ECO-FRIENDLY INSECTICIDES FOR THE MANAGEMENT OF MAJOR PESTS OF AMARANTHS

By
M. K. LEENA

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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DECLARATION

I hereby declare that the thesis entitled '**Eco-friendly insecticides for the management of major pests of amaranths**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or society.

Vellanikkara **M.K. LEENA**

CERTIFICATE

Certified that the thesis entitled **'Eco-friendly insecticides for the management of major pests of amaranths'** is a record of research work done independently by **Miss. M.K. Leena** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, diploma or associateship to her.

Suma Paulose

Dr. SUMA PAULOSE
Chairperson

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Miss. M.K. Leena** a candidate for the degree of **Master of Science in Agriculture**, agree that the thesis entitled **'Eco-friendly insecticides for the management of major pests of amaranths**''may be submitted by Miss. M.K. Leena. in partial fulfillment of the requirement for the degree.

Suma P.
Dr. SUMA PAULOSE 14 - 12-2001
Associate Professor
Communication centre
Mannuthy
(Chairperson)

14/12/01
Dr. Jim Thomas
Associate Professor and Head of Dept. (in-Charge)
Department of Entomology
College of Horticulture
Vellanikkara
(Member)

14/12/01
Dr. P.G. Sadankumar
Associate Professor, AICVIP
Dept. of Olericulture
College of Horticulture
Vellanikkara
(Member)

Dr. M.K. Sheela
Associate Professor
Communication centre
Mannuthy
(Member)

14/12/01

14/12/01
K.C. Varghese
EXTERNAL EXAMINER.
Retd. Professor of Entom

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Affectionately dedicated to

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INTRODUCTION

1. INTRODUCTION

Green leafy vegetables represent an excellent component of habitual diet in the tropical countries. It enriches the diet with minerals, vitamins, and proteins and is also a good source of roughage. The per capita intake of vegetables is estimated to be only about 210g against the requirement of about 285 g. About 80 g leafy vegetables are required for the balanced diet, hence leafy vegetables are known to be protective food (Pandey, 1993).

Amaranths (*Amaranthus tricolor* L.) constitute one of the major leafy vegetables belonging to the family amaranthaceae and consumed world wide, particularly in south east asian countries (Prakash and Pal, 1991). It is considered as a 'poor man's vegetable' because of its low production cost and high yield. It also fits well in crop rotation due to its short duration.

The major factors which reduce the quality and yield of amaranths are pests and diseases. About two dozen insects have been recorded as pests of amaranths. Among these, attack of a weevil and leaf-eating caterpillars are the major problems. These pests cause extensive damage to the crop. A number of contact and systemic chemical insecticides that are being used by the farmers leave heavy residue deposits on the leaves. Since the leaves are used for consumption without much cooking, indiscriminate use of these insecticides may cause health hazards. In many cases, alternate methods of insect management offer adequate levels of pest control and pause fewer or no hazards. One such alternative is the use of eco-friendly insecticides, such as microbial and botanical pesticides. These insecticides are valuable because of their safety to non-target organisms compared to other commonly used chemical insecticides. Microbial insecticides are comprised of microscopic living organisms *viz.*, bacteria, viruses, fungi, protozoa, rickettsiae and nematodes or their toxins produced by these organisms. They are formulated to be applied as conventional insecticide sprays, dusts or granules. Each product's specific properties determine the way in which it can be used most effectively. The botanicals are plant products that are used as toxicants or insecticides, attractants, repellents etc. (Srivastava, 1996).

The main objective of the present study is to identify the safer eco-friendly insecticides to check the population of major pests of leafy vegetable amaranths.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Amaranths (*A. tricolor* L.) is a potentially important vegetable crop because of its high nutritional value. Numerous phytophagous pests feed on this crop. With the ever increasing awareness of the harmful effects of chemical pesticides on the environment and man, the immediate need for sustainable eco-friendly pest management have been felt very strongly providing an impetus for research and development of botanical and microbial insecticides. Microbial and botanical insecticides are extensively used in vegetables like cabbage, cauliflower and tomato. A search for the publication of the use of these insecticides in amaranths revealed to be scanty. But similar researches carried out in other vegetables are reviewed here. The review of literature includes the studies in this aspect from 1990 to 2001.

2.1. Role of microbial insecticides

2.1.1. Bacteria

The role of bacteria in controlling the pests of vegetables has been studied by various workers. Of the current microbial insecticides available, the bacteria *Bacillus thuringiensis* dominates in the current market. *B. thuringiensis* is claimed to be increasingly cost effective, making them more competitive with the chemical insecticides.

Justin *et al.* (1990), Wyman *et al.* (1999) and Ignacimuthu (2000) observed better control of cabbage diamondback moth *Plutella xylostella* (Lepidoptera: Plutellidae) with the bacteria *B. thuringiensis.* Kao *et al.* (1990) tested nine microbial pesticides of *B. thuringiensis* to various pests of cabbage like diamondback moth, cabbage butterfly *Pieris rapae* and tobacco cutworm *Spodoptera litura* in the field and all were equally effective in controlling these pests. Rodrigo (1995) used different *B. thuringiensis* formulations to control cabbage diamondback moth. He observed that Dipel (0.5 kg ha^{-1}) treated plot recorded the highest yield which was followed by Javelin (1 kg ha^{-1}) and Thuricide (0.5 kg ha^{-1}). Ashokan *et al.* (1996) evaluated the efficacy of *B. thuringiensis* in comparison with chemical insecticides in cabbage. It was noted that Dipel 8L effectively controlled diamondback moth larvae with increase in yield of 15 t ha^{-1} over control where as Endosulfan treated plots recorded a yield of 8 t ha^{-1} only.

Krnjajic *et al.* (1997) observed effective control of cabbage butterfly and diamondback moth with *B. thuringiensis* var. *kurstaki.* According to Mori (1997), application of *B. thuringiensis* (1g l^{-1}) gave better results than other methods in the control of cabbage butterfly *Pieris brassicae* in Italy. The *B. thuringiensis* was found to be more cost effective in controlling brinjal shoot and fruit borer *Leucinodes orbonalis* than other methods tested (Patnaik and Singh, 1997; Sasikala *et al.*, 1999). Reddy *et al.* (1997) and Guptha and Babu (1998) observed cent per cent control of tomato fruit borer *Helicoverpa* *armigera* with Delfin (*B. thuringiensis*). Babu and Krishnayya (1998) noticed better control of *S. litura* in cauliflower with *B. thuringiensis*.

Monnerat and Bordat (1998) reported that HD-1 strain of *B. thuringiensis* was safe to *Diadegma sp.* (Hymenoptera: Ichneumonidae) a parasitoid of cabbage diamondback moth.

Tomar (1998) noted that Dipel (0.1 per cent) treated plots gave maximum protection to okra shoot and fruit borer *Earias vitella*. Gopalakrishnan (1999) studied the efficacy of *B. thuringiensis* formulations Dipel and Biobit in brinjal and the results showed that Biobit (1 kg ai ha^{-1}) recorded low shoot and fruit borer infestation when applied at weekly intervals right from flowering. Eco-friendly insecticides tested against lepidopteran pests of cabbage showed that Delfin was very effective against the leaf webber *Crocidolomia binotalis*, *P. xylostella* and *S. litura* (Malathi *et al.*, 1999).

The study on the effect of *B. thuringiensis* (0.25 per cent) against epilachna beetle of brinjal *Henosepilachna vigintioctopunctata* by leaf dip treatment gave 68.9 per cent mortality in the case of first instar grubs where as adults were found to be less susceptible (Rajendran and Gopalan, 1999).

The *B. thuringiensis* (Halt) was found effective to bihar hairy caterpillar *Spilosoma obliqua* infesting vegetables (Battu *et al.*, 2000).

Loganathan *et al.* (2000) studied the effect of commercial formulations of *B. thuringiensis* var. *kurstaki* (Delfin) and *B. thuringiensis var. gallariae* (Spicturin) against the predatory lacewing *Chrysoperla carnea* in cauliflower. The percentage of pupation and adult emergence were 52.34 and 33.75 in the case of Delfin, and 83.75 and 56.25 in the case of Spicturin.

Among the different formulations of *B. thuringiensis* like Dipel, Halt and Biolep tested against the cabbage diamondback moth, Dipel was found most promising in controlling the larvae in which the third instar was found to be the most susceptible (Singh *et al.*, 2000).

2.1.2. Virus

Insect viruses particularly of the family baculoviridae have great potential for the development as microbial insecticides. They include Nuclear Polyhedrosis Virus (NPV) and Granulosis Virus (GV). In vegetables NPV is utilized extensively for controlling lepidopteran pests.

Singh (1990) and Sathpathy and Samarjith Rai (2000) reported *H. armigera* NPV (HaNPV) at 250 to 500 Larval Equivalents (LE) in combination with jaggery (0.5 per cent) and ranipal (0.1 per cent) to be effective in controlling *H. armigera* on tomato. In *P. xylostella,* severe infection of NPV was reported from Punjab by Battu (1995). Padmavathamma and Veeresh (1995) observed that NPV at 1.7×10^8 Poly Inclusion Bodies ml^{-1} (PIB's) in combination with Indian ink gave greater reduction of cabbage diamondback moth. The experiments with HaNPV and Endosulfan on tomato for controlling fruit borer revealed that HaNPV (250 LEha^{-1}) was superior to Endosulfan (260 g ha^{-1}) (Ganguli *et al.*, 1997; Sivaprakasm, 1998). Hirsch *et al.* (1997) and Battu *et al.* (1998) controlled *S. litura* in vegetable with *S. litura* NPV (SlNPV).

Mehetre and Salunkhe (1998) tested NPV and egg parasite *Trichogramma pretiosum* on fruit borer of tomato and found that percentage of damaged fruits were very less in both the treated plots as compared to control.

2.1.3. Fungi

Entomopathogenic fungi are of considerable importance because of their ability to infect a wide range of insects like aphids, caterpillars, white flies, leaf miners, weevils, grasshoppers *etc.*

Prasad *et al.* (1990) studied the susceptibility of gram caterpillar to entomopathogenic fungi *Paecilomyces fumosoroseus* and *Beauveria bassiana* and found the LC_{50} values $4.19x10^8$ and $5.22x10^9$ conidia ml^{-1} respectively. The susceptibility of larvae to *B. bassiana* decreased with the increase in age of the larvae. Hall (1992) observed that *Thrips palmi* on aubergins was found to be infected with a fungus *Hirsutella* sp. in Trinidad and destroyed nearly 80 per cent of the population. The control of white fly *Trialeurodes vaporariorum* with the fungus *Verticillium lecanii* was reported by Masuda and Kikuchi (1993).

Butt *et al.* (1994) reported that *Metarrhizium anisopliae* ($1x10^{10}$ conodia ml^{-1}) was more pathogenic to cabbage flea beetle, *Psylliodes chrysocephala* than *B. bassiana* and both fungi were found safe to honey bee.

According to Stirmanova (1994) and Meade and Byrne (1991) *V. lecanii* was effective in controlling white flies. In the studies conducted by Sosnowska and Piatkowski (1995), it was observed that *P. fumosoroseus* (0.2 to 0.4 per cent) was effective to white fly *T. vaporariorum.* Parker *et al.* (1996) recorded that *M. anisopliae* and *Fusarium* sp. to be highly toxic to thrips infesting vegetables. Pas *et al.* (1996) pointed out effective control of *T. vaporariorum* with Mycotal (*V. lecanii*) in tomato and cucurbits. Quick knockdown effect was observed after the application of the fungus and the mortality ranged between 80 and 90 per cent.

The fungus *B. bassiana* was highly effective against white flies, thrips and mites in green house crops and there was no adverse effect on natural enemies and safe to human beings, live stock, birds, fishes and ground water resources. It was also compatible with pesticides and fertilizers and not with fungicides (Wright and Kennedy, 1996; Ota *et al.*, 1999).

Selman and Dayer (1997) and Yoon *et al.* (1999) showed the effectiveness of *B. bassiana* on larvae of *P. xylostella* infesting cole crops. The studies conducted by Sunitha (1997) revealed the effect *of Fusarium pallidoroseum* on pea aphid *Aphis craccivora*. She has also observed that spore suspension and wettable powder ($7x10^6$ spores ml^{-1}) were equally effective to control the pest. Askary *et al.* (1998) recorded that Vertalec (*V. lecanii*) was more virulent to aphids infesting cucumber. Bradley *et al.* (1998) tested BotaniGard (*B. bassiana*) on thrips infesting vegetables and noted that weekly application could reduce the population. The toxicity was found more in immature stages than adults. The effectiveness of *B. bassiana* against *P. xylostella* was tried by Masuda (1998) and highest pathogenicity was recorded from the strain *B. bassiana* MGBb-1 at 10^7 spores ml^{-1}.

McLeod *et al.* (1998) controlled *Myzus persicae* infesting spinach with the fungus *Erynia neoaphidis*. In vitro evaluation of three fungi *B. bassiana, M. anisopliae* and *P. fumosoroseus* on adult cabbage root fly *Delia radicum* caused cent per cent mortality of adults due to *B. bassiana* (Meadow *et al.*, 1998; Vannien *et al.*, 1999).

Mycotrol (*B. bassiana*) was found effective to *P. xylostella* larvae of which the second instar was found most susceptible and the fungus persisted on the treated leaves for more than two weeks (Shelton *et al.*, 1998; Vanderberg *et al.*, 1998). Vidal *et al.* (1998), Lacey *et al.* (1999) and Wraight *et al.* (2000) observed 70 per cent mortality of *Bemisia argentifolii* of cucumber and tomatoes with P. *fumosoroseus.* Zaki (1998) reported that *B. bassiana* caused cent per cent mortality in *A. craccivora* and *Bemisia tabaci* infesting cucumber and nymphs were found to be more susceptible to the fungus than the adults. Cabbage diamondback moth was effectively controlled by the destruxins (A, B and E) produced from *M. anisopliae* and mortality was more in adults. (Amiri *et al*., 1999). Rajendran and Gopalan (1999) observed that direct spraying of *B. bassiana* to the spotted beetle of brinjal *Henosepilachna vigintioctopunctata* could cause mortality of 35.2 and 58.00 per cent in pre pupal and grub stage respectively.

Ignacimuthu (2000) found that *B. bassiana* and *Nomurea rileyi* were effective to *H. armigera* and S. *litura*. Shah *et al.* (2000) reported that the fungi *Erynia neoaphidis* and *B. bassiana* were effective in controlling *Macrosiphum euphorbiae* infesting sweet pepper and the mortality recorded were 10 to 14 per cent and 50 to 60 per cent respectively. Wraight *et al.* (2000) noticed that third and fourth instars of *B. argentifolii* on cucumber and melons were more susceptible to *B. bassiana* than the adults.

2.1.4. Actinomycetes

Microbial insecticide derived from actinomycetes especially Spinosad is very effective in controlling the pests of vegetables.

Spinosad is a fermented product derived from an actinomycete *Saccharopolyspora spinosa* (Tong-Xian *et al.*, 1999). According to Elanko (1994) Spinosad has very low vertebrate toxicity and oral LC_{50} for rats is 3500 mg kg^{-1}.

SpinTor (*S. spinosa*) was effective for controlling many lepidopteran and dipteran pests (Adam *et al.*, 1996). A commercial formulation of *S. spinosa,* Tracer can control most of the lepidopteran pests of cabbage *viz.*, looper *Trichoplusia ni, Spodoptera exigua* and *H. armigera* (Porteous *et al.*, 1996; Tong-Xian, 1999).

The residual level of Spinosad in vegetables like cabbage, lettuce, tomato and capsicum was found to be very low (Yeh *et al.*, 1997).

Yee and Toscano (1998) reported that Spinosad was effective in controlling *S. exigua* infesting lettuce. Boucher (1999) observed that Spinosad was very effective against the vegetable pests like colorado potato beetle, cabbage diamondback moth, cabbage looper, cabbage worm, leaf miners, thrips etc., and was found to be very safe to natural enemies like ladybird beetles, predaceous fly larvae, parasitic wasps and spiders. Gahbiche and Aoun (1999) reported that Spinosad was very effective to leaf miner *Liriomyza trifolii* and was safer to larval parasitoids with in a week of application. According to Mau *et al.* (1999), Spinosad appeared to be very effective against the pests of aubergins.

According to Dey and Somchoudhury (2001) Spinosad was found effective to *P. xylostella* @15 to 25 kg ai ha^{-1} and safe to its larval parasitoids. Sannino (2001) reported that Spinosad was very effective to *Spodoptera littoralis* infesting lettuce.

2.2. Role of botanicals

Botanicals are plant products that have been used as insect attractants, repellents and toxic insecticides. They are many times cheaper than synthetic insecticides and can be afforded even for repeated treatments.

Rao *et al.* (1992) reported that extracts of *Bougainvillea spectabilis* Willd, *Parthenium hysterophorus* Linn. (0.2 and 0.5 per cent) and *Azadirachta indica* (0.5 per cent) gave cent per cent protection to brinjal from the attack of spotted leaf beetle. Prazybyszewski (1993) tested the leaf and seed extracts of neem (2.5 to 10 per cent) to control the lepidopteran pests of cabbage and found that seed extract was better than leaf extract. Amaranths leaf webber and grasshopper, bhindi leaf roller, epilachna beetle of brinjal and bittergourd, aphids, jassids and mealy bugs of brinjal and bhindi could be controlled by four per cent leaf extracts of neem, thevetia and clerodendron. Bhindi fruits could be protected from borers by the four per cent extracts of neem and thevetia only (KAU, 1996).

Naqui *et al.* (1996) studied the phagodeterrent effect of neem formulation Margosan against cabbage grasshopper *Eyprepocnemis plorans* and found significant control of the pest. Neem seed oil emulsion and leaf extract of *Hyptis suaveolens* (10 per cent) were tested against pea aphid by Reghunath and Gokulapalan (1996) and the results showed that both were very effective and also were on par with Malathion (0.05 per cent). Azadirachtin (*A. indica*) and plumbagin (*Plumbago* sp.) were very effective in controlling gram pod borer (Gujar, 1997; Patel and Patel, 1997; Guptha *et al.*, 1998). Chandrasekharan and Veeravel (1998) evaluated the efficacy of Achook, neem oil and neem cake extract on chilli thrips *Scirtothrips dorsalis*. They found that Achook (0.15 per cent) was more effective in controlling the pest, followed by neem oil (3 to 5 per cent) and neem cake extract.

A commercial formulation of neem Nimbicidine gave highest mortality of insect pest complex of cabbage and found safe to natural enemies (Dhaliwal *et al.*, 1998; Meadow *et al.,* 1999). According to Moorthy *et al.* (1998) the population of *P. xylostella* was found to be reduced from 40 to 100 per cent by the application of neem seed kernal extract. Raja *et al.* (1998) studied the effect of neem oil (2 per cent), Endosulfan (0.07per cent) and *Trichogramma chilonis* on bhindi fruit borer and observed that all the treatments were effective in controlling the pest. Rajendran and Varghese (1998) noticed that neem oil (4 per cent) reduced the fecundity (by 62.8 per cent) and hatchability of brinjal epilachna beetle. Sharma *et al.* (1999) reported that tobacco cutworm on cauliflower could be easily controlled by neem. Efficacy of neem and garlic was tried on chilli aphid and found that both the treatments lowered the pest population (Singh *et al.*, 1999). Neem formulation Achook (0.5 per cent) was found effective in controlling fruit borers *Earias vitella* and *Earias insulana* infesting bhindi (Ambekar *et al.*, 2000).

Bernice (2000) studied the effect of neem oil and *H. suaveolens* extract on pests of brinjal and found effective to shoot and fruit borers, epilachna beetle and aphids. She also noted that botanicals were safe for the natural enemies like coccinellids, staphylinids and spiders. According to Ignacimuthu (2000) Neem Azal, a commercial neem formulation was highly effective to *S. litura.* Singh (2000) reported that neem products (neem cake, neem oil and neem based insecticides) were effective in reducing the incidence of brinjal shoot and fruit borer. Srinivasan and Sundarababu (2000) reported that the neem products *viz.*, Neem Azal, Nimbicidine, TNAU neem products (60EC and 0.03 percent EC), Indeem, Neem Gold and Neem Seed Kernal Extract (NSKE) 10 per cent were effective against nymphs of brinjal leaf hopper *Amrasca biguttula biguttula.* They (2001) also reportd that these products were effective to brinjal white fly.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field trials for evaluation of the bio insecticides and chemical insecticides were conducted in the vegetable field of the Department of Olericulture, College of Horticulture, Vellanikara during 2000 – 2001 (Plate 1). The quality evaluation studies were conducted in the laboratory of the Department of Entomology. The field trials were conducted in a phased manner as follows:

- First experiment (September 2000 – November 2000).
- Second experiment (December 2000 – February 2001)

3.1. First experiment:

The field experiment was laid out in RBD with 14 treatments (Table 1) and replicated thrice. The variety used for the cultivation was "Arun". Nursery was raised before the main field planting. After 30 days, transplanting was done at a spacing of 15 cm between the shallow trenches and 10 cm between the plants. The plot size was 2 m x 2 m. All the agronomic practices as per package of practices, recommendations of KAU (1996) were followed. Applications of all the insecticides were done at ten days after transplanting (first spraying) and one month after the first spraying (second spraying). The insecticides were sprayed in the evening hours. Technical details of the pesticides are given in Table 2. The leaves were screened for all sorts of insect pests. Dead insects

Plate 1. Field view of the experimental plot

after each spray were collected from the plots, the pathogen was reisolated and the pathogenicity of the organism was proved according to Koch's postulates.

3.2. Second experiment.

Of the 14 treatments screened for testing their effectiveness on the control of major pests, the six treatments were tested again at two lower doses (Table 3). Thus the total number of treatments tested in this trial with the same basic design and replication was 13. The plot size was 3 m x 3 m and the variety used was Arun itself. The same procedure was followed for taking observations and detection of infectivity in the second experiment.

3.3. Field observations:

Observations on the impact of commercial formulation were taken by recording the mortality of the major pests at two and eight days after spraying. The total number of each pest present in the field before spraying were recorded separately from ten selected plants at random from each replication. The effect of the tested insecticides on the natural enemies and other bio control agents were recorded by catching them by net sweeping in the field before and after the spraying. The leaf area damage was assessed graphically from ten leaves at random per replication.

Table 1. Details of insecticides used in the first experiment

Treatments	Name of insecticides	Dose ml (g)/l
T_1^1	Oil based neem product - Econeem	3 ml
T_2^1	Neem seed extract based - Neem Azal	3 ml
T_3^1	Fungus based – *B. bassiana*	1 g
T_4^1	Fungus based – *V. lecanii*	1 g
T_5^1	Fungus based – *H. thompsonii*	1 g
T_6^1	Virus (NPV) - *H. armigera*	0.5 ml
T_7^1	Virus (NPV) - *S. litura*	0.5 ml
T_8^1	Bacteria based – *B. thuringiensis* - Halt	1 g
T_9^1	Bacteria based – *B. thuringiensis* - Dipel	1ml
T_{10}^1	Bacteria based– *B. thuringiensis* - Delfin	1g
T_{11}^1	Actinomycete based - Spinosad	1.5 ml
T_{12}^1	Chemical insecticide - Nuvan	0.5 ml
T_{13}^1	Chemical insecticide - Malathion	1 ml
T_{14}^1	Control	

Table 2. Technical details of insecticides

Treatments	Name	Active ingredient	Formulation
1	Econeem	Azadirachtin	EC
2	Neem Azal	Azadirachtin	EC
3	*B. bassiana*	Spores	WP
4	*V. lecanii*	Spores	WP
5	*H. thompsonii*	Spores	WP
6	HaNPV	PIB's	SL
7	SlNPV	PIB's	SL
8	Halt	toxin+ spores	WP
9	Dipel	toxin+spores	SL
10	Delfin	toxin+spores	G
11	Spinosad	Spinosyn	SL
12	Nuvan	O, O-dimethyl- 2,2- dichloro vinyl phoshate	EC
13	Malathion	O, O- dimethyl S (1,2- dicarbethoxy ethyl) phosphorodithioate	EC
14	Control		

Table 3. Details of neem products, microbial and chemical insecticides used in the second experiment

Treatments	Insecticides	Dose ml (g)/l
T_1^2	Econeem	2.3 ml
T_2^2	Halt	0.7 g
T_3^2	Dipel	0.7 ml
T_4^2	Delfin	0.7 g
T_5^2	Neem Azal	2.5 ml
T_6^2	Nuvan	0.4 ml
T_7^2	Econeem	1.9 ml
T_8^2	Halt	0.6 g
T_9^2	Dipel	0.6 ml
T_{10}^2	Delfin	0.6 g
T_{11}^2	Neem Azal	2.1 ml
T_{12}^2	Nuvan	0.3 ml
T_{13}^2	Control	

3.3.1. Yield data

The total leaf yield from each treatment was separately recorded during each harvest.

3.3.2. Economics of treatments

Economic analysis of the effective treatments was undertaken by working out the benefit cost ratio.

BCR (Benefit cost ratio)

$$= \frac{\text{Value of increased yield over control - cost of application of insecticide}}{\text{cost of application of insecticide}}$$

The cost that has been taken into consideration for the economic analysis are added cost namely the cost of insecticides which has been considered over and above the fixed cost.

3.3.3. Data analysis

Data were analysed following the analysis of variance for randomised block design, (Gomez and Gomez, 1984). Data on insect mortality were subjected to angular transformation. The observations on the natural enemies and other bio control agents were subjected to square root transformation $\sqrt{x + \frac{1}{2}}$, (Gomez and Gomez, 1984).

3.4. Organoleptic quality evaluation

Organoleptic quality evaluation was done to know whether the applied chemical insecticides and bio insecticides have any effect on the taste, appearance, flavour, texture, colour and bitterness. After cooking the leaves with the following recipe, ten judges were called for scoring the scorecard. The score chart is shown in Appendix.

3.4.1. Recipe

The fresh leaves (100 g) were washed thoroughly in water to remove the adhering dirt and cut into pieces using a stainless steel knife. Ten gram coconut oil was heated and the mustard spluttered in the frying pan. The leaves were then added with sufficient quantity of salt, chilli powder and water to meet the taste and the frying was done under low flame (Mathew, 2000).

3.4.2. Sample collection

Organoleptic quality test was done using the samples collected from the plots where spraying of six insecticides at their two lower doses were done. Collection of samples was done in eight days after spraying. The total number of samples for organoleptic evaluation including control was 39 (13x3).

3.4.3. Analysis of data:

The scores obtained from the score card for each sample was analysed using Kruskel Wallis one way analysis of variance by ranks for each characters (Siegal, 1959).

RESULTS

RESULTS

The results of the experiment were statistically analysed and presented in this chapter.

4.1. Evaluation of the effect of eco-friendly pesticides and chemical insecticides against key pests of amaranths

4.1.1. The following pests were observed in the field experiment

a. Amaranths leaf webber: *Hymenia recurvalis* Fab. Lepidoptera: Pyralidae (Plate 2 and Plate 3)

b. Amaranths leaf webber: *Psara basalis* F. Lepidoptera: Pyralidae (Plate 4 and Plate 5)

c. Amaranths weevil: *Hypolixus truncatulus* F. Coleoptera:Curculionidae (Plate 6)

d. Green grasshopper: *Atractomorpha crenulata* F. Orthoptera: Acrididae (Plate 7)

4.1.2. First experiment

The study was undertaken to select the most effective insecticides listed in Table 1 against the pests of amaranths. The pre treatment count (PTC) showed a uniform infestation in all the treated plots. The results on the efficacy of different insecticides against the pests are summarized below.

Plate. 2. Different stages of amaranths leaf webber *H. recurvalis*

2a. Larva

2b. Pupa

2c. Adult

Plate. 3. Leaves damaged by the leaf webber *H. recurvalis*


2a


2b


2c


3

Plate 4. Different stages of amaranths leaf webber *P. basalis*

4a. Larva

4b. Pupa

4c. Adult

Plate 5. Leaves damaged by the leaf webber *P. basalis*


4a


4b


4c


5

Plate 6. Amaranths weevil *H. truncatulus*

Plate 7. Grasshopper *A. crenulata*


6


7

4.1.3. Effect of test insecticides on the population of leaf webber *H. recurvalis*

The data on the mean cumulative per cent mortality of leaf webber larvae at different intervals are presented in Table 4. Post treatment count at two and eight days after the two spraying revealed significant difference among the treatments. Mortality was recorded in all the treatments except *B. bassiana, V. lecanii, H. thompsonii,* HaNPV and SlNPV treated plants. In control also no mortality was recorded.

4.1.3.1. First spray

The post treatment observation at two days after spraying revealed that maximum larval mortality was observed in the plot treated with Nuvan (75.22 per cent) and Malathion (66.69 per cent). The mortality in *B. thuringiensis* (Dipel) increased rapidly to 90.13 per cent at eight days after treatment (DAT), even the mortality in second day was only 30.23 per cent. In Nuvan and Malathion treated plot, the cumulative mortality was only 79.99 and 71.81 per cent at 8 DAT.

4.1.3.2. Second spray

The cumulative per cent mortality at second day was almost same as the first spraying. At eighth day, maximum mortality was recorded in Dipel 96.97 per cent.

Table 4. Effect of neem, microbial and chemical insecticides on the population of amaranths leaf webber *H. recurvalis*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^1	37.43 (37.69)	75.64 (60.62)	40.21 (39.31)	76.72 (61.44)
T_2^1	35.58 (36.58)	70.53 (57.14)	34.00 (35.62)	72.37 (58.95)
T_3^1	0.00	0.00	0.00	0.00
T_4^1	0.00	0.00	0.00	0.00
T_5^1	0.00	0.00	0.00	0.00
T_6^1	0.00	0.00	0.00	0.00
T_7^1	0.00	0.00	0.00	0.00
T_8^1	27.13 (31.34)	85.73 (68.16)	44.60 (40.74)	96.67 (83.82)
T_9^1	30.23 (33.10)	90.13 (76.37)	42.42 (40.48)	96.97 (84.11)
T_{10}^1	27.08 (31.34)	86.00 (71.80)	38.73 (38.45)	92.59 (80.59)
T_{11}^1	26.96 (31.36)	51.77 (46.01)	29.70 (32.97)	53.28 (47.02)
T_{12}^1	75.22 (60.49)	79.99 (63.73)	76.17 (60.80)	78.96 (62.72)
T_{13}^1	66.69 (54.82)	71.81 (57.99)	66.39 (54.56)	73.28 (58.85)
T_{14}^1	0.00	0.00	0.00	0.00
CD	5.26**	11.36**	22.24**	12.09**

** Significant at 5 %level

Figures in parenthesis are values after angular transformation

4.1.4. Effect of test insecticides on the population of leaf webber *P. basalis*

The results of the step-wise statistical analysis is reported in Table 5.

4.1.4.1. First spray

In Halt sprayed plot ($T^1{}_8$) there was an increase in mortality from 37.76 to 78.04 per cent after eight days of spraying. The infected larvae are shown in Plate 8. But in Nuvan treated plot ($T^1{}_{12}$), increase was from 75.23 to 84.95 per cent. There was no mortality in control group and plots treated with *B. bassiana, V. lecanii, H. thompsonii,* HaNPV and SlNPV.

4.1.4.2. Second spray

The post treatment observations at two and eight DAT revealed significant difference in cumulative mortalities among the treatments. The highest mean cumulative mortality was recorded in $T^1{}_{12}$ (68.33 per cent) followed by $T^1{}_{13}$ (65.58 per cent) at 2 DAT. But at 8 DAT, highest mean cumulative mortality was recorded in Halt ($T^1{}_8$), Dipel ($T^1{}_9$) and Delfin ($T^1{}_{10}$) treated plots. Cent per cent mortality was observed in Halt treated plot. All the treatments except $T^1{}_{13}$ were statistically on par.

4.1.5. Effect of test insecticides on the population of amaranths weevil *H. truncatulus*

The effect of test insecticides on the population of amaranths weevil is given in Table 6. There was no mortality in the plots treated with *B. bassiana, V. lecanii, H. thompsonii,* HaNPV, SlNPV and control.

Table 5. Effect of neem, microbial and chemical insecticides on the population of amaranths leaf webber *P. basalis*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^1	41.27 (39.95)	79.63 (63.25)	40.95 (39.69)	86.67 (76.89)
T_2^1	31.19 (33.88)	69.98 (57.09)	42.14 (35.55)	82.78 (61.57)
T_3^1	0.00	0.00	0.00	0.00
T_4^1	0.00	0.00	0.00	0.00
T_5^1	0.00	0.00	0.00	0.00
T_6^1	0.00	0.00	0.00	0.00
T_7^1	0.00	0.00	0.00	0.00
T_8^1	37.76 (37.86)	78.04 (62.70)	61.30 (56.88)	100.00(89.96)
T_9^1	39.09 (38.67)	76.04 (60.69)	41.00 (39.69)	96.29 (83.47)
T_{10}^1	36.78 (37.32)	72.96 (58.75)	44.12 (41.52)	97.44 (84.60)
T_{11}^1	26.75 (31.12)	71.07 (57.58)	28.36 (31.85)	88.89 (78.21)
T_{12}^1	75.23 (60.81)	84.95 (71.15)	68.33 (55.74)	90.10 (76.20)
T_{13}^1	66.76 (54.98)	75.35 (61.02)	65.58 (54.07)	68.91 (56.16)
T_{14}^1	0.00	0.00	0.00	0.00
CD	5.84**	10.68**	15.19**	19.92**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

Plate 8. Larvae of *P. basalis* infected with *B. thuringiensis*

Table 6. Effect of neem, microbial and chemical insecticides on the population of amaranths weevil *H. truncatulus*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^1	47.53 (43.54)	70.88 (57.40)	58.44 (54.76)	85.39 (66.70)
T_2^1	47.49 (43.52)	68.14 (55.72)	52.38 (46.35)	75.79 (65.97)
T_3^1	0.00	0.00	0.00	0.00
T_4^1	0.00	0.00	0.00	0.00
T_5^1	0.00	0.00	0.00	0.00
T_6^1	0.00	0.00	0.00	0.00
T_7^1	0.00	0.00	0.00	0.00
T_8^1	23.53 (28.97)	72.85 (58.68)	39.29 (38.62)	86.11 (71.94)
T_9^1	26.46 (30.85)	82.09 (65.78)	57.69 (54.55)	97.44 (84.60)
T_{10}^1	24.03 (29.34)	72.07 (58.10)	32.70 (34.82)	86.04 (68.92)
T_{11}^1	15.96 (23.54)	62.77 (52.38)	18.52 (25.43)	70.37 (57.09)
T_{12}^1	68.54 (56.14)	74.91 (60.37)	69.44 (56.76)	76.31 (61.34)
T_{13}^1	64.56 (54.48)	64.56 (54.48)	63.33 (52.71)	63.33 (52.71)
T_{14}^1	0.00	0.00	0.00	0.00
CD	8.22*	9.14**	21.43**	19.64**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

4.1.5.1. First spray

The mean cumulative mortality at 2 DAT ranged from 15.96 per cent (T^1_{11}) to 68.54 (T^1_{12}) per cent. At 8 DAT, Dipel recorded a maximum cumulative mortality of 82.09 per cent, followed by Halt (72.85) and Delfin (72.07). The mean cumulative per cent mortality in Nuvan treated plot at 2 DAT and 8 DAT were 68.54 and 74.91 per cent respectively. The treatments T^1_9 and T^1_{12} were statistically on par.

4.1.5.2. Second spray

Dipel recorded a maximum mean cumulative mortality of 97.44 per cent at 8 DAT. Econeem and Neem Azal treated plots recorded cumulative mortalities of 85.39 and 75.79 per cent respectively. In Halt (T^1_8) and Delfin (T^1_{10}) treated plots almost same mortality (86.11 and 86.04) was observed at 8 DAT. The treatments T^1_1, T^1_8, T^1_9 and T^1_{10} were statistically on par.

4.1.6. Effect of test insecticides on the population of green grasshopper *A. crenulata*

Mortality was observed only in Econeem, Neem Azal, Nuvan and Malathion treated plots (Table 7).

4.1.6.1. First spray.

Among the treatments, Nuvan (T^1_{12}) recorded a high mean cumulative mortality of 77.42 per cent followed by Malathion (67.77 per cent) at 2 DAT.

Table 7. Effect of neem, microbial and chemical insecticides on the population of green grasshopper *A. crenulata*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^1	30.02 (33.21)	73.10 (58.78)	37.62 (37.77)	75.24 (60.44)
T_2^1	31.64 (34.16)	80.35 (68.05)	22.98 (23.89)	82.22 (71.10)
T_3^1	0.00	0.00	0.00	0.00
T_4^1	0.00	0.00	0.00	0.00
T_5^1	0.00	0.00	0.00	0.00
T_6^1	0.00	0.00	0.00	0.00
T_7^1	0.00	0.00	0.00	0.00
T_8^1	0.00	0.00	0.00	0.00
T_9^1	0.00	0.00	0.00	0.00
T_{10}^1	0.00	0.00	0.00	0.00
T_{11}^1	0.00	0.00	0.00	0.00
T_{12}^1	77.42 (62.10)	86.71 (72.31)	78.84 (62.72)	86.17 (69.08)
T_{13}^1	67.77 (55.43)	71.58 (57.91)	68.26 (55.70)	71.43 (57.67)
T_{14}^1	0.00	0.00	0.00	0.00
CD	4.04**	11.13**	9.75**	5.26**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

The next better treatment was Neem Azal. In Nuvan treated plot, the mortality was increased from 67.77 to 71.58 per cent at 8 DAT. In the case of Neem Azal treated plot, the mortality was increased from 31.64 to 80.35 per cent at 8 DAT.

4.1.6.2. Second spray

In second spray also the maximum mortality of 86.17 per cent was recorded in Nuvan after second and eighth days of spraying. The treatments T^1_2 and T^1_{12} were found to be statistically on par.

4.2. Second experiment

The six insecticides selected from the first experiment were applied at two lower doses in order to identify the most promising one (Table 3). The schedule of application of insecticides was same as in the case of first experiment. The observations on the mean cumulative per cent mortality of leaf webbers, weevil and grasshopper on second and eighth day are presented in Tables 8, 9, 10 and 11.

4.2.1. Effect of test insecticides on the population of leaf webber *H. recurvalis*

Table 8 shows the mean cumulative per cent mortality of larvae of leaf webber *H. recurvalis* at different intervals. The control group recorded no mortality throughout the experiment.

Table 8. Effect of neem, microbial and chemical insecticides on the population of amaranths leaf webber *H. recurvalis*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^2	37.49 (37.71)	75.33 (60.68)	45.30 (41.83)	80.65 (68.77)
T_2^2	27.12 (31.36)	84.94 (67.39)	41.27 (39.77)	95.24 (82.95)
T_3^2	36.87 (37.28)	86.11 (72.62)	53.03 (50.83)	96.97 (84.12)
T_4^2	30.12 (33.13)	82.67 (69.60)	58.73 (55.36)	94.44 (81.94)
T_5^2	25.36 (30.20)	71.79 (57.91)	28.33 (32.13)	71.67 (57.84)
T_6^2	73.84 (60.19)	80.56 (68.22)	74.67 (59.77)	78.67 (62.49)
T_7^2	30.25 (33.35)	73.27 (58.85)	30.95 (33.62)	69.05 (61.34)
T_8^2	26.03 (30.66)	72.77 (58.78)	32.14 (34.39)	92.31 (80.40)
T_9^2	29.33 (32.70)	72.72 (59.28)	38.09 (40.32)	78.57 (67.15)
T_{10}^2	27.86 (31.84)	74.87 (60.14)	47.22 (43.49)	81.48 (68.84)
T_{11}^2	27.15 (31.25)	75.28 (65.09)	25.07 (29.71)	72.81 (63.58)
T_{12}^2	72.19 (58.42)	74.23 (59.70)	71.79 (57.89)	76.92 (61.26)
T_{13}^2	0.00	0.00	0.00	0.00
CD	7.89**	19.74**	NS	25.83**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

4.2.1.1. First spray

Analysis of variance has shown that there was significant difference in the cumulative per cent mortalities in different treatments. At 2 DAT, the highest mean cumulative larval mortality was recorded in T^2_6 (73.84 per cent) followed by T^2_{12} (72.19 per cent). But in the eighth day, T^2_3 recorded a cumulative mean mortality of 86.11 per cent followed by T^2_2 (84.94 per cent) and T^2_4 (82.67 per cent). In $T^2_{6,}$ the cumulative mortality was 80.56 per cent.

4.2.1.2 Second spray

Among the treatments, the mean cumulative mortality was ranged from 25.07 (T^2_{11}) to 74.67 per cent (T^2_6) at 2 DAT and from 69.05 (T^2_7) to 96.97 (T^2_2) at 8 DAT. The treatment T^2_6 recorded a mortality of 78.67 per cent. All the treatments except T^2_7 were statistically on par.

4.2.2. Effect of test insecticides on the population of leaf webber *P. basalis*

In the pre treatment investigation the population of leaf webber *P. basalis* was found uniform.

4.2.2.1 First spray

At 2 DAT, the maximum mean cumulative mortality was found in T^2_6 (73.84 per cent). The treatments T^2_6 (73.84 per cent) and T^2_{12} (72.19) were statistically on par. However after eight days, T^2_3 recorded the highest

Table 9. Effect of neem, microbial and chemical insecticides on the population of amaranths leaf webber *P. basalis*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^2	42.04 (40.39)	81.02 (64.89)	66.67 (59.98)	85.19 (76.03)
T_2^2	33.13 (35.09)	80.29 (65.21)	53.53 (52.14)	87.18 (77.19)
T_3^2	41.06 (39.81)	85.38 (68.84)	60.00 (56.05)	93.33 (81.11)
T_4^2	39.82 (38.95)	76.43 (65.84)	65.00 (58.83)	77.17 (66.92)
T_5^2	25.36 (30.20)	71.79 (57.91)	28.33 (32.13)	71.67 (57.84)
T_6^2	73.84 (60.19)	79.17 (64.29)	74.67 (59.77)	78.67 (62.49)
T_7^2	30.25 (33.35)	73.27 (58.85)	30.95 (33.62)	69.05 (61.34)
T_8^2	26.03 (30.66)	72.77 (58.78)	32.14 (34.39)	92.31 (80.40)
T_9^2	29.33 (32.30)	72.72 (59.28)	44.05 (45.15)	77.38 (66.34)
T_{10}^2	27.86 (31.84)	74.87 (60.14)	47.22 (43.49)	81.48 (68.84)
T_{11}^2	27.15 (31.25)	75.28 (65.09)	25.07 (29.71)	72.81 (63.58)
T_{12}^2	72.19 (58.42)	74.23 (59.70)	71.79 (57.90)	76.92 (61.26)
T_{13}^2	0.00	0.00	0.00	0.00
CD	8.15**	19.14**	NS	29.75**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

cumulative mean mortality of 85.38 per cent followed by T^2_1 and T^2_2. The treatments T^2_6 recorded a mean cumulative mortality of 79.17 per cent.

4.2.2.2 Second spray

In T^2_3 there was an increase in mortality from 60.00 to 93.33 per cent after eight days of spraying. But in T^2_6, increase was from 74.67 to 78.67 per cent (Table 9).

4.2.3. Effect of test insecticides on the population of amaranths weevil *H. truncatulus*.

The post treatment observations, at two and eight DAT revealed significant difference among the treatments. There was no mortality in the control group (Table 10).

4.2.3.1. First spray

At 2 DAT, T^2_6 recorded a maximum mean cumulative mortality of 67.19 per cent. But after eight days T^2_2 (82.96 per cent) recorded the maximum mortality. The next better treatment was T^2_6 (81.60 per cent). The treatments except, T^2_1, T^2_5, T^2_7 T^2_{11} and T^2_{12} were statistically on par (Table 10).

4.2.3.2. Second spray

The data on the cumulative percentage mean mortality at different intervals are presented in Table 10. The post treatment observations at 2 DAT

Table 10. Effect of neem, microbial and chemical insecticides on the population of amaranths weevil *H. truncatulus*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^2	41.52 (40.10)	56.90 (48.97)	43.58 (41.26)	67.97 (56.64)
T_2^2	22.96 (28.32)	82.96 (67.93)	74.07 (69.35)	94.44 (81.94)
T_3^2	24.22 (29.40)	72.98 (59.63)	51.53 (50.94)	84.74 (71.90)
T_4^2	23.96 (29.27)	73.29 (59.46)	40.32 (38.71)	90.48 (79.20)
T_5^2	13.85 (21.74)	61.04 (51.36)	21.69 (26.60)	69.31 (56.88)
T_6^2	67.19 (55.52)	81.60 (68.97)	65.71 (54.15)	82.86 (65.51)
T_7^2	39.23 (38.72)	59.26 (50.54)	53.39 (47.48)	72.16 (63.15)
T_8^2	20.32 (26.78)	77.11 (61.44)	29.52 (32.69)	83.81 (70.35)
T_9^2	24.77 (29.72)	74.65 (60.70)	49.17 (43.81)	73.64 (59.94)
T_{10}^2	20.47 (26.83)	68.94 (56.41)	29.36 (32.15)	81.54 (69.20)
T_{11}^2	13.12 (21.21)	60.57 (51.11)	20.38 (26.76)	65.56 (54.52)
T_{12}^2	61.16 (51.43)	61.92 (51.88)	65.92 (54.26)	67.40 (55.18)
T_{13}^2	0.00	0.00	0.00	0.00
CD	6.82**	15.76**	28.19**	24.47**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

showed that T^2_2 was superior over all the other treatments. The next better treatments were T^2_6 and T^2_{12}. The cumulative mean mortality recorded in T^2_6 was 65.71 per cent and that in T^2_{12} was 65.92 per cent. The differences between treatments were significant at 2 and 8 DAT. At 8 DAT the mean cumulative mortality was increased from 74.07 to 94.44 per cent in T^2_2. Whereas in the case of T^2_6, the mean mortality was increased from 65.71 to 82.86 per cent. The treatments T^2_2, T^2_3, T^2_4, T^2_6, T^2_7, T^2_8, T^2_9 and T^2_{10} were statistically on par.

4.2.4. Effect of test insecticides on the population of green grasshopper *A. crenulata*

The observation from the experiment and the results of its statistical analysis are given in Table 11. It was observed that all the treatments except T^2_1, T^2_5, T^2_6, T^2_7, T^2_{11} and T^2_{12} were ineffective to grass hoppers. The maximum cumulative mortality was observed in T^2_6. No mortality was observed in control group.

4.2.4.1. First spray

There was a general increase in mean cumulative percentage mortalities of all the treatments except T^2_{12}. At 2 DAT, the highest mean cumulative mortality of grasshopper was in T^2_{12} (75.9? per cent) while it was least in T^2_7 (26.99 per cent). Analysis of variance showed that the treatments T^2_6 and T^2_{12} were statistically on par. In the subsequent observation at 8 DAT, the treatment T^2_6 recorded maximum mortality of 82.14 per cent. The plots which received

Table 11. Effect of neem, microbial and chemical insecticides on the population of green grasshopper *A. crenulata*

Treatments	Mean cumulative per cent mortality at intervals (in days)			
	First spray		Second spray	
	2	8	2	8
T_1^2	29.50 (32.86)	68.68 (56.00)	41.67 (39.91)	75.56 (65.14)
T_2^2	0.00	0.00	0.00	0.00
T_3^2	0.00	0.00	0.00	0.00
T_4^2	0.00	0.00	0.00	0.00
T_5^2	29.49 (32.65)	60.41 (51.03)	64.72 (53.55)	81.94 (65.04)
T_6^2	74.58 (60.65)	82.14 (69.19)	70.13 (56.91)	76.72 (61.15)
T_7^2	26.99 (31.24)	69.39 (56.66)	32.42 (34.34)	68.48 (61.03)
T_8^2	0.00	0.00	0.00	0.00
T_9^2	0.00	0.00	0.00	0.00
T_{10}^2	0.00	0.00	0.00	0.00
T_{11}^2	60.79 (51.22)	75.71 (60.54)	43.15 (40.84)	77.59 (61.75)
T_{12}^2	75.99 (65.47)	75.99 (65.47)	71.47 57.700	71.47 (57.70)
T_{13}^2	0.00	0.00	0.00	0.00
CD	11.84**	13.77**	10.63**	15.62**

** Significant at 5 % level

Figures in parenthesis are values after angular transformation

the treatment T^2_{12} recorded a mean cumulative mortality of 75.99 per cent followed by T^2_{11} (75.71 per cent).

4.2.4.2. Second spray

Analysis of variance showed significant difference in mortalities due to various treatments at 2 DAT and 8 DAT. At 2 DAT, T^2_5, T^2_6 and T^2_{12} were on par. There was a decline in grasshopper population in all the treatment plots. At 8 DAT, the mean cumulative mortality was increased from 70.13 to 76.72 per cent in T^2_6. But in T^2_5, the mean cumulative mortality was found to be 81.94 per cent. The treatment without insecticidal application always recorded higher grasshopper population.

4.3. Effect of test insecticides on the population of natural enemies and other bio control agents

The following natural enemies and bio control agents were observed during the experiment.

a. Parasite

b. *Rhinocoris marginatus*

c. Spiders

d. Coccinellids and

e. Dragon fly

The mean population of natural enemies and other bio control agents observed before and after spraying is presented in Table 12. In the pre treatment observation the population of natural enemies were observed in all the treated plots. No disease symptom or deformities were observed in any of the bio control agents. It was also observed that more number of natural enemies and bio control agents were present in control after spraying. In Neem treated plots, the natural enemy population was decreased after spraying. In the case of Econeem (2.3 ml l^{-1}), the mean population of coccinellids was decreased from 3.96 to 0.27. In the case of Nuvan treated plots, a drastic reduction in population of bio control agents was observed.

4.4. Assessment of leaf area damage

The extend of damage caused by the pest on the treated plot was assessed by graphical method. The maximum leaf area damage was observed in control (69.30 cm^2) and the minimum in the treatment Delfin at the rate of 0.7 g l^{-1} with a value of 20.75cm^2 (Table13).

Table 12. Effect of neem, microbial and chemical insecticides on the population of natural enemies and other bio control agents

Treatment	Parasites		*Rhinocoris marginatus*		Spiders		Coccinellids		Dragon flies	
	Before spray	After spray	Before spray	After spray	Before spray	After spray	Before spray	After spray	Before spray	After spray
T_1^2	1.63 (1.46)	0.00 (0.71)	2.29 (1.67)	0.27 (0.88)	3.00 (1.87)	0.27 (0.88)	3.96 (2.11)	0.27 (0.88)	2.67 (1.76)	0.00 (0.71)
T_2^2	1.63 (1.46)	2.64 (1.77)	0.99 (1.22)	1.63 (1.46)	1.92 (1.56)	3.00 (1.87)	2.95 (1.86)	3.65 (2.04)	0.87 (1.17)	1.63 (1.46)
T_3^2	1.92 (1.56)	2.64 (1.77)	1.30 (1.34)	1.30 (1.34)	1.92 (1.56)	2.31 (1.68)	3.84 (2.08)	4.88 (2.32)	1.42 (1.39)	2.95 (1.86)
T_4^2	1.56 (1.44)	2.31 (1.68)	1.92 (1.56)	2.31 (1.68)	1.56 (1.44)	2.31 (1.68)	2.52 (1.74)	3.31 (1.95)	1.30 (1.34)	1.92 (1.56)
T_5^2	1.30 (1.34)	0.00 (0.71)	2.31 (1.68)	0.27 (0.88)	3.10 (1.90)	0.27 (0.88)	2.31 (1.68)	0.27 (0.88)	1.92 (1.56)	0.00 (0.71)
T_6^2	1.92 (1.56)	0.00 (0.71)	1.30 (1.34)	0.00 (0.71)	2.95 (1.86)	0.00 (0.71)	2.95 (1.86)	0.00 (0.71)	2.19 (1.64)	0.00 (0.71)
T_7^2	1.92 (1.56)	0.00 (0.71)	2.64 (1.77)	0.27 (0.88)	3.96 (2.11)	0.27 (0.88)	1.30 (1.34)	0.27 (0.88)	1.56 (1.44)	0.00 (0.71)
T_8^2	2.52 (1.74)	2.95 (1.86)	1.92 (1.56)	2.95 (1.86)	2.19 (1.64)	2.95 (1.86)	1.56 (1.44)	3.50 (2.00)	1.30 (1.34)	2.00 (1.58)
T_9^2	2.31 (1.68)	2.95 (1.86)	1.92 (1.56)	3.62 (2.03)	3.24 (1.93)	3.24 (1.93)	1.92 (1.56)	2.95 (1.86)	1.63 (1.46)	1.92 (1.56)
T_{10}^2	2.95 (1.86)	3.96 (2.11)	1.92 (1.56)	2.64(1.77)	1.30 (1.34)	2.64 (1.77)	2.95(1.86)	3.31 (1.95)	3.31 (1.95)	3.31 (1.95)
T_{11}^2	1.56 (1.44)	0.60 (1.05)	2.95 (1.86)	0.27 (0.88)	1.56 (1.44)	0.60 (1.05)	1.30 (1.34)	0.27 (0.88)	1.30 (1.34)	0.00 (0.71)
T_{12}^2	2.60 (1.76)	0.27 (0.88)	1.30 (1.34)	0.00 (0.71)	2.60 (1.76)	0.27 (0.88)	3.96 (2.11)	0.27 (0.88)	1.30 (1.34)	0.00 (0.71)
T_{13}^2	5.20 (2.39)	5.60 (2.47)	3.00 (1.87)	4.98 (2.34)	2.60 (1.76)	4.25 (2.18)	3.96 (2.11)	5.27 (2.40)	2.31 (1.68)	3.65 (2.04)
CD	NS	0.38**	0.39**	0.38**	NS	0.43**	NS	0.49**	NS	0.28**

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

Values given in tables are mean population per replication

** Significant at 5 % level

Table 13. Assessment of leaf area damage

Treatments	Leaf area damaged (cm^2)	Percentage of leaf area damaged
T_1^2	24.10	24.10
T_2^2	21.50	21.50
T_3^2	24.50	24.50
T_4^2	20.75	20.75
T_5^2	27.70	27.70
T_6^2	49.09	49.09
T_7^2	22.80	22.80
T_8^2	22.50	22.50
T_9^2	36.94	36.94
T_{10}^2	22.00	22.00
T_{11}^2	35.67	35.67
T_{12}^2	49.22	49.22
T_{13}^2	69.30	69.30

Standard leaf area 100 cm^2

Values given in the table are mean of ten observations per plot.

4.5. Yield

The yield obtained in different treatments is presented in the Table 14. The treatment Delfin at the rate of 0.7 g l^{-1} ($T^2{}_4$) recorded the highest mean yield of 12.33 kg per plot (9 m^2) followed closely by Halt at the rate of 0.7 g l^{-1} (11.67 kg) and Delfin @ 0.6 g l^{-1} (11.33 kg). Control recorded a lowest yield of 6.66 kg per plot. The yield recorded showed significant difference between the treatments.

4.6. Economics of insecticidal treatment.

The benefit cost ratio of different treatments was calculated and furnished in Table 15. The highest benefit cost ratio of 39:1 was recorded in treatment $T^2{}_3$ (Dipel @ 0.7 ml l^{-1}). The maximum net profit per acre was obtained in *B. thuringiensis* based Delfin at the rate of 0.7 g l^{-1} (Rs.24401). The next profitable treatment was Halt at the rate of 0.7 g l^{-1} which fetched a net profit of Rs.21578. The lowest net profit was recorded in Nuvan treated plots.

4.7. Organoleptic evaluation

The data presented in Table 16 shows total rank scores based on Kruskel Wallis One Way analysis of variance by ranks for the qualities *viz*., appearance, colour, texture, taste, flavour and bitterness. There was no significant difference in the total rank scores due to different treatments.

Table 14. Yield obtained in different treatments

Treatments	Per plot ($9m^2$) yield (kg)	Per acre yield (kg)
T_1^2	11.23	4993
T_2^2	11.67	5185
T_3^2	10.92	4852
T_4^2	12.33	5481
T_5^2	10.73	4778
T_6^2	7.00	3111
T_7^2	11.17	4963
T_8^2	11.25	5000
T_9^2	10.05	4467
T_{10}^2	11.33	5037
T_{11}^2	10.17	4519
T_{12}^2	6.88	3059
T_{13}^2	6.66	2963
CD	1.18**	547.88**

Significant at 5 % level

* Values given in the table are mean yield per plot and per acre

Table 15. Economic analysis of test insecticides

Treatments	Mean yield of healthy leaves (kg acre^{-1})	Increased yield over control		Cost of insecticides* (Rs. acre^{-1})	Net Profit (Rs. acre^{-1})	Benefit Cost ratio
		Quantity in (kg.acre^{-1})	Value in (Rs. acre^{-1})			
T_1^2	4993	2030	20300	960	19340	20 :1
T_2^2	5185	2222	22220	642	21578	34 :1
T_3^2	4852	1889	18890	473	18417	39 :1
T_4^2	5481	2518	25180	779	24401	31 :1
T_5^2	4778	1815	18150	1067	17083	16 :1
T_6^2	3111	148	1480	70	1410	20 :1
T_7^2	4963	2000	20000	800	19200	24 :1
T_8^2	5000	2037	20370	566	19804	35 :1
T_9^2	4467	1504	15040	394	14646	37 :1
T_{10}^2	5037	2074	20740	656	20084	31 :1
T_{11}^2	4519	1556	15560	909	14651	16 :1
T_{12}^2	3059	96	960	45	915	20:1
T_{13}^2	2963	—	—	—	—	—

* Added cost over and above the fixed cost.

Table 16. Organoleptic evaluation of cooked amaranths leaves

Treatments / Qualities of cooked leaves	T^2_1	T^2_2	T^2_3	T^2_4	T^2_5	T^2_6	T^2_7	T^2_8	T^2_9	T^2_{10}	T^2_{11}	T^2_{12}	T^2_{13}
Appearance	35	34	42	44	43	35	29.5	29.5	43	44	42	34	52.5
Colour	28.5	34	39.5	43	39	37.5	28.5	39	39.5	34	37.5	43	56.5
Flavour	51	26.5	42	53.5	51	35	33.5	33.5	33.5	26.5	325	42	53.5
Texture	46.5	48	39	48	35.5	42.5	35	35.5	35	48	31.5	39	42.5
Taste	44.5	33	51.5	38.5	44.5	29.5	33	38.5	29.5	44.5	33	38.5	51.5
Bitterness	35	30	52	30	40.5	51	34.5	51	30	35	40.5	34.5	52.0

Values given are total rank scores based on Kruskel Wallis One way analysis of variance by ranks.

DISCUSSION

5. DISCUSSION

The effect of Neem products, Neem Azal and Econeem, *B. thuringiensis* formulations Halt, Dipel and Delfin and the chemical insecticide Nuvan on the leaf webbers, weevil and grasshopper of amaranths were evaluated on the basis of mortality, antifeedant and repellent effects, deformities and its influence on natural enemies and other bio control agents. Organoleptic quality evaluation was done on the basis of palatability of cooked amaranths leaves. Data obtained from observations on these aspects were analysed statistically and the results are presented in chapter 4. A detailed discussion on the results is presented under the following headings.

a) Bioefficacy of Neem, microbial and chemical insecticides against the key pests of amaranths.

b) Yield and Economic analysis

5.1 Bioefficacy of neem, microbial and chemical insecticides against the key pests of amaranths

5.1.1 Against the leaf webber *H. recurvalis*

The results of the present investigation revealed that *B. thuringiensis* formulation Dipel @ 0.7 ml l^{-1} gave consistently good results throughout the experiment. This could be exemplified from 86.11 and 96.97 per cent reduction of leaf webber larvae, after eight days of first and second spraying. Several authors reported the efficacy of *B. thuringiensis* formulations in controlling the lepidopteran pests of vegetables (Mahapatro *et al.*, 1998). Application of *B. thuringiensis* formulation Dipel gave effective control of cabbage diamondback moth larvae (Ashokan *et al.*, 1996). The next better treatment was Halt @ 0.7 g l^{-1} with mortalities of 84.94 and 95.24 per cent after eight days of first and second spraying. This is in confirmation with the findings of Battu *et al.* (2000). They observed cent per cent mortality of young larvae of bihar hairy caterpillar *S. obliqua* with the application of Halt. Delfin @ 0.7 g l^{-1} was also found effective to leaf webber *H. recurvalis* with a mortality of 94.44 per cent after eight days of second spraying. Excellent control of tomato fruit borer *H. armigera* was achieved by Reddy *et al.* (1997) and Gupta and Babu (1998), when Delfin was used. Among the neem products Econeem and Neem Azal, Econeem @ 2.3 ml l^{-1} gave good control of the pest. Supporting this finding are the reports by Gujar (1997), confirming the superiority of azadirachtin in effectively checking the population of the tomato fruit borer *H. armigera.* Malformed adults were obtained offering the evidence of strong physiological action of neem. Deformation, inactivation and mortality in the quiescent stage were also found. Isman (1997) have opined that the important physiological actions of azadirachtin are those resulting from the release of ecdysteroids causing disruption in larval moulting, interference with pupation, eclosion of adults and also the interference with reproduction. Here the findings are in agreement to his views. The chemical insecticide Nuvan (0.4 ml l^{-1}) recorded a mortality of 80.56 after eight days of first spraying. The observations made during the present studies showed that the population shot up in the PTC of second spraying, necessitating a spray before seven days. But in the case of *B. thuringiensis* treated plots, the PTC of second spraying recorded a low population only. Thus a single application is necessary, because the pathogen perpetuate in the field if the host insect is available.

5.1.2. Against the leaf webber *P. basalis*

B. thuringiensis formulation Dipel @ 0.7 ml l^{-1} gave excellent control of the leaf webber and was found superior to all the treatments. Efficacy of Dipel against the leaf webber of cabbage was in consonance with the study of Malathi *et al.* (1999). There was a gradual reduction of population in Halt and Delfin treated plots (Table 9). This could be attributed to the occurrence of the natural enemies and other bio control agents. The next best treatment among *B. thuringiensis* was proved to be Halt @ 0.7 g l^{-1} which recorded a cumulative mortality of 80.29 per cent after eight days of second spraying. Regarding the effectiveness of neem products, Econeem 2.3 ml l^{-1} was resulted with cumulative mortalities of 81.02 and 85.19 per cent after eight days of first and second spraying respectively. Singh (2000) reported that neem based insecticides was very effective in reducing the incidence of brinjal shoot and fruit borer *L. orbonalis.* This increased control could be attributed to the additive effects of repellency and phagodeterrncy of azadirachtin. In Nuvan treated plots, population of larvae was found increased in the PTC of second spraying. The present studies showed that *B. thuringiensis* was found superior to all the other treatments.

5.1.3. Against the population of amaranths weevil *H. truncatulus*

The data on the cumulative mortality of weevil revealed that all the tested components were toxic to them (Table 10). *B. thuringiensis* formulation Halt @ 0.7 g l^{-1} was found more effective causing greater mean cumulative mortality of 82.96 and 94.44 per cent after eight days of first and second spraying. This may be ascribed to long term effect of bacteria *B. thuringiensis* multiplying through the host insect. This was in corroboration with the study of Rajendran and Gopalan (1999), who opined that *B. thuringiensis* 0.25 per cent was effective to epilachna beetle, infesting brinjal. Neem formulation Econeem @ 2.3 ml l^{-1} was also found to be effective with a mean cumulative mortality of 67.97 per cent at 8 DAT from 43.58 per cent at 2 DAT of second spraying. According to Rao *et al.* (1992), neem extract (0.5 per cent) gave cent per cent control of brinjal from the attack of epilachna beetle. Similar result was also reported by Bernice (2000). The control plot recorded the maximum insect population.

5.1.4. Against the population of green grasshopper *A. crenulata*

Nuvan was found to be more effective to grasshopper than Econeem and Neem Azal. The mean cumulative mortality recorded in the case of Nuvan @ 0.4 ml l^{-1} and 0.3 ml l^{-1} was 76.72 and 71.47 respectively at 8 DAT of second spraying. Among neem formulations, Neem Azal proved itself to be more effective to weevils. Naqui *et al.* (1996) studied the phagodeterrant effect of neem formulation Margosan against cabbage grasshopper and found that significant control could be achieved against the pest. The population of grasshopper was found to be increased in the case of control plot compared to insecticide treated plots.

5.2. Effect of neem, microbial and chemical insecticides on the natural enemies and other bio control agents

All the *B. thuringiensis* formulations Halt, Dipel and Delfin were found safe to natural enemies and other bio control agents. The population of bio control agents were found high in *B. thuringiensis* treated plots compared to other insecticides treated plot (Figures 1 to 5). Dhaliwal and Arora (1998) reported that the use of *B. thuringiensis* based biopesticide in place of chemical insecticides is much safer to natural enemies of cabbage diamondback moth. In Nuvan treated plots, the population of natural enemies and bio control agents were found nil or lower than the pre treatment observations. Same result was obtained in the case of neem based insecticides. This could be attributed to the repellent or toxic action of azadirachtin. Thus in the view of their demonstrated efficacy, safety and selectivity, the bio pesticide Dipel, Delfin and Halt could preferably be utilized for the management of major pests of amaranths.

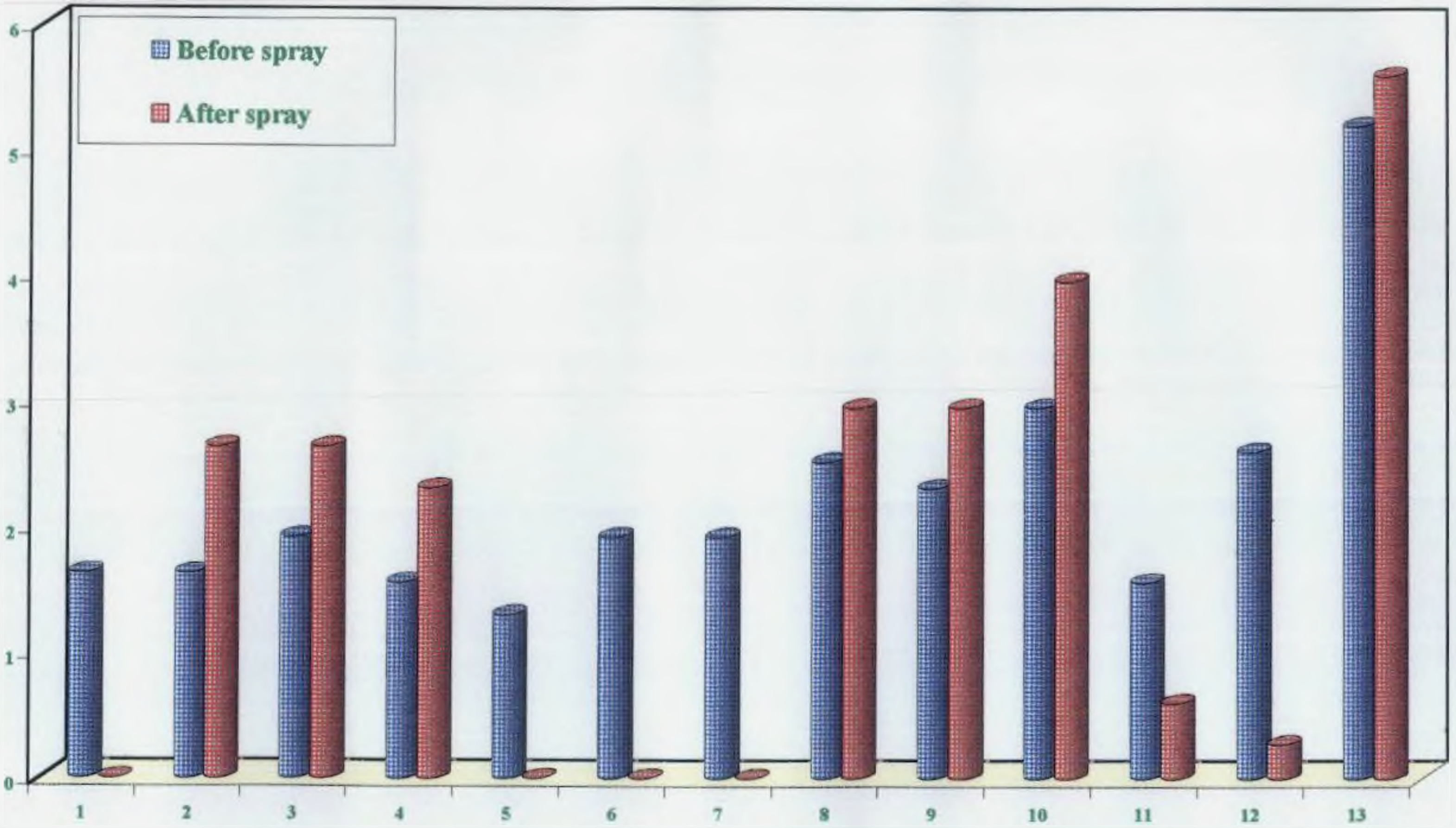

Fig. 1. Effect of neem, microbial and chemical insecticides on the population of Parasite

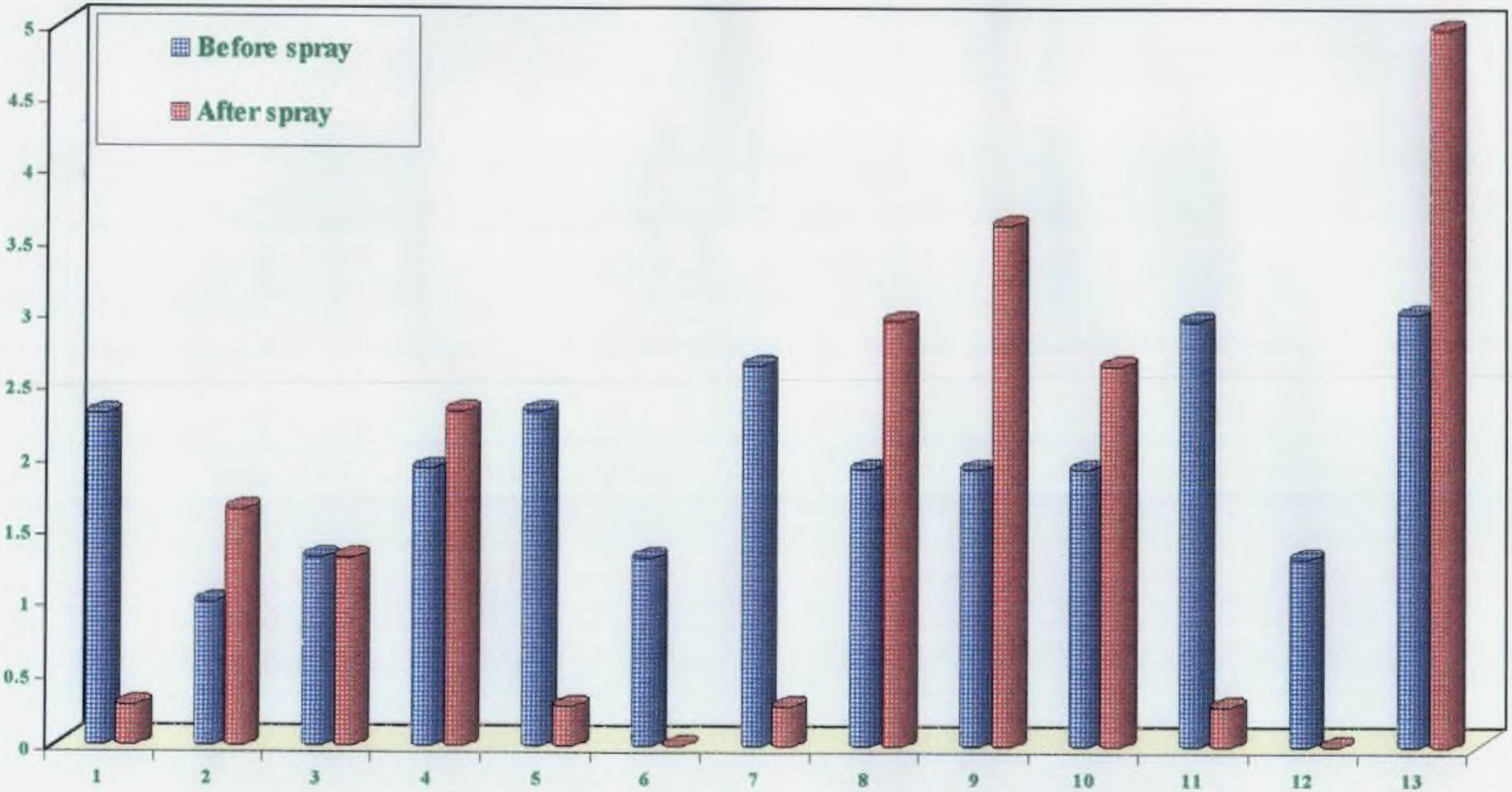

Fig. 2. Effect of neem, microbial and chemical insecticides on the population of *Rhinocoris marginatus*

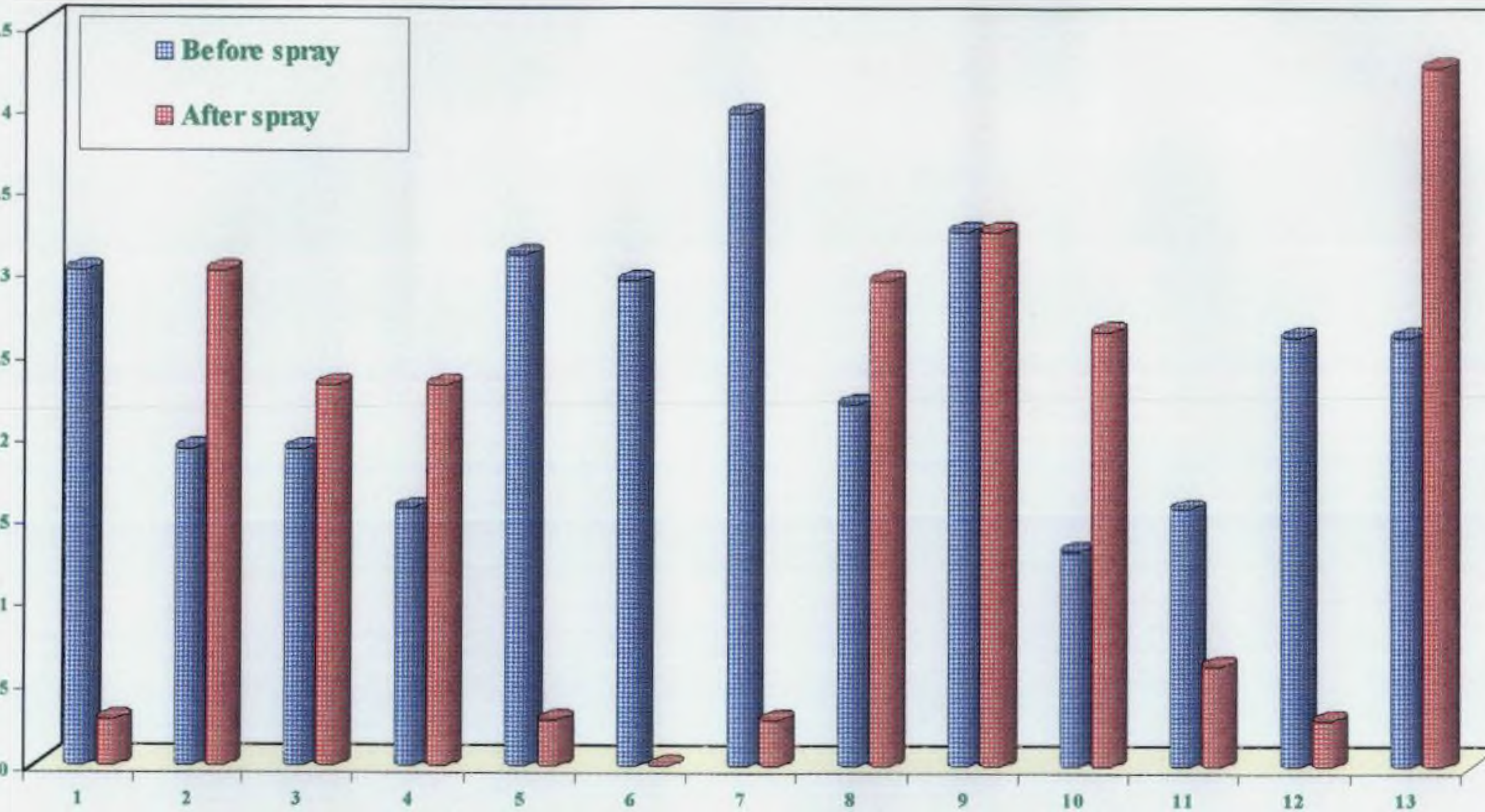

Fig. 3. Effect of neem, microbial and chemical insecticides on the population of spiders

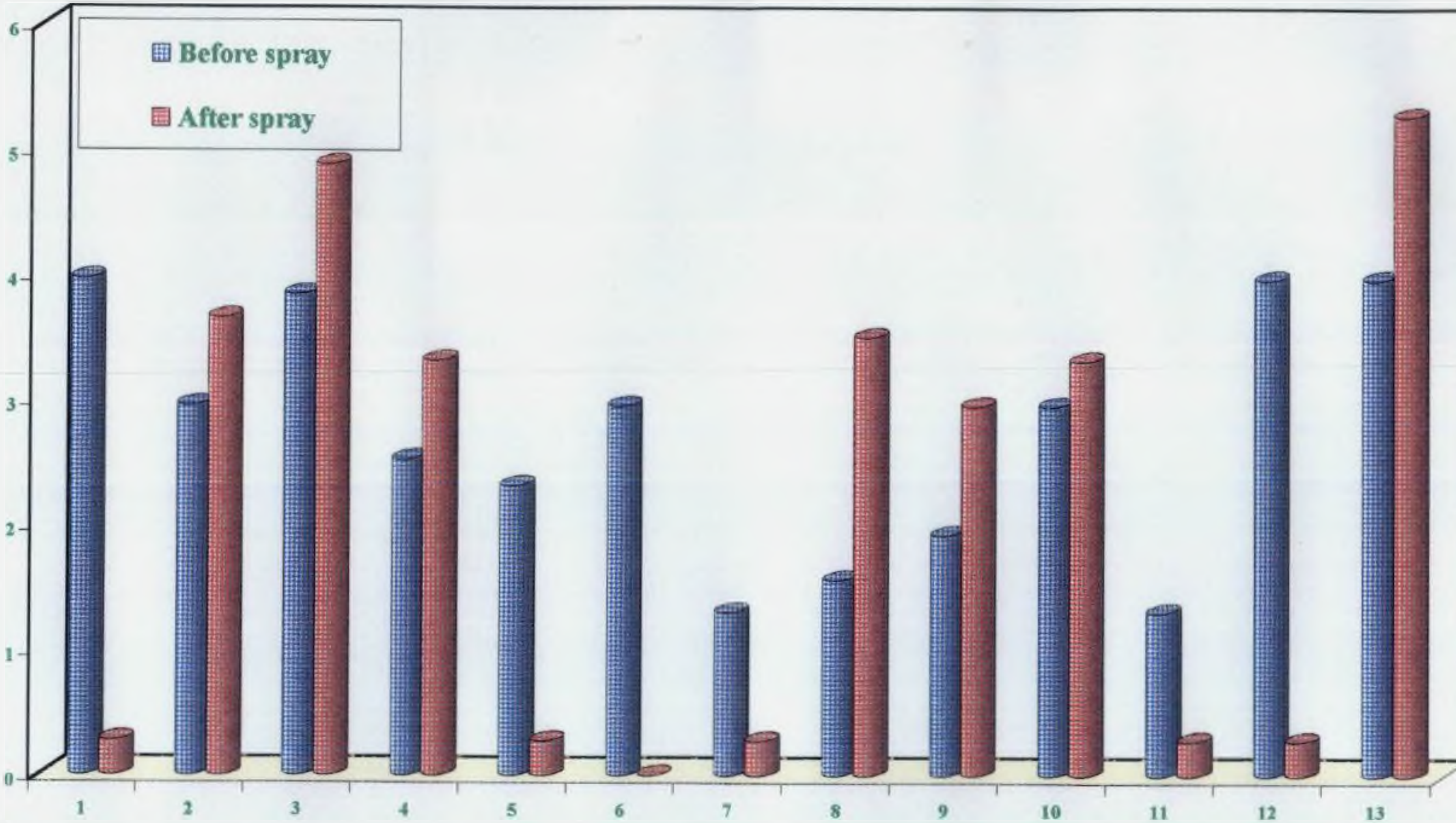

Fig. 4. Effect of neem, microbial and chemical insecticides on the population of coccinellids

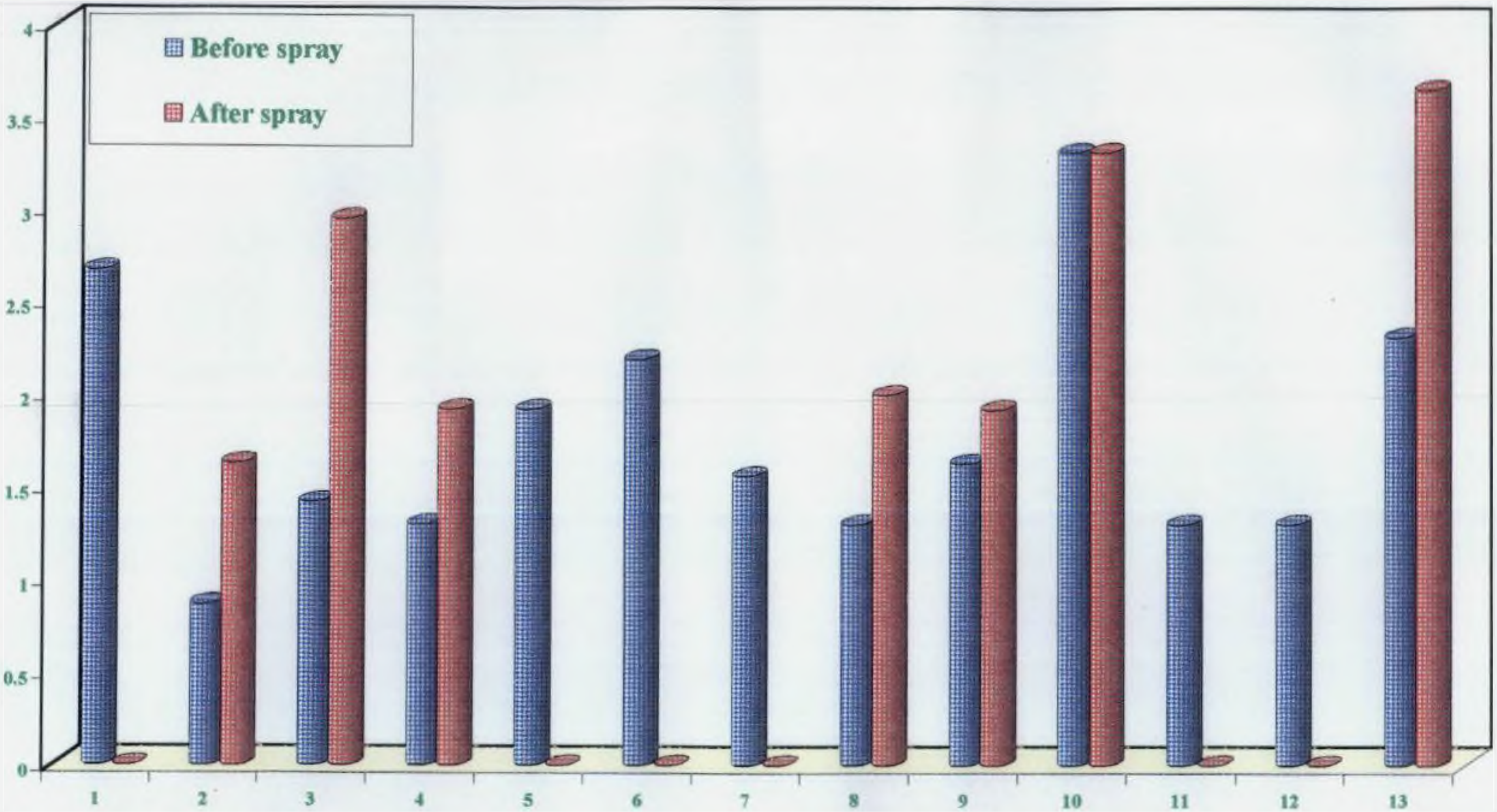

Fig. 5. Effect of neem, microbial and chemical insecticides on the population of dragon fly

5.3. Yield and economic analysis

The highest yield of 12.33 kg per plot was recorded in Delfin @ 0.7 g l^{-1} followed by Halt @ 0.7 g l^{-1} (11.67). This was in confirmation with the study of Arora *et al.* (2000). They recorded the highest yield of cauliflower curd in *B. thuringiensis* treated plot. The lowest mean yield of 6.66 kg per plot was recorded in control which was on par with the yield obtained from Nuvan treated plot.

In the present study, the highest net profit of Rs. 24401 per acre was obtained from the plots which received Delfin @ 0.7 g l^{-1}. Here the benefit cost ratio was 31:1. But in the case of Dipel @ 0.7 ml l^{-1}, a maximum benefit cost ratio of 39:1 was obtained. Here the cost of insecticide was less compared to Delfin. This was followed by Dipel @ 0.6 ml l^{-1}, which recorded a maximum per acre yield of 4467 kg with a net profit of Rs. 14646. The benefit cost ratio obtained was 37:1. The higher benefit cost ratio obtained in the above treatments might be due to the effectiveness of the treatments against various pests. The benefit cost ratio of Nuvan was almost same as that of neem based formulation Neem Azal. Eventhough the cost of insecticides was high in *B. thuringiensis* based insecticides, the yield was found high.

Analysis of data on total rank score revealed that there was no significant difference in qualities of cooked amaranths due to treatments. No bitterness was observed in any of treated leaves even after cooking.

SUMMARY

5. SUMMARY

Investigations were undertaken at the Department of Agricultural Entomology, College of Horticulture, and Vellanikkara during 2000-2001 to evaluate the bioefficacy of eco-friendly pesticides and chemical insecticides for the management of leaf webbers, weevil and grasshopper infesting amaranths. It was found that *B. thuringiensis* based bio pesticides in place of chemical insecticides is much effective to the pests observed. The six commercial products namely Econeem, Neem Azal, Halt, Dipel, Delfin and Nuvan were tested against the major pests of amaranths. The study resulted in the following finding.

1. The *B. thuringiensis* products were found effective in controlling the larvae of leaf webbers viz., *H. recurvalis* and *P. basalis.* Dipel @ 0.7 ml l^{-1} showed drastic reduction in the population of both the leaf webbers.

2. Treatment effects were significant in controlling weevil. Chemical insecticide Nuvan @ 0.4 ml l^{-1} was found effective for a short period only. Halt @ 0.7 g l^{-1} showed significant control of the pest by the gradual increment in the mortality. Econeem @ 2.3 ml l^{-1} was also found to be effective in controlling the weevil.

3. Among different treatments, Nuvan @ 0.4 ml l^{-1} significantly reduced the population of grasshopper.

4. In studies on the effect of tested insecticides on the population of natural enemies and other bio control agents, it was found that they did not show any symptoms of infection due to *B. thuringiensis*. In the plots treated with chemical and neem based insecticides, the population of natural enemies and other bio control agents were found to be drastically reduced.

5. The yield obtained from different plots was found significant due to various treatments. *B. thuringiensis* applied plots recorded higher yield than the other treatments.

6. Organoleptic quality evaluation of cooked amaranths leaves revealed that there was no significant difference in appearance, colour, texture, flavour, taste and bitterness due to treatments in comparison with untreated control.

Based on the results obtained it can be concluded that *B. thuringiensis* products Halt, Dipel and Delfin have exhibited significant effects in suppressing the population of leaf webbers and weevils. So it is proposed that *B. thuringiensis* products can be included in the list of pesticides for the management of leaf webbers and weevil in amaranths.

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APPENDIX

APPENDIX

Organoleptic quality test - score card

No:	Characters	Description	Score					
				1	2	3	4	5
I	Appearance	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
II	Colour	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
III	Flavour	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
IV	Texture	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
V	Taste	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
VI	Bitterness	Not at all bitter	5					
		Slightly bitter	4					
		Bitter	3					
		Moderately bitter	2					
		Highly bitter	1					

ECO-FRIENDLY INSECTICIDES FOR THE MANAGEMENT OF MAJOR PESTS OF AMARANTHS

By

M. K. LEENA

ABSTRACT OF THE THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

There has been increasing reports on health hazards in human beings from the unscientific and intensive use of pesticides in crops, especially vegetables. It was in this backdrop, a scientific investigation was designed to evolve safer and eco-friendly methods in pesticide use to control the major pests of the popular leafy vegetable amaranths. Field experiments were conducted at the college of Horticulture, Vellanikkara during 2000-2001 to identify the safer, eco-friendly insecticides. For the first experiment, thirteen different commercial formulations of neem, microbial and chemical pesticides were evaluated for the control of amaranths leaf webbers *viz., H. recurvalis, P. basalis*, weevil *H. truncatulus* and grasshopper *A. crenulata.* The best six effective components were further screened at lower doses, so as to identify the most promising one in the second experiment. The effect of the tested components on the natural enemies and other bio control agents were also studied. Organoleptic quality evaluation of cooked amaranths leaves was done to know, whether the applied insecticides have any effect on the taste, appearance, colour, flavour, texture and bitterness.

Of the insecticides tested in the first experiment, Econeem, Neem Azal, Halt, Dipel, Delfin and Nuvan were the most effective in controlling the pest population. The results of the second experiment indicated that the plots treated with Dipel @ 0.7 ml l^{-1} gave better control of both the leaf webbers. Halt @ 0.7

g l^{-1} gave comparably good results for the control of weevil. All the microbial insecticides tested were found ineffective to grasshopper. No disease symptom or deformities were observed in any of the natural enemies and other bio control agents. In the field, though Nuvan was found to control the pests, it was not effective in the long run. All the microbial products were found to protect the crop for a longer period of time. The crop sprayed with Delfin @ 0.7g l^{-1} gave an yield of 5481 kg green leaves per acre compared to untreated control (2963 kg). Organoleptic quality evaluation of cooked amaranths leaves revealed that, there was no significant difference in qualities of cooked amaranths due to treatments compared to untreated control.