dose, none applied the fertilizers at the dose recommended in the Package of Practices of Kerala Agricultural University (2007) for any of the four crops. Most of the farmers (60 to100 per cent) applied a higher dose of the fertilizers (Fig. 7). However, subtle difference could not be discerned in the extent of infestation when either predominantly organic manures or fertilizers were applied. The extent of infestation was in bitter gourd, in snake gourd, in cucumber and in coccinia when predominantly organic manures and fertilizers were applied, respectively. Influence of the fertilizers applied on pest infestation has been reported earlier in different crops. Extent of damage by the American serpentine leaf miner, *Liriomyza trifolii* (Burgess) Dietars was observed to be significantly higher in pulses when high doses of inorganic fertilizers were applied (Zambon et al., 1991; Reji, 2002). Contrarily, no remarkable difference could be discerned in

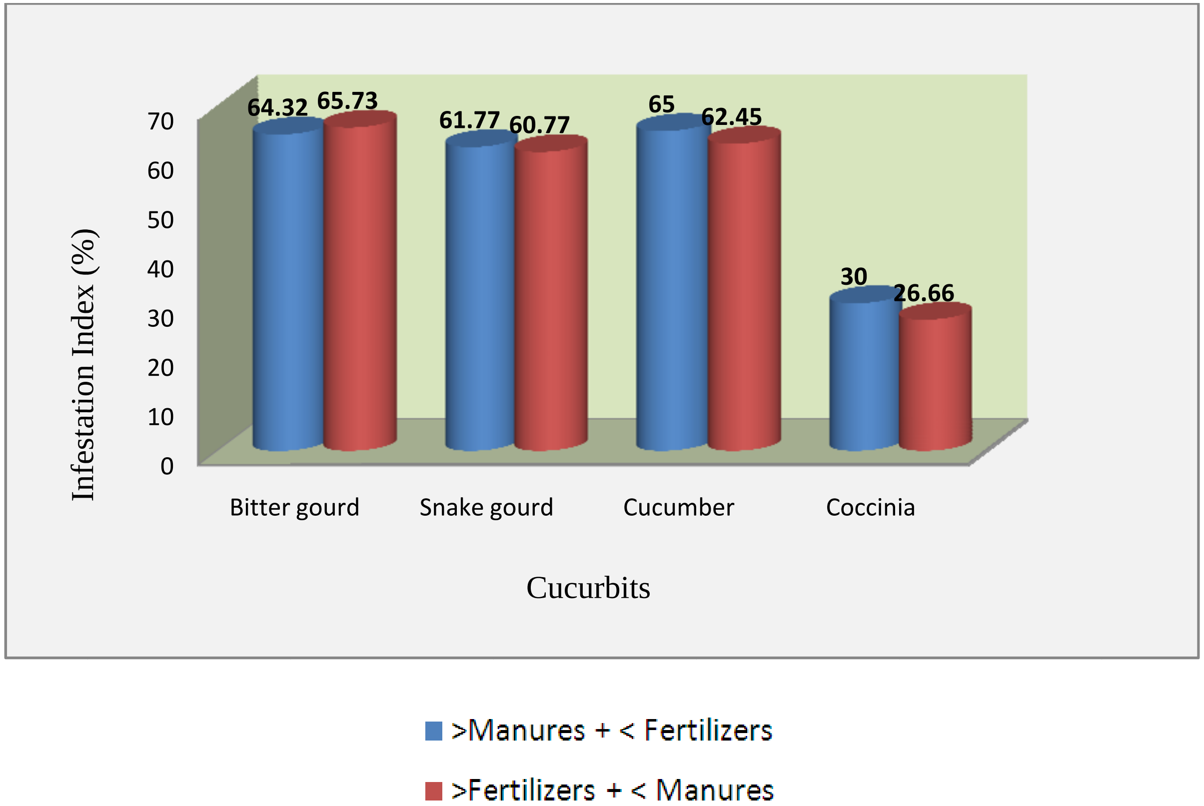


Fig. 6. Influence of manures and fertilizers on infestation of *Diaphania indica* in cucurbitaceous vegetables

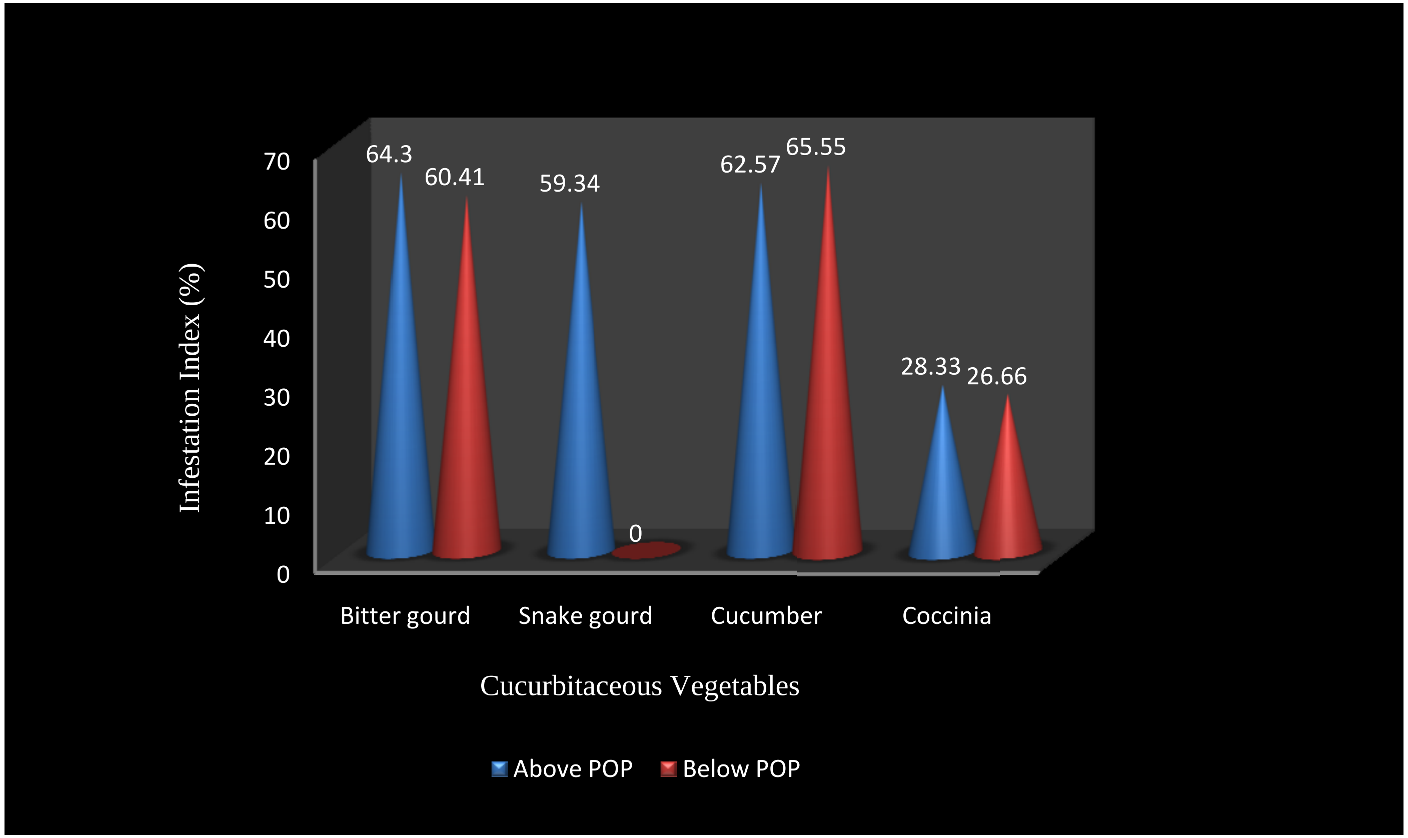


Fig. 7. Influence of fertilizer dose on infestation of *Diaphania indica* in cucurbitaceous vegetables

the extent of damage in the various cucurbits when high and low doses of fertilizers were applied.

Though insecticides were applied by the farmers to control the pests attacking the cucurbitaceous vegetables including the pumpkin caterpillar, mean infestation index was high in all the crops, irrespective of the type of insecticide used. With the exception of coccinia, more than 50 per cent infestation was observed in all the vegetables in the different stages indicating the ineffectiveness of the treatments in protecting the plants (Fig.8). Information gathered from the farmers revealed that the organophosphates and carbaryl insecticides were routinely used for plant protection over the years. Imidacloprid and fenvalerate were of recent introduction. Comparatively, the infestation was low when organophosphates + imidacloprid (0-30 per cent) and organophosphates + carbaryl (0 -20 per cent) were used. Infestation was higher when synthetic pyrethroid (10-51.85 per cent) and organophosphates (16.66-50 per cent) were used alone (Fig.9). Ineffectiveness of continuous use of a single group of insecticide against pests on account of development resistance consequent to prolonged exposure to the toxicant is a well established fact. This might have been the reason for the high infestation of the pumpkin caterpillar registered in the present study. Rotation with molecules having different modes of action is definitely better to overcome such a phenomenon.

5.1.3. Other host plants

Individual insects manifest considerable degree of plasticity in their behaviour. Over time many insects tend to expand their host range, posing threat to a series of crops. The melon moth is an oligophagous insect restricted to family Cucurbitacea (Ayyar, 1940). Oligophagous insects can feed on botanically unrelated food plants other than the natural host (Gupta and Thorsteinson, 1960). Exploration of the crop and weed plants prevailing in the vicinity of the cucurbitaceous

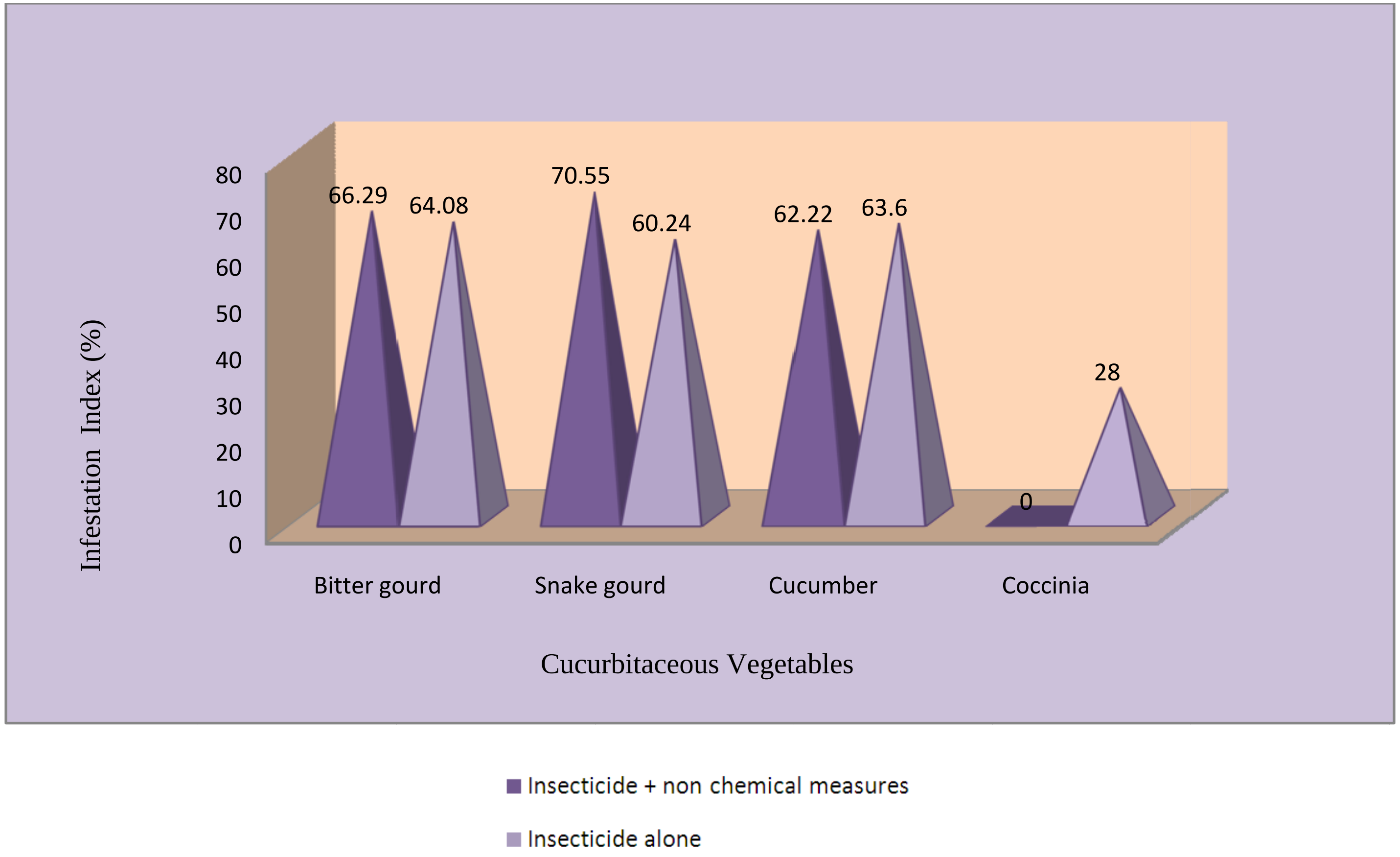


Fig. 8. Influence of pest management measures on the extent of infestation of *Diaphania indica* in cucurbitaceous vegetables

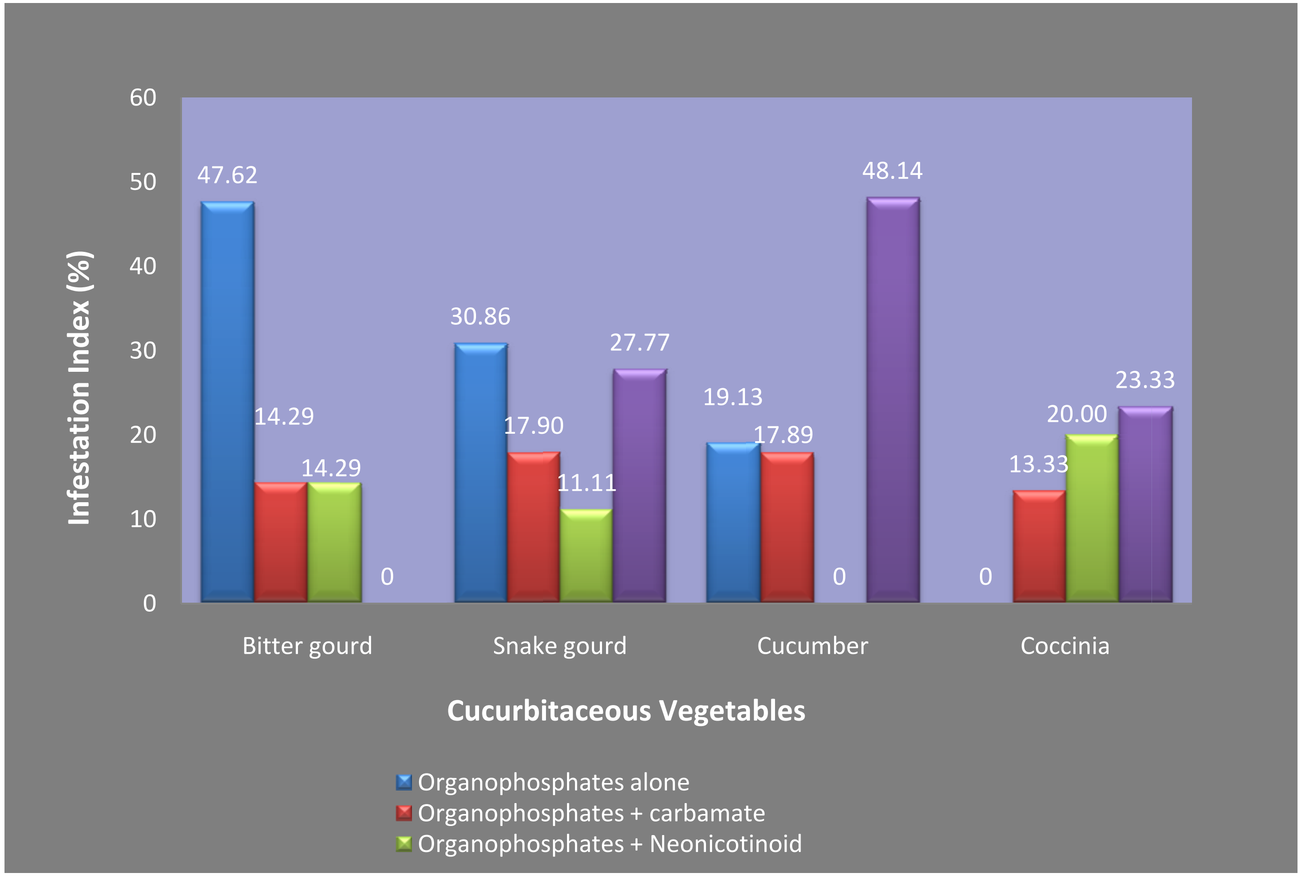


Fig. 9. Influence of different groups of insecticides on infestation of *Diaphania indica* in cucurbitaceous vegetables

vegetables revealed the attack of *D. indica* in the vegetable, red amaranth (*A. tricolor*) and green amaranth (*A. dubius*) and the two weed plants *viz*., slender amaranthus (*A. viridis*) and bristly starbur (*A. hispidum*). Striking damage was noted in the plants. Incidence of the pest in other crops had been recorded earlier. Attack of the pest was seen on beans, okra, passion fruit, pigeon pea, Indian mustard and short staple cotton (Ba- Angood, 1979) and cowpea (Sankar et al., 2005) and in other plant families, notably Leguminosae and Malvaceae (EPPO, 2005). The red amaranth and green amaranth (Amaranthaceae) and the weed plants viz. slender amaranthus (Amaranthaceae) and bristly starbur (Compositae) are being reported as host plants of the pest for the first time. In a state like Kerala where a range of vegetables are cultivated in a locality, the growing preference of the pest for other crops assumes significance as it could adversely affect the productivity of various crops. Moreover, if left unattended, the weeds would form a repository of the pest.

5.1.4 Natural enemies

Biocontrol agents play a pivotal role in natural control mechanisms within agroecosystems. Identification of the potential indigenous species and suitable ecosystem manipulation to increase their effectiveness would naturally reign in the pests. Though attempts were made during the survey to locate the natural enemies of *D. indica, Apanteles* sp. a common parasitoid of the pest could alone be identified. Only stray incidence of the bioagent could be seen in the fields examined. Several natural enemies of the pest had been documented elsewhere. In a survey conducted in India, 20 species of parasitoids, predators and pathogens were recorded. Sixteen parasitoids mostly belonging to the families Braconidae, Ichneumonidae, Bethylidae, Elasmidae and Chalcididae were reported specific for *D. indica*. Among these, *A. taragamae* was identified as the key mortality factor of *D. indica*. (Peter and David, 1991 b). The low number of natural enemies seen in the present study might be due to the constant use of insecticides in the locality. Presumably, the toxicants might have kept the ‘farmer’s friends’ at bay.

5.2 MANAGEMENT

Control of pests with the highly toxic conventional insecticides is fast losing its attraction in pest control. Safer alternatives are being progressively explored for pest management, especially in vegetables. Plant products with diverse biological activities, bioagents and newer insecticide molecules with high efficacy, low dose requirement and low toxicity are gaining importance.

5.2.1 Efficacy of Botanical and Chemical Insecticides

Six botanicals including two plant extracts (annona seed extract and neem seed kernel extract), one plant oil (neem oil) and three commercial formulations (Anosom, Derisom and NeemAzal T/S) when screened showed varying effects on the pest. Topical application of the same resulted in 100 per cent mortality of the pest on the third day after treatment. When released on treated leaves, with the exception of neem seed kernel extract 5%, all the other treatments *viz*., Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and annona seed extract 5%, NeemAzal T/S 2ml $l^{-1}$and neem oil garlic emulsion 2% resulted in high mortality of the larvae one day after treatment. By the third day all the botanicals registered 100 per cent mortality of the larvae. Anosom 2ml l^{-1}, Derisom 2ml l^{-1}, NeemAzal T/S 2ml l^{-1} and annona seed extract 5% registered more than 50 per cent mortality even on the fifth day. However, only low mortality was noted in neem oil garlic emulsion 2% and neem seed kernel extract 5%. Even on the seventh day after treatment, Anosom 2ml l^{-1} gave 100 per cent mortality, proving to be the best treatment. The efficacy of plant products in managing the pest has also been documented earlier. Application of acetone extract of *V. negundo* 0.05% (Kalavathi et al.,

1991) and neem oil 2.5% + garlic 20g 1^{-1} (Sivakumar, 2001) were effective against the pest. Turpentine oil, citriodore oil and ageratochromene showed antifeedant activities against second-instar larvae of the insect (Namvar and Alipanah, 2002).

The ryanodine analogue flubendiamide 0.004% and the naturalyte spinosad 0.015% were superior to all the other insecticides in their efficacy in containing the pest. Both the insecticides registered 100 per cent mortality up to the seventh day after treatment. While the efficacy of flubendiamide 0.004% continued up to the thirteenth day after treatment registering more than 50 per cent mortality of the caterpillars, spinosad 0.015% recorded substantial mortality up to nine days after the treatment. Profenophos 0.05% and diafenthiuron 0.02% recorded more than 50 per cent mortality only up to five days after treatment while triazophos 0.05% and chlorpyriphos 50% + cypermethrin 5% 0.05% recorded more than 50 per cent mortality up to three days after treatment. Thus, the insecticides with novel modes of action definitely established their efficacy against the pest. Insecticides like deltamethrin and fenvalerate at 15 g ai ha^{-1} (Ravindranath, 1982), sevin, sumicidin and thiodan (Banasihan, 1983), methomyl, endosulfan, synthetic pyrethoids and dimethoate (Wang and Huang, 1999), were effective against the pest. The newer insecticide molecules *viz.*, indoxacarb, methoxyfenozide, spinosad, emamectin benzoate and novaluron too controlled the pest efficiently (Kay, 2007).

The efficacy of any treatment cannot be garnered through laboratory testing only. The treatments have to be necessarily tested in the field conditions to establish their efficacy. When sprayed on infested bitter gourd plants in the vegetative phase, both the insecticides flubendamide 0.004% and spinosad 0.015% and the botanicals Anosom 2ml l^{-1} and annona seed extract 5% reduced the population of the caterpillars significantly up to seven days after spraying. No pest was seen in the plots sprayed with the chemical insecticides even when observed fifteen days after spraying. However, in the plots treated with the botanicals there was a gradual build up of the population. Evidently, the botanicals could be relied on for a week to suppress the pest population while the insecticides gave a longer effect.

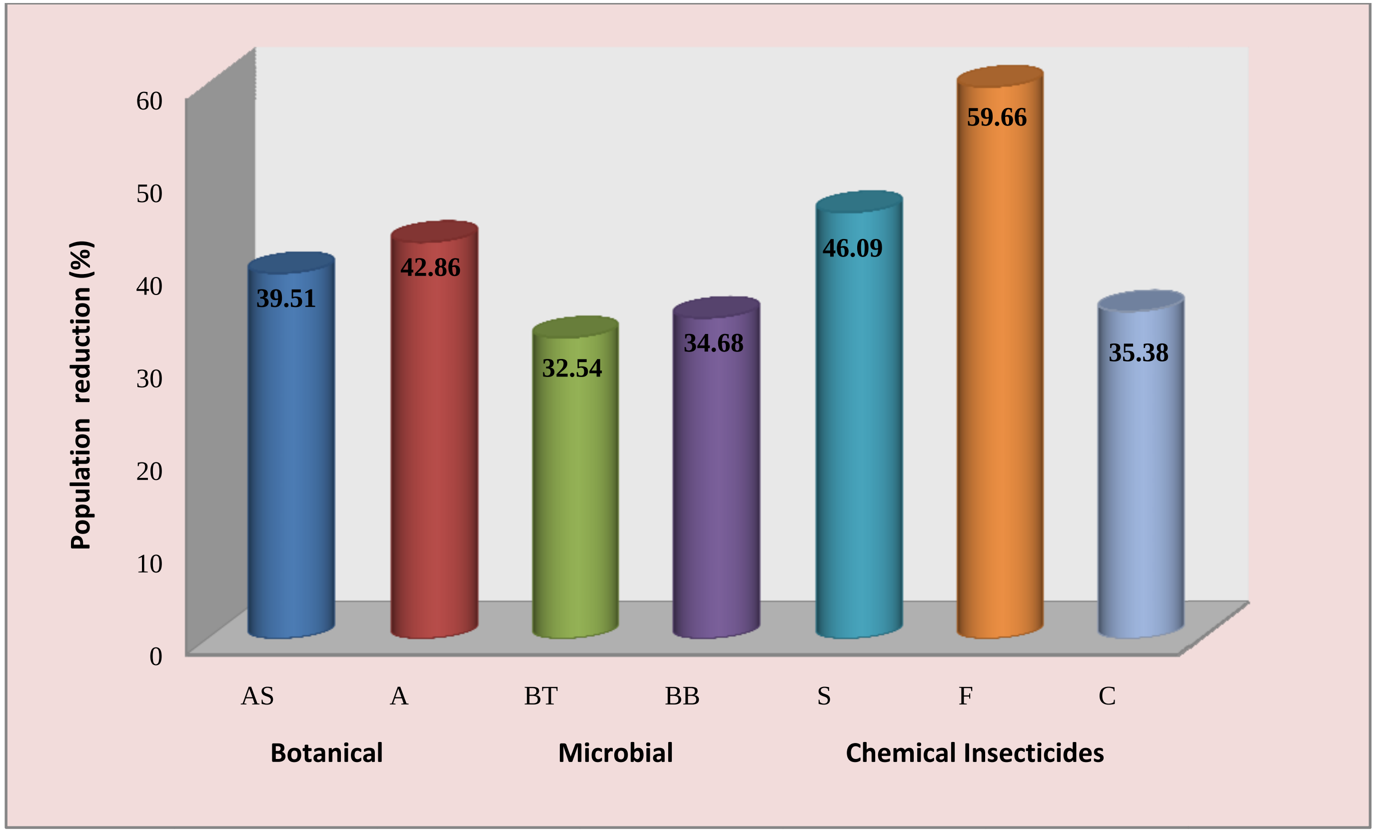
5.2.2 Field Evaluation

The effective botanical (Anosom 2ml l^{-1} and annona seed extract 5%) and chemical (flubendamide 0.004% and spinosad 0.015%) insecticides identified in the preliminary screening trials were further evaluated in the field along with two microbials (*B. bassiana* and *B. thuringiensis*) to assess their over all efficacy against *D. indica* and other pests infesting bitter gourd. Subsequent to two sprays given at three weeks interval, there was a significant reduction in the population of the pest in all the treatments. Among the treatments, the insecticide flubendiamide 0.004% was the most effective, the reduction in the pest population being 60 per cent. Spinosad 0.015% and Anosom 2ml l^{-1} also resulted in substantial reduction in the pest population, the extent of reduction being 46 and 43 per cent, respectively. Annona seed extract 5% too was equally effective as Anosom 2ml l^{-1} in its efficacy, the population of the pest being reduced by 40 per cent. The extent of reduction in the pest population in carbaryl 0.15%, *B. bassiana* and *B. thuringiensis* was 35, 35 and 33 per cent, respectively.

More than 50 per cent reduction in the population of the pest was recorded in the plots treated with the botanicals Anosom 2ml l^{-1} and annona seed extract 5% up to seven days after spraying. However, the extent of reduction in the pest population decreased from the ninth day onwards and was on par with control by the fifteenth day. The extent of reduction in the population was very low in the plots sprayed with microbial insecticides one day after spraying. However, from the third to seventh day more than 50 per cent reduction was recorded in the treatments. From the ninth day on wards the extent of reduction in the population decreased. Among the insecticides flubendimaide 0.004% gave significant reduction in the population up to 15 days after spraying. Spinosad 0.015% too gave substantial reduction of the pest up to eleven days after spraying. Carbaryl 0.15% gave more than 50 per cent reduction of the pest population up to 5 days and more than 30 per cent up to 9 days after spraying (Fig. 10).

Considering the fruit damage by the pest, more than 50 per cent reduction in the number of fruits damaged was recorded in *B. bassiana* 2g l^{-1} flubendiamide 0.004%, *B. thuringiensis* 2g l^{-1} and spinosad 0.015% sprayed plots. The botanicals Anosom 2ml $l^{-1}$and annona seed extract resulted in more than 40 per cent reduction in the fruit damage. Carbaryl 0.15% registered 39 per cent reduction in the fruit damage (Fig. 11). A significant increase was seen in the yield of the crop due to the treatments, the extent of yield increase ranging from 36 to 44 per cent in the insecticide treatments, 39 to 41 per cent in the botanical treatments and 26 to 39 per cent in the microbial treatments (Fig. 12).

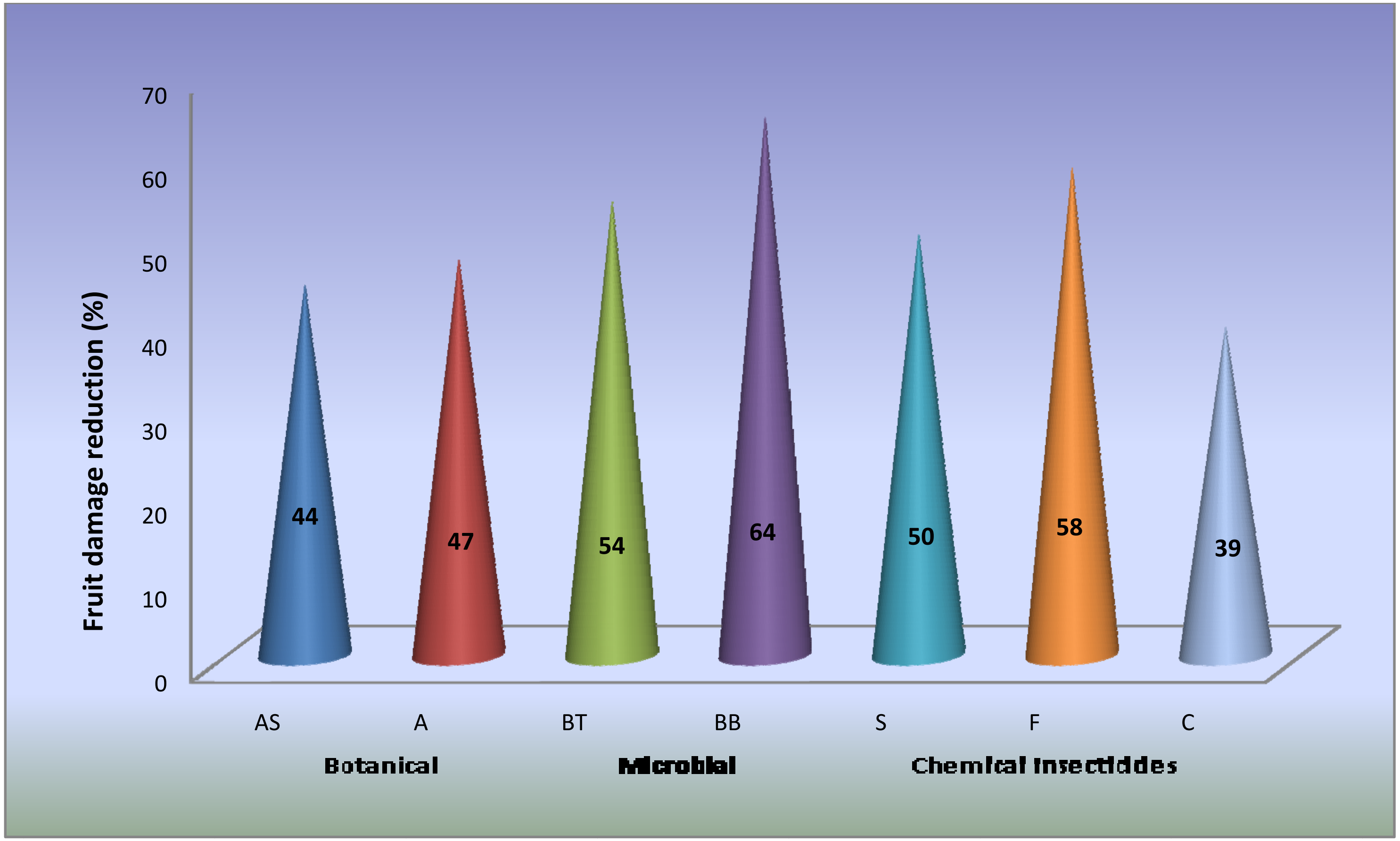
The efficacy of certain plant products like ageratochromene from *A. conyzoides* (Qin et al., 2001) and neem oil 2.5% + garlic 20g/l (Sivakumar, 2001) and inefficacy of neem cake extract and multineem (Singh and Naik, 2006) in managing the pest have been reported earlier. Though the insecticidal activity of annona seed extract has been reported against lepidopteran larvae like *S. litura*, *Trichoplusia ni* (hb.) and *Plutella xylostella* Linn. (Leatemia and Isman, 2004; Dadang et al., 2009 and Pratibha et al., 2010) reports on its efficiency against the pest *D. indica* are lacking. The effectiveness of the microbial insecticides, *B. thuringiensis* (Wang and Huang, 1999) and *B. bassiana* (Jiji, et al., 2008) have been observed earlier and the results of the study are in conformity with the findings. Similarly, the effectiveness of insecticides with novel modes of action like indoxacarb, methoxyfenozide, spinosad, emamectin



AS- Annona seed extract
BT -*B. thuringiensis*
S – Spinosad
C – Carbaryl

A - Anosom
BB - *B. bassiana*
F – Flubendiamide

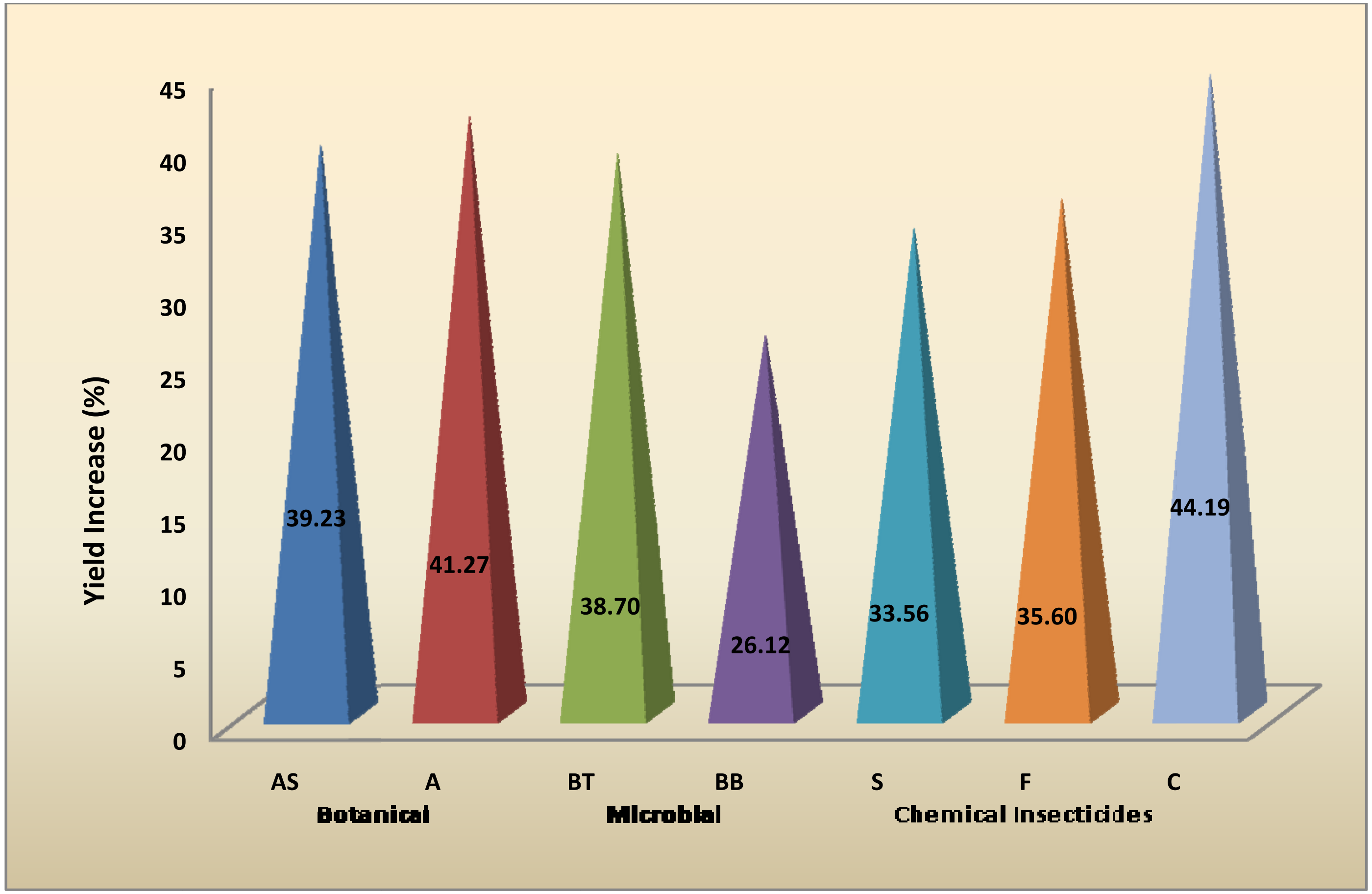
Fig. 10. Reduction in population of *Diaphania indica* in bitter gourd plots sprayed with botanical, microbial and chemical insecticides



AS- Annona seed extract
BT -*B. thuringiensis*
S – Spinosad
C – Carbaryl

A - Anosom
BB - *B. bassiana*
F – Flubendiamide

Fig. 11. Reduction in fruit damage due to *Diaphania indica* in bitter gourd plots sprayed with botanical, microbial and chemical insecticides



AS- Annona seed extract
BT -*B. thuringiensis*
S – Spinosad
C – Carbaryl

A - Anosom
BB - *B. bassiana*
F – Flubendiamide

Fig. 12. Yield increase in bitter gourd plots sprayed with botanical, microbial and chemical insecticides

benzoate and novaluron (Kay, 2007) against the pest too was documented and the efficacy of spinosad observed in the present study conform to the findings. The insecticidal activity of flubendiamide against lepidopteran pests of various crops is well documented (Hirooka et al., 2007; Ebbinghaus et al., 2007).

An overall analysis of the results of the study spot lights the changing dimensions in the pest status of the largely over looked lepidopteran. The caterpillar is on the verge of becoming a serious threat to the cultivation of cucurbitaceous vegetables. Though primarily a leaf feeder, the increasing preference for fruits of the crops spells doom for the cucurbit farmers. Furthermore, the expansion of its host range to other vegetables like red and green amaranthus is to be viewed gravely, especially in Kerala where a range of vegetables is cultivated in a locality. Presently, the leafy vegetable is attacked by an array of leaf feeders like *Hymenia recurvalis* (Fab.), *Psara basalis* F., *Plusia signata* Fb. and *S. litura* to name a few. An additional leaf feeder in the crop would be devastating. The preference of *D. indica* for certain weed host plants too is menacing, since the pest could lurk and multiply on these plants in the absence of the natural host and migrate to the same when cultivation is initiated. Apart from this, decimation of the pest at the early instars is crucial as once the larvae penetrate the fruits, it is near impossible to kill them. Moreover, marketability of the fruits would be adversely affected due to spoilage.

The results of the studies on the efficacy of the various groups of insecticides are encouraging. Both the botanical, microbial and chemical insecticides have proved their relative efficacy in managing the pest. The custard apple seeds often discarded after consumption of the fruits proved to be an efficacious pest control agent which could be utilized especially in homestead cultivations. Though effective, the exploitation of Anosom, a commercial formulation is a problem since at present it is not widely available in the market. In the light of the findings of the study, promotion of the same could be thought of. The potential benefits of the biopesticides *B. bassiana* and *B. thuringiensis* necessitate their increased adoption. With mounting stress on organic farming and residue free products, both the botanicals and biopesticides are crucial for plant protection. Of course, insecticides are the premier choice in any pest out break situation. In this context, flubendiamide, a green labeled insecticide which manifested its potent efficacy could be safely relied on. Similarly, spinosad, a blue labeled insecticide too could be considered for rotational spray in the crop.

To surmise, the results indicate that destruction of the weed and other volunteer host plants, early detection of the pest and its annihilation with either the botanical or microbials could be considered for managing the pest. When there is a phenomenal spurt in the pest population, flubendimaide 0.004% or spinosad 0.015% could be used as a safe therapeutic measure.

SUMMARY

6. SUMMARY

The changing dimensions in insect herbivory pattern in agro ecosystems have profound implications in the productivity of the crop. One recent aberration noted in the cucurbit fields of the State was the compounding damage by the hitherto minor pest, *D. indica*. The altering pest scenario warrants information on the incidence of the pest, extent of injury and consequent loss. With this view, survey was conducted in the Kalliyoor panchayath, an important vegetable growing tract of Thiruvananthapuram district during 2009-2010 to document the incidence and damage done by the pumpkin caterpillar on the major cucurbitaceous vegetables. Botanical, microbial and chemical insecticides with novel modes of action too were tested for their efficacy against the pest. The major findings of the study are summarized below.

- Incidence of *D. indica* was recorded in bitter gourd, snake gourd, cucumber and coccinia in varying intensities during the active vegetative, flowering and early fruiting stages of the crops.
- The extent of infestation was significantly higher in bitter gourd, snake gourd and cucumber. Only low damage was recorded in coccinia.
- Infestation was significantly higher during the fruiting stage followed by the flowering and vegetative stages.
- Leaves and fruits of bitter gourd, snake gourd and coccinia were damaged by the pest. Only leaves of cucumber were damaged.
- Application of neither more manures nor more fertilizer influenced the extent of infestation in the crops significantly. Similarly, application of high and low doses of fertilizers also did not influence the extent of damage appreciably.
- The plant protection measures adopted, either solely insecticides or insecticides supplemented with organic measures did not influence the

extent of infestation remarkably. However, the groups of the chemicals influenced the extent of infestation strikingly. Infestation of the pest was higher when a single group was used. Rotation with other groups reduced the infestation substantially.

- *A. tricolor* (red amaranth) and *A. dubius* (green amaranth) and the weed plants *viz*., the slender amaranth (*A. viridis*) and bristly starbur (*A. hispidium*) were found to be attacked by *D. indica*. The host plants recorded were new reports from India.

- The parasitoid *Apanteles* sp. was the only natural enemy recorded during the survey.

- Topical application of annona seed extract 5%, neem oil garlic emulsion 2%, neem seed kernel extract 5%, Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and NeemAzal T/S 2ml l^{-1} resulted in 100 per cent mortality of the caterpillars three days after treatment.

- When the caterpillars were released on treated leaves, all the botanicals resulted in high mortality upto three days after treatment. Anosom 2ml l^{-1}, Derisom 2ml l^{-1}, NeemAzal T/S 2ml l^{-1}, and annona seed extract 5% registered more than 50 per cent mortality on the fifth day too. Anosom 2ml l^{-1} gave 100 per cent mortality even on the seventh day after treatment.

- Topical application of spinosad 0.015%, flubendiamide 0.004%, profenophos 0.05%, diafenthiuron 0.02%, triazophos 0.05% and chlorpyriphos 50%+ cypermethrin 5% 0.05% resulted in 100 per cent mortality of the caterpillars one day after treatment.

- When released on treated leaves, flubendiamide 0.004% and spinosad 0.015% registered 100 per cent mortality upto the seventh day after treatment. While the efficacy of flubendiamide 0.004% continued upto the thirteenth day registering more than 50 per cent mortality of the caterpillars, spinosad 0.015% recorded substantial mortality upto nine days after the treatment. Prophenophos 0.05% and diafenthiuron 0.02% recorded more than 50 per cent mortality only upto five days while triazophos 0.05% and chlorpyriphos 50% + cypermethrin 5% 0.05% recorded more than 50 per cent mortality upto three days after treatment.

- Testing of flubendiamide 0.004%, spinosad 0.015%, Anosom 2ml l^{-1} and annona seed extract 5% on infested bitter gourd plants in the vegetative phase, indicated that both the insecticides and the botanicals reduced the population of the caterpillars significantly upto seven days after spraying . No pest was seen in the plots sprayed with the chemical insecticides even when observed 15 days after spraying. However, a gradual build up in the pest population was seen in the plants sprayed with the botanicals.

- Field trial with annona seed extract 5%, Anosom 2ml l^{-1}, *B. thuringiensis* 2g l^{-1}, *B. bassiana* 2g l^{-1}, flubendiamide 0.004%, spinosad 0.015%, and carbaryl 0.15% revealed that flubendiamide 0.004% was the most effective, the reduction in the pest population being 60 per cent. Spinosad 0.015% (46 per cent) Anosom 2ml l^{-1} (43 per cent) and Annona seed extract 5% (40 per cent) also resulted in substantial reduction in the pest population. The extent of reduction in the pest population was 35, 35 and 33 per cent in carbaryl 0.15%, *B. bassiana* 2g l^{-1} and *B. thuringiensis* 2g l^{-1}, respectively.

- More than 50 per cent reduction in the number of fruits damaged was recorded *B. bassiana* 2g l^{-1}, flubendiamide 0.004%, *B. thuringiensis* 2g l^{-1} and spinosad 0.015% treatments. Anosom 2ml l^{-1} and annona seed extract resulted in more than 40 per cent reduction in the fruit damage. Carbaryl 0.15% registered 39 per cent reduction in the fruit damage.

- The treatments increased the yield of the crop significantly, the extent of yield increase ranging from 36 to 44 per cent in the insecticide treatments, 39 to 41 per cent in the botanical treatments and 26 to 39 per cent in the microbial treatments.

Based on the results of the study, destruction of the weed and other volunteer host plants, detection of the pest in the early stages of infestation and its management through application of either the botanical or microbials could be recommended for controlling the pest. When there is an acceleration in the damage, the safer molecules of insecticides *viz*. flubendimaide 0.004% and spinosad 0.015% could be used.

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INFESTATION OF THE PUMPKIN CATERPILLAR, *Diaphania indica* Saunders IN CUCURBITS AND ITS MANAGEMENT

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ABSTRACT

Survey conducted in the Kalliyoor panchayath of Thiruvananthapuram district during 2009-2010 revealed the incidence of the pumpkin caterpillar, *Diaphania indica* Saunders in bitter gourd, snake gourd, cucumber and coccinia. The extent of infestation was high in bitter gourd, snake gourd and cucumber and low in coccinia. The infestation was significantly higher during the fruiting followed by the flowering and vegetative stages. Leaves and fruits of bitter gourd, snake gourd and coccinia were damaged by the pest. Only the leaves of cucumber were damaged. No significant differences were noted in the extent of infestation when more organic manures or more fertilizers were applied by the farmers. Similarly, the high and low doses of fertilizers applied also did not influence the extent of damage. The plant protection measures adopted by the farmers too had no significant effect on the extent of damage. The red amaranth (*Amaranthus tricolor* Linn.) and green amaranth (Amaranthus dubius L.) and the weed plants, the slender amaranthus (*Amaranthus viridis* L.) and bristly starbur (*Acanthospermum hispidum* DC.) were recorded as host plants of *D. indica*. The parasitoid *Apanteles* sp. was the only natural enemy recorded during the survey.

Among the botanicals screened, annona seed extract 5%, neem oil garlic emulsion 2%, neem seed kernel extract 5%, Anosom 2ml l^{-1}, Derisom 2ml l^{-1} and NeemAzal T/S 2ml l^{-1} resulted in high mortality of the caterpillars upto three days after treatment both when applied topically and released on treated leaves. The efficacy of Anosom 2ml l^{-1} extended to the seventh day when released on treated leaves.

Topical application of spinosad 0.015%, flubendiamide 0.004%, profenophos 0.05%, diafenthiuron 0.02%, triazophos 0.05% and chlorpyriphos 50%+ cypermethrin 5% 0.05% resulted in 100 per cent mortality of the caterpillars one day after treatment. When released on treated leaves, flubendiamide 0.004% and spinosad 0.015% proved to be the better treatments, registering mortality of the pest upto 15 days after treatment.

Field evaluation with annona seed extract 5%, Anosom 2ml l^{-1}, *B. bassiana* 2g l^{-1}, *B. thuringiensis* 2g l^{-1}, flubendiamide 0.004% spinosad 0.015% and carbaryl 0.15% indicated that flubendiamide 0.004% was the most effective, the reduction in the pest population being 60 per cent. Spinosad 0.015% and Anosom 2ml l^{-1} also resulted in significant reduction in the pest population, the extent of reduction being 46 and 43 per cent, respectively. Annona seed extract 5% too was equally effective as Anosom 2ml l^{-1} in its efficacy, the population of the pest being reduced by 40 per cent. The extent of reduction in the pest population in carbaryl 0.15%, *B. bassiana* 2g l^{-1} and *B. thuringiensis* 2g l^{-1} treatments was 35, 35 and 33 per cent, respectively.

More than 50 per cent reduction in the number of fruits damaged was recorded *B. bassiana* 2g l^{-1}, flubendiamide 0.004%, *B. thuringiensis* 2g l^{-1} and spinosad 0.015% treatments. Anosom 2ml l^{-1} and annona seed extract 5% resulted in more than 40 per cent reduction in the fruit damage. Carbaryl 0.15% registered 39 per cent reduction in the fruit damage. All the treatments increased the yield of the crop significantly, the extent of yield increase ranging from 36 to 44 per cent in the insecticide, 39 to 41 per cent in the botanical and 26 to 39 per cent in the microbial treatments.

Based on the results of the study, destruction of the weed and other volunteer host plants and early detection of the pest and its management with either the botanicals or microbials would be a viable option for controlling the pest. The safer insecticides flubendiamide 0.004% or spinosad 0.015% could be used when there is a substantial increase in the pest population.