SEASONAL OCCURRENCE AND ECOFRIENDLY MANAGEMENT OF PESTS OF AMARANTHUS (*Amaranthus tricolor* L.)

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DECLARATION

I hereby declare that this thesis entitled "**Seasonal occurrence and ecofriendly management of pests of amaranthus (*Amaranthus tricolor* L.)**" 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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Certified that this thesis entitled "**Seasonal occurrence and ecofriendly management of pests of amaranthus (*Amaranthus tricolor* L.)**" is a record of research work done independently by Ms. Asha J. S (2003-11-05) 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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Introduction

1. INTRODUCTION

Vegetable crops are a sacrosanct group of edible protective food plants having essential vitamins, minerals, proteins and dietary fibres. Since Vedic times, vegetable cultivation has had a chequered history in India. At present, India is the second largest producer of vegetables in the world, next to China. In spite of this, the productivity of vegetables is low in India compared to the developed countries. The per capita availability of vegetables is only 135 g as against the minimum requirement of 285 g per day. The low intake of vegetables is one of the important reasons for malnutrition in the country. Addition of vegetables including leafy species like amaranthus in the average Indian diet will considerably increase its quality.

Amaranthus spp. are one of the major tropical vegetables cultivated in India, Malaysia, Myanmar, Taiwan, South Pacific islands, tropical Africa, the Caribbean, Central and South America (Tindall, 1983). Amaranthus or Indian spinach leaves are a bountiful source of calcium, potassium, vitamin A, ascorbic acid and iron. In India, it is cultivated largely in the southern states. In Kerala, amaranthus is raised round the year in the erstwhile paddy lowlands, garden lands and homesteads.

One of the major factors, which hamper the productivity and yield of amaranthus is the infestation by insect pests. Insects like leaf webbers, green grasshopper and tobacco caterpillar infest and devour the leaves of amaranthus (Nair, 1975). Hitherto, plant protection measures against the pests especially in the market oriented cultivation of amaranthus has largely been chemical pesticide based. The package of practice of the Kerala Agricultural University (KAU, 2002) recommends the use of malathion 0.10 per cent or 10 per cent malathion dust in cases of severe infestation. Studies conducted by Rahiman *et al.* (1986), Meera (1995)

and Nandakumar (1999) have revealed the unwarranted use of a broad range of pesticides by vegetable growers in Kerala. The residues of pesticides like carbofuran have been detected in market samples of amaranthus leaves (Rajendran *et al.*, 1991). The indiscriminate use of chemical pesticides have resulted in resurgence and resistance in pests. destruction of natural enemies of pests, harm to non-target organisms. contamination of the environment, pesticide residues in the produce and consequent health hazards.

It is high time that we take cognizance of the deleterious effects of chemical pesticides. There is an imperious need to evolve alternatives to the toxic and harmful chemicals. Integrated pest management focusses on the reduction of the pest status which is related to population of pests. their extent of damage and the crop in question. Thus knowledge on the seasonal occurrence of pests in the crop environment is important. Then pest populations have to be brought down to tolerable levels by developing strategies and tactics with least harm to the environment. One approach would be to develop cost effective products desirably from botanical sources. Botanicals like neem have a multi-pronged action against insect pests and are compatible with other methods of pest suppression in IPM. They are benign to the natural enemies of pests, non-target organisms and the other components of the agro-ecosystem. The use of botanicals in control of pests of amaranthus offers the prospect of obtaining uncontaminated good quality produce.

The information on the status of pests of amaranthus, their seasonal occurrence and non-chemical management measures are meagre. Hence the present studies were taken up with the following objectives.

1. To study the seasonal incidence of pests, their natural enemies and leaf blight disease of amaranthus.
2. To evolve an ecofriendly management strategy against the pests.

Review of Literature

2. REVIEW OF LITERATURE

Amaranthus (*Amaranthus tricolor* L.) is the most popular leafy vegetable consumed in Kerala. The crop is cultivated throughout the year. The productivity and yield of the crop is adversely affected by the infestation of a number of pests and diseases like leaf blight. Natural enemies of the pests of amaranthus have also been identified. The effects of chemical pesticides and botanicals in controlling the pests have been studied. The literature related to the different pests and their natural enemies, antifeedant action of botanicals and insecticidal action of chemical pesticides are reviewed hereunder.

2.1 SEASONAL OCCURRENCE OF PESTS OF AMARANTHUS AND THEIR DAMAGE.

Leaf webber

Lefroy (1909) observed that in India, cultivated amaranthus was infested by leaf webber in almost all the gardens during the warmer and early winter months. Fletcher (1914) has recorded the occurrence of leaf webber *Hymenia recurvalis* (F) on various species of amaranthus in South India. The leaf caterpillar *H. recurvalis* is a major pest of *Amaranthus* spp. and beet in Africa (Epenhuijsen, 1974 and Grubben, 1976).

In India, it is found on all the species of amaranthus, but the cultivated species *Amaranthus cruentatus* L. and *Amaranthus dubius* Mart. are more seriously infested. The moths were found in large numbers from July to October on various species of amaranthus. As the severity of winter increased, their numbers gradually dwindled (Bhattacherjee and Menon, 1964). In January and February, they became very scarce and by the advent of summer, their numbers again increased. The caterpillar feed on the epidermis and palisade tissues of the leaves which are webbed up

with silvery threads. Sometimes the caterpillar webs together the leaves. feeds from within and skeletonises them completely (Bhattacherjee and Menon, 1964; Nair, 1975 and Nair, 1999).

Psara basalis F. is another leaf webber of amaranthus (Ayyar. 1963). The occurrence of leaf webber *Psara pallidalis* F. on amaranthus in West Africa was reported by Epenhuijsen (1974). The green caterpillar of the species *P. basalis* commonly occurs in Kerala. The larvae web together the leaves and feed from within (Nair, 1975 and Nair, 1999).

Amaranthus weevil

The occurrence of amaranthus weevil *Hypolixus truncatulus* (F.) was reported by Nair (1975), Grubben (1976), Nayar *et al.* (1976) and David (2001).

Nair (1975) reported that an infested plant may contain 17 to 18 grubs causing it to rupture and break. Stunting and twisting of the plant. swelling of the branches and stems and suppression of shoot and leaf production are other symptoms of attack. David (2001) stated that the grubs bored into stems and caused gall like thickening, no serious damage was inflicted by the pest.

Green grasshopper

Nair (1975) stated that *Atractomorpha crenulata* F. is a polyphagous grasshopper enjoying a countrywide distribution. The nymphs and adults of grasshopper *A. crenulata* feed on leaves of amaranthus.

Nair (1975) observed that the grasshopper was most active from July to September during which period, they caused the maximum damage and bred profusely. The activity decreased as the temperature fell and was lowest during December and January.

Tobacco caterpillar

Nair (1975) and Nair (1999) reported that the larvae of the polyphagous pest *Spodoptera litura* (F.) fed on the leaves of amaranthus occasionally.

Butani (1977) and Reddy and Kumar (2004) reported that *S. litura* was present in the field throughout the year except during September to October.

American serpentine leaf miner (ASLM)

In a survey conducted for assessing the incidence and severity of leaf miner, *Liriomyza trifolii* (Burgess) in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, 70 plant species including vegetables were identified as host plants (Srinivasan *et al.*, 1995). Studies by Reji (2002) revealed that *A. viridis* L. is a host plant of *L. trifolii*. She observed that the damage of this pest in cowpea was more severe during summer season in Kerala.

Jayakumar and Uthamasamy (2000) found that the incidence of *L. trifolii* was higher in summer than winter in cotton. Reddy and Kumar (2004) reported that the peak infestation of leaf miner was noticed during March-April and the population declined during November-December.

Aphid

Nayar *et al.* (1976) reported that *Aphis craccivora* Koch. was a pest of *A. viridis*.

Scale insects

The scale insects *Lecanium hesperidium* L. and *Pulvinaria durantae* T. infested the plants in South India (Nair, 1975; Nayar *et al.*, 1976 and Nair, 1999).

Inflorescence thrips

The thrips *Euryaplothrips crassus* R. & M. and *Haplothrips ceylonicus* Sch. infested the inflorescence of *Amaranthus* spp. (Nayar *et al.*, 1976 and David, 2001).

Green semilooper

The green semilooper *Plusia eriosoma* D. feeds on leaves of amaranthus (Nayar *et al.*, 1976 and David, 2001). The occurrence of the semilooper *Plusia signata* F. in amaranthus was reported by Nair (1999).

Tortoise beetle

The beetle *Cassida exilis* B. feeds on leaves of amaranthus by scrapping the green tissue both in the grub and adult stages (Nair, 1975; Nair, 1999 and David, 2001).

Other pests

Coreid bugs *Cletus* spp. infests the amaranthus crop in West Africa. The bugs cause damage to immature seeds by sucking on the inflorescence (Bohlen, 1973).

Leaf webber *Psara bipunctalis* F. feed on leaves of amaranthus in West Africa. The caterpillar spins a web causing the leaves to curl around them (Epenhuijsen, 1974).

African mole cricket *Gryllotalpa gryllotalpa* L. is an important pest on amaranthus in Africa. The cricket cuts off young plants (Wyniger, 1962 and Grubben, 1976).

Nayar *et al.* (1976) reported the occurrence of leaf caterpillars such as *Junonia orithya* Linn., *Othreis fullonica* Linn., *Othreis materna* Linn. and *Spodoptera exigua* (Hb.) on amaranthus.

2.2 NATURAL ENEMIES OF PESTS OF AMARANTHUS

Many parasitoids were recorded on the leaf webber, *H. recurvalis* by Bhattacherjee and Menon (1964). In Hawaii, *Cremastus hymeniae*

Viereck and *Casinaria infesta* (Cresson) have been found to be very effective on the pest. In USA, *Trichogramma minutum* Reley. attacks the eggs and *Apanteles marginiventris*(Cresson), *Eupteromalus viridescens* Walsh. and *Sagaritis provencheri* D.T. attack the larvae. *Apanteles hymeniae* Wilkinson has been found to breed on the larvae in Fiji. In India, Muesebeck and Rao (1958) had found *Apanteles delhiensis* Muesb. & Rao actively parasitising the pest in Delhi. Field collected *H. recurvalis* larvae had exhibited upto 11.43 per cent natural parasitism by the parasitoid *A. delhiensis* (Bhattacherjee and Menon, 1964). According to Nair (1975), *Apanteles ruidus* Wlk and *Chardiochiles hymeniae* F. and P. also attack the pest larvae.

Nair (1975) reported that parasites like *Telenomus javensis* Dodd., *Pareuderus torymoides* Ferr. and *Erytoma curculionum* Mayr. attack different stages of the weevil *H. truncatulus*.

The eggs of *S. litura* are parasitised by *Telenomus remus* Nixon and *Trichogramma australicum* Gir. while larvae are parasitised by *Apanteles prodeniae* Veir. and *Strobliomyia aegyptia* Vill. and pupae by *Blepherella setigera* Corti. in tobacco (Nair, 1975).

2.3 SPIDER PREDATORS OF PESTS OF VEGETABLES

Nandakumar and Saradamma (1996) reported the occurrence of spiders *Tetragnatha* sp. and *Oxyopes* sp. from bittergourd fields of Thiruvananthapuram district in Kerala.

Survey conducted in different regions of Assam by Debnath and Borah (2002) on natural enemies of potato tuber moth revealed that the spiders *Oxyopes* sp. and *Plexippus* sp. were present in the field throughout the year.

Thamilvel (2004) observed the activity of spider predators *Oxyopes* sp. and *Tetragnatha* sp. in bhindi crop in Kerala.

2.4 LEAF BLIGHT DISEASE OF AMARANTHUS

Foliar blight caused by *Rhizoctonia solani* Kuhn. is a serious disease of amaranthus (*A. tricolor* L.) in Kerala (Nayar *et al.*, 1996). Gokulapalan *et al.* (2000) reported that the symptoms of the disease were manifested as small irregular whitish cream spots on leaves which enlarged under high humidity to cause extensive translucent and light green lesions and shot-hole symptoms. Aerial blights caused by *R. solani* have been reported on other vegetables such as radish, cabbage, spinach and sugar beet (Baker, 1970 and Jana *et al.*, 1990).

2.5 ANTIFEEDANT ACTION OF BOTANICALS AGAINST PESTS OF VEGETABLES

Hozosawa *et al.* (1974) reported that one per cent ether extract of *Clerodendron fragrans* L. gave 80-100 per cent protection from third instar larvae of *S. litura*. The antifeedant and repellent action of neem kernel extract against tobacco caterpillar was observed by Joshi and Ramaprasad (1975).

Singh and Sharma (1987) observed that neem kernel suspension at 0.10, 0.20 and 0.40 per cent concentrations and neem oil emulsion at 0.50, 1.00 and 2.00 per cent concentrations had significant antifeedant effect against second and third instar larvae of *Pieris brassicae* (Linn.) on cabbage and cauliflower. This reduced the mean leaf area consumption by 40 to 50 per cent.

Saradamma (1989) observed 100 per cent mortality of aphid *A. craccivora* in the laboratory when sprayed with two per cent water extract of neem leaf. Leaf extracts of neem at three and five per cent concentrations exhibited high antifeedant activity against *Selepa docilis* Btlr. in brinjal (KAU, 1991).

Dimetry *et al.* (1995) reported that NeemAzal-S and Margosan-O showed significant feeding deterrent activity against *L. trifolii* when sprayed at two per cent and the effect lasted for five days after treatment.

Ethanol extract of neem kernel powder recorded 100 per cent protection of tobacco leaves from *S.litura* 48 hours after feeding. Petroleum extracted fraction of neem kernel powder recorded a protection of 93.10 percent and 80.79 per cent 24 hours and 48 hours after feeding respectively (Rao *et al.*, 1996).

Hebsybai (1996) reported that seed extracts of *Thevetia neriifolia* Juss. was an effective antifeedant leading to larval starvation in epilachna beetle.

Babu *et al.* (1998) found that the crude oils from seeds of *Annona squamosa* L. at 2.50 and five per cent concentrations significantly reduced the leaf damage caused by *S. litura* larvae.

Thara and Kingsly (2001) studied the antifeedant effect of neem oil and neem cake extract on *Earias vittella* F. High level of feeding deterrency was exhibited by the botanicals at 2.00, 1.00 and 0.50 per cent concentrations.

2.6 CONTROL OF PESTS OF AMARANTHUS

2.6.1 Effect of Chemical Pesticides

Bhattacherjee and Menon (1964) stated that BHC dust containing 0.65 per cent active gamma isomer and a spray containing 0.25 per cent DDT were very effective against *H. recurvalis*. Nair (1975) recommended the application of insecticides like malathion and lindane against the leaf webber. *H. recurvalis* in heavily infested amaranthus plots.

Grubben(1976) reported that chemicals such as bromophos, carbaryl and lindane were effective in controlling the pest *H. recurvalis* and *H. truncatulus*. He also opined that malathion was effective against these pests but this insecticide tainted the leaves.

Spray application of profenofos 0.05 per cent or phosalone 0.07 per cent was effective against *H. recurvalis* (David, 2001).

KAU (2002) recommended the use of malathion 0.10 per cent spray or 10.00 per cent malathion dust for the control of pests of amaranthus in severe cases of infestation.

2.6.2 Effect of Botanicals

Srinath (1990) found that four per cent extract of *Azadirachta indica* A.Juss with soap water and four per cent extract of *T. neriifolia* controlled the leaf webber of amaranthus *P. basalis* effectively. He also reported that *A. indica* (four per cent), *T. neriifolia* (two per cent) and *Clerodendron infortunatum* L. (two per cent) protected the amaranthus crop against *A. crenulata* for 14 days after spraying.

Tobacco decoction, four per cent leaf extracts of *T. neriifolia, C. infortunatum* (with soap water) and 1.50 per cent fish oil soap emulsion are being recommended against the pests of amaranthus (KAU, 1993).

Two per cent seed extract of *T. neriifolia* was effective in controlling leaf webber caterpillars of amaranthus (Hebsybai, 1996).

Reghunath *et al.* (2001) recommended the spraying of a combination of cow's urine 10.00 per cent and 0.10 per cent bird chilli extract against leaf webbers of amaranthus.

Studies conducted by Leena (2001) revealed that neem pesticides *viz.*, Econeem and NeemAzal were effective in controlling leaf webbers of amaranthus.

2.7 CONTROL OF PESTS OF OTHER VEGETABLES USING BOTANICALS

The first report of the insecticidal property of neem seed kernel was made by Cherian and Menon (1944) who found that cold extracts of neem seed kernel was toxic to *Aphis gossypii* Glover.

Under field conditions, one to five percent neem seed kernel suspension in water was found as effective as fentin acetate 0.0075 per cent and fentin hydroxide 0.0075 per cent against tobacco caterpillar *S. litura* (Joshi *et al.*, 1978).

Fagoonee (1980) observed in a field experiment that two per cent neem extract was effective against cabbage leaf webber *Crocidolomia binotalis* Zell.

Srinath (1990) reported that four per cent extract of *A. indica* was superior to carbaryl in controlling *A. crenulata* in bhindi. He also observed that four per cent extracts of *T. neriifolia* and *A. indica* were highly effective against the shoot and fruit borer, *E. vittella*.

NSKE five per cent spray was recommended by Bandara and Kudagamage (1996) against diamond back moth larvae in cabbage. Srinivasan and Moorthy (1996) reported that four and five per cent NSKE provided best control of the pest *P.xylostella* and recorded higher yields in cabbage.. Diamond back moth (*P.xylostella*) populations were 10 times greater in deltamethrin than in neem treated plots and the number of marketable heads from neem treated plots was 1.5 times greater than deltamethrin treated plots (Goudegnon *et al.*, 2000).

Four per cent neem seed kernel extract in water or cow's urine and two per cent custard apple seed extract were effective against pests of cabbage and pigeon pea respectively (Baskaran and Narayanasamy, 1990).

Srinivasan and Sundarababu (1998) reported that neem products like Neemol, AzalF and Nimbecidine were comparable to synthetic insecticides in controlling the shoot and fruit borer, *Leucinodes orbonalis* Guen. of brinjal.

NeemAzal 0.50 per cent gave very good control of *L. trifolii* in snap bean (Omar and Faris, 2000).

Saikia *et al.* (2000) observed that five per cent neem seed kernel extract was effective against bean aphid *A. craccivora* as it produced 97.50 per cent mortality of the aphid.

Foliar spray of neem oil along with basal application of neem cake reduced the incidence of fruit borer and increased the yield of brinjal (Singh, 2000). Krishnamoorthy *et al.* (2001) reported that application of neem cake at 250 kg ha^{-1} at planting and repeated twice at 30 days interval controlled the fruit borer in brinjal.

Chakraborti (2001) observed that pre-sowing soil application of neem cake at 300 kg ha^{-1} and foliar application of azadirachtin / NSKE / NSO at nine ml a.i. per litre was effective against the aphid *Lipaphis erysimi* (Kalt.) and diamond back moth *P. xylostella* of cabbage. This was significantly superior to chemical control (phosphamidon at two ml a.i. per litre).

Reddy and Srinivasa (2001) reported fruit borer damage of 11.40 per cent in pongamia oil two per cent and 14.60 to 15.90 per cent in neem oil two per cent treatments as against 22.30 per cent in untreated control.

Satpathi (2001) reported that application of neem cake at a rate of 500 kg ha^{-1} followed by spraying of three per cent water suspension of neem seed protected brinjai from leaf folder *Antoba olivacea* (Wlk), stem borer *Euzophera perticella* (Raj.) and shoot and fruit borer *L. orbonalis*.

2.8 EFFECT OF BOTANICALS ON POPULATION OF SPIDER PREDATORS

Nandakumar and Saradamma (1996) reported that neem based pesticides were safe to spiders like *Tetragnatha* sp. and *Oxyopes* sp.

Mann and Dhaliwal (2001) evaluated the impact of a neem based pesticide, NeemAzal against the beneficial arthropods of cotton. It was found that the number of spiders per plant was significantly higher upon treatment with one litre NeemAzal ha^{-1} than that of control.

Dash *et al.* (2001) observed that neem sprays harboured spiders (*Lycosa* sp., *Tetragnatha maxillosa* Thorell and *Argiope* sp.) when applied in rice fields.

Neem formulations Neemark and Achook at 0.30 per cent were quite safe to spider *Oxyopes* spp. in tea ecosystem (Sharma and Kashyap, 2002).

Studies by Thamilvel (2004) revealed that NeemAzal 1% T/S 0.40 per cent was benign to spiders like *Oxyopes* sp. and *Tetragnatha* sp. in bhindi fields.

Materials and Methods

3. MATERIALS AND METHODS

Seasonal occurrence of pests of amaranthus was studied in the Instructional Farm, College of Agriculture, Vellayani for an year. A field experiment was also conducted to evolve an ecofriendly management strategy against the pests of amaranthus. The materials used for the study and the methods followed are given.

3.1 SEASONAL OCCURRENCE OF PESTS OF AMARANTHUS

The occurrence of pests of amaranthus and their natural enemies were studied for an year from April 2004 to April 2005 in amaranthus. *Amaranthus tricolor* var. Arun raised in an area of 40 m^2 in the Instructional Farm, College of Agriculture, Vellayani (8.5°N, 76.9°E : 29 m above MSL).

An area of 40 m^2 was selected and divided into three equal plots of size 13.33 m^2. Twenty days old seedlings of amaranthus var. Arun was planted at a spacing of 30 x 20 cm in each of these plots at an interval of 45 days. After leaving one border row (4.33 m^2), each plot had a net plot size of 9 m^2 with a population of 150 plants. The crop was maintained in the field giving management practices as per KAU package of practices without any plant protection intervention until about 50 per cent of plants perished naturally. Replanting with 20 days old seedlings was done in each plot separately. Thus a continuous crop of more or less uniform age was maintained in the field throughout the one year period of study.

3.1.1 Observation on Pest Incidence

The population of important pests of amaranthus and extent of damage caused by them were recorded at weekly intervals for an year starting from April 2004. Relative estimate of adult population was made using sweep net method. The larval population and extent of damage were

recorded from the plants selected at random from among the 150 plants in a plot.

The methodology adopted for recording observations of population of pests, their natural enemies and the damage done by pests in amaranthus were as follows:

Sl. no.	Pests	Observations recorded and intensity of damage assessed
1	Leaf webber *Psara basalis*, F.	(1) Number of moths per sweep** (2) Mean number of caterpillars per plant * (3) Percentage of plants infested* (4) Percentage of leaves infested per plant*
2	Leaf webber *Hymenia recurvalis* (F.)	(1) Number of moths per sweep** (2) Mean number of caterpillars per plant * (3) Percentage of plants infested* (4) Percentage of leaves infested per plant*
3	Green grasshopper *Atractomorpha crenulata* F.	(1) Number of grasshoppers per plant* (2) Percentage of plants infested* (3) Percentage of leaves infested per plant*
4	Tobacco caterpillar *Spodoptera litura* (F.)	(1) Percentage of plants infested* (2) Percentage of leaves infested per plant*
5	American serpentine leaf miner (ASLM) *Liriomyza trifolii* (Burgess)	(1) Percentage of plants infested* (2) Percentage of leaves infested per plant*
6	Aphid (*Aphis craccivora* Koch.)	(1) Mean population of aphids per plant* (2) Percentage of plants infested*

**Mean of five random sweeps

*Mean of 15 plants

3.1.2 Observation on Incidence of Natural Enemies of Pests

Population of spider predators were recorded from 15 plants selected at random from each plot and expressed as mean population per plant. All plants in a plot were critically examined for the presence of parasitised larvae or pupae of leaf webbers and the parasitisation was confirmed by rearing of the suspected larvae and observing emergence of parasitoid.

3.1.3 Observation on Disease Incidence

Fifteen plants were selected at random from each plot. The total number of leaves and number of leaves infected by leaf blight disease caused by *R. solani* were recorded from these plants. The infected leaves were graded using a 0-9 scale (KAU, 1996).

Grade	Description
0	No infection
1	1-10 per cent leaf area infected
3	11-25 per cent leaf area infected
5	26-50 per cent leaf area infected
7	51-75 per cent leaf area infected
9	>76 per cent leaf area infected

Percentage disease index (PDI) was calculated following the method of Mayee and Datar (1986)

$$PDI = \frac{\text{Sum of grades of each leaf}}{\text{Number of leaves assessed}} \times \frac{100}{\text{Maximum grade used}}$$

3.1.4 Correlation between Weather Parameters and Incidence of Pests and Disease in Amaranthus

The weather parameters *viz.*, maximum and minimum temperature, relative humidity, rainfall and number of rainy days were recorded from

Plate 1. 0-9 scale for the scoring of foliar blight of amaranthus

the meteorological observatory of the Department of Meteorology, College of Agriculture, Vellayani.

The mean population of pests, percentage of plants infested by the pests and percentage disease index on amaranthus were worked out at fortnightly intervals and the data were correlated with weather parameters to find out the degree of association between the abiotic factors and pests, their natural enemies and disease incidence.

3.2 ESTIMATION OF ANTIFEEDANT EFFECT OF BOTANICALS ON PESTS OF AMARANTHUS

The botanicals tested were

(1) Neem seed kernel extract (NSKE) five per cent

(2) Neem cake extract (NCE) 10 per cent

(3) Azadirachtin 0.0025 per cent (NeemAzal 1 % TS @ 2.5 ml l^{-1})

(4) Cow's urine 10 per cent + NSKE five per cent

(5) Pongamia (*Pongamia glabra* L.) oil soap emulsion two per cent

(6) Annona (*Annona squamosa* L.) seed extract two per cent

Preparation of botanicals

(1) Neem seed kernel extract (NSKE) five per cent

Neem seeds were dried and 50 g of kernel was weighed out after removing the seed coat. The kernel was crushed well, tied in a piece of cloth and immersed in one litre of water for 12 hours to get five per cent neem seed kernel extract

(2) Neem cake extract (NCE) 10 per cent

Neem cake of good quality was supplied by M/s Srivinayaka Stores, Chalai, Thiruvananthapuram. Hundred grams of neem cake was weighed out and soaked in one litre of water for 24 hours to get 10 per cent neem cake extract.

(3) Azadirachtin 0.0025 per cent

Two and half ml of NeemAzal T/S one per cent supplied by M/s E.I.D. Parry (India) Ltd., Chennai was added to one litre of water to get the required concentration of azadirachtin 0.0025 per cent.

(4) Cow's urine 10 per cent + NSKE five per cent

Hundred ml of cow's urine was diluted with 400 ml of water. Fifty grams of neem seed kernel was crushed and then extracted in 500 ml of water. These two solutions were mixed to get one litre of spray solution.

(5) Pongamia oil – soap emulsion two per cent

Five grams bar soap shavings were dissolved in 980 ml of water. To this soap solution 20 ml of pongamia oil was added to obtain two per cent emulsion.

(6) Annona seed extract two per cent

Twenty grams of dried annona seeds were soaked in water for a week to soften the seed coat. After this the seeds were macerated well and diluted in one litre of water. This was sieved to obtain a two per cent annona seed extract.

Rearing of the test insect

(1) Leaf webbers

Cultures of *H. recurvalis* and *P. basalis* were established in the laboratory from field collected final instar larvae. The emerged out adults were sexed, paired and mated females were kept for egg laying. The neonate larvae were transferred onto amaranthus leaves in clean glass troughs of dimension 20 x 15 cm and covered with muslin cloth. The feed was changed daily. The newly moulted third instar larvae were used for the study.

2) Green grasshopper

Fifth instar nymphs of the grasshopper *A. crenulata* were collected from the amaranthus fields of the Instructional Farm, Vellayani. These

nymphs were fed daily with fresh amaranthus leaves till they reached adulthood. One day old adults were used for the experiment.

3) Tobacco caterpillar

Culture of *S. litura* was established in the laboratory from the eggs collected from the unsprayed amaranthus fields of the Instructional Farm. Vellayani. The early instar larvae were fed daily with fresh amaranthus leaves and were transferred to clean troughs daily. The newly moulted third instar larvae were used for the study.

Experiment procedure

Amaranthus leaves of uniform age and size were weighed in an electronic balance and then dipped in solutions of the selected botanical treatments, air dried and used for the experiment. The test insects were pre-conditioned without food for four hours. The leaves were kept moist by providing a wet cotton plug around the leaf petiole.

The test insects (three numbers each) were released on pre-weighed treated leaves taken in a petriplate. Each treatment was replicated thrice.

Twenty four and 48 hours after exposure, the uneaten portions of the leaves were taken out, cleaned and weighed. The difference in weight gave the quantity of leaves consumed by the insects. Pre-weighed leaves dipped in water and exposed to the test insect served as control.

The percentage of leaf protected by the extracts was estimated as

$$\frac{A - B}{A} \times 100$$

Where A – Weight of leaf consumed in control

B – Weight of leaf consumed in treatment.

The data were tabulated and subjected to analysis of variance.

3.3 FIELD EVALUATION OF DIFFERENT BOTANICALS FOR THE MANAGEMENT OF PESTS OF AMARANTHUS

The trial was conducted on an amaranthus crop var. Arun raised in the Instructional Farm, College of Agriculture, Vellayani from December 2004 to February 2005.

Experimental design

Design	- RBD
Treatments	- 8
Replications	- 3
Spacing	- 30 x 20 cm
Net plot size	- 3 x 2 m^2

Treatments

(1) Neem seed kernel extract (NSKE) five per cent

(2) Neem cake(NC) soil application @ 250 kg ha^{-1} at planting + neem cake extract (NCE) 10 per cent spray

(3) Azadirachtin 0.0025 per cent (NeemAzal 1%TS @ 2.5 ml l^{-1})

(4) Cow's urine 10 per cent + NSKE five per cent

(5) Pongamia oil soap emulsion two per cent

(6) Annona seed extract two per cent

(7) Malathion 0.10 per cent (check)

(8) Control

(Botanical pesticides were prepared as given in 3.2)

The insecticide malathion 0.10 per cent was prepared by mixing two ml. of Malathion 50 EC formulation (supplied by M/s Sree Ramcides Chemicals Pvt. Ltd., Chennai) in one litre of water.

Three sprays of treatments were given during one season; two sprays were given at fortnightly intervals before first harvest and one, two weeks after the first harvest.

Labelling

Ten plants were selected at random from each replication and labelled for recording observations.

3.3.1 Assessment of Population and Extent of Damage by *P. basalis*

Population of larvae

The count of *P. basalis* larvae was taken one, three and seven days after each spraying from 10 labelled plants in each treatment and the mean population per plant was worked out.

Population of moths

The count of *P. basalis* moths was recorded one, three and seven days after each spraying from each treatment plot after taking five sweeps using sweepnet by walking diagonally across the plot. The mean number of moths per sweep was then worked out.

Infestation on plants

The number of plants infested per 10 selected plants in each treatment was recorded one, three and seven days after each spraying. The percentage of plants infested was then worked out.

Infestation on leaves

The total number of leaves and number of leaves infested was recorded from 10 observational plants one, three and seven days after each spraying. The percentage of leaves infested was estimated in each treatment.

3.3.2 Assessment of Population and Extent of Damage by Leaf Webber *H. recurvalis*

Population of larvae

The count of *H. recurvalis* larvae were taken one, three and seven days after each spraying from 10 labelled plants, in each treatment and expressed as mean population per plant.

Population of moths

The count of *H. recurvalis* moths was recorded from each treatment plot one, three and seven days after each spraying after taking five sweeps using sweepnet. The mean population of moths per sweep was then worked out.

Infestation on plants

The number of plants infested per 10 selected plants in each treatment plot was recorded one, three and seven days after each spraying and percentage of plants infested was then worked out.

Infestation on leaves

The total number of leaves and number of leaves infested by *H. recurvalis* was recorded from 10 observational plants at one, three and seven days after each spraying and percentage of leaves infested was then worked out.

3.3.3 Assessment of Population and Extent of Damage by Green Grasshopper *A. crenulata*

Population of grasshopper

The count of grasshopper nymphs and adults were taken one, three and seven days after each spraying from 10 labelled plants in each treatment plot. The mean population per plant was then worked out.

Infestation on plants

The number of plants infested by grasshopper per 10 selected plants in each treatment plot was recorded one, three and seven days after each spraying and percentage of plants infested was worked out.

Infestation on leaves

The total number of leaves and number of leaves infested by grasshopper were recorded from 10 observational plants one, three and seven days after each spraying and percentage of leaves infested was worked out in each treatment plot.

3.3.4 Assessment of Extent of Damage by Tobacco Caterpillar *S. litura*

Infestation on plants

The number of plants infested by *S. litura* per 10 selected plants in each treatment plot was recorded one, three and seven days after each spraying and percentage of plants infested was worked out.

Infestation on leaves

The total number of leaves and number of leaves infested by *S. litura* was recorded from 10 observational plants one, three and seven days after each spraying and percentage of leaves infested was worked out in each treatment plot.

3.3.5 Assessment of Mean Population of Spider Predators at Different Intervals of Spraying

The count of spider predators was recorded one, three and seven days after each spraying from 10 labelled plants in each plot. The mean population per plant was then worked out.

3.4.6 Assessment of Disease Intensity at Different Intervals Before and after Spraying

Ten plants were selected randomly from each plot. From these plants,the total number of leaves and number of leaves infected with leaf blight disease were recorded. The infected leaves were scored as per the standard method of Mayee and Datar (1986) and the percentage disease

intensity (PDI) was calculated before spraying and seven days after spraying.

3.3.7 Yield of amaranthus

Yield in terms of weight of marketable leaves (along with tender shoots) from each plot was recorded after removing the infested leaves. The benefit:cost ratio was calculated after giving a fifty per cent addition in value to yield from botanical treated plots over yield from malathion treated plots.

Statistical Analysis

Data obtained from the field experiment were tabulated and subjected to analysis of variance (Panse and Sukhatme, 1967).

Results

4. RESULTS

4.1 SEASONAL OCCURRENCE OF PESTS, THEIR NATURAL ENEMIES AND DISEASE OF AMARANTHUS

Seasonal incidence of pests, their extent of damage, natural enemies of pests and disease of amaranthus were studied from second fortnight of April 2004 to first fortnight of April 2005 in the Instructional Farm, College of Agriculture, Vellayani.

The results are presented in Tables 1 to 3.

4.1.1 Seasonal Occurrence of Pests and their Extent of Damage in Amaranthus

The different pests observed on amaranthus during the course of the study are given below.

Common name	Scientific name	Family
Leaf webbers	*Psara basalis* F. *Hymenia recurvalis* (F.)	Pyralidae "
Green grasshopper	*Atractomorpha crenulata* F.	Acrididae
Tobacco caterpillar	*Spodoptera litura* (F.)	Noctuidae
American serpentine leaf miner	*Liriomyza trifolii* (Burgess)	Agromyzidae
Aphid	*Aphis craccivora* Koch.	Aphididae

4.1.1.1 Leaf Webber P. basalis

The mean population of *P.basalis* larvae was generally high during the second fortnight of April 2004(2.19), first fortnight of April 2005

Larvae

Adult

Infestation on plant

Plate 2. Leaf webber (*P. basalis*) of amaranthus

Table 1. Seasonal occurrence of pests on amaranthus (from April 2004 to April 2005)

Fortnight number	*P. basalis*		*H. recurvalis*		*A. crenulata* Population /plant*	*A.craccivora* population/ plant*
	Larvae/ plant*	Moths/ sweep**	Larvae/ plant*	Moths/ sweep**		
2004 April 2	2.19	1.40	0.60	0.10	0.17	0.00
May 1	1.66	0.93	0.60	0.80	0.26	1.11
May 2	1.10	0.70	0.93	1.10	0.27	3.93
June 1	0.74	0.50	1.40	1.10	0.34	0.00
June 2	0.90	0.80	2.27	1.00	0.20	0.00
July 1	0.70	0.30	1.54	0.90	0.17.	0.00
July 2	0.57	0.40	1.80	1.10	0.23	0.00
Aug 1	1.16	0.80	1.22	0.60	0.56	0.00
Aug 2	0.67	0.80	0.77	0.30	0.63	0.00
Sept 1	1.06	0.80	0.67	0.10	0.60	0.00
Sept 2	1.30	0.40	0.17	0.10	0.67	0.00
Oct. 1	1.13	0.80	0.40	0.20	0.87	0.67
Oct. 2	1.10	0.70	0.86	0.50	0.44	5.14
Nov. 1	1.13	0.67	1.75	0.93	0.73	0.87
Nov. 2	0.77	0.40	1.87	1.50	0.57	0.00
Dec. 1	0.53	0.40	1.60	1.00	0.50	0.00
Dec. 2	0.63	0.70	1.37	0.80	0.40	0.00
2005 Jan 1	0.94	0.70	1.34	0.70	0.37	0.00
Jan 2	0.82	0.90	1.58	0.87	0.60	0.00
Feb 1	1.00	0.80	1.40	0.40	0.50	0.00
Feb 2	1.37	1.40	1.10	0.40	0.33	0.00
Mar 1	1.70	1.50	1.13	0.50	0.37	0.00
Mar 2	1.73	1.60	0.90	0.30	0.33	0.00
April 1	1.80	1.50	0.67	0.40	0.20	1.14

**Mean of five sweeps

*Mean of observation on 15 plants

(1.80) and first (1.70) and second (1.73) fortnight of March 2005. The highest mean population was observed during the second fortnight of April 2004 (2.19). The population was found to diminish thereafter and remained more or less constant till February 2005. The lowest mean population of 0.53 was observed in the first fortnight of December 2004. The larval population started building up again from second fortnight of February to April 2005, the population ranged from 1.37 to 1.80.

The mean population of *P. basalis* moths was high during the month of March (1.50 and 1.60 during the first and second fortnights respectively) and first fortnight of April 2005 and low during the month of July (0.30 and 0.40 in first and second fortnights respectively), second fortnight of November (0.40)and first fortnight of December 2004 (0.40). The mean population was 1.40 during the second fortnight of April 2004.Thereafter the population diminished and recorded a minimum in first fortnight of July 2004 (0.30). The population remained more or less constant till February 2005. An increase in population was observed in second fortnight of March 2005 (1.60).

The percentage of plants infested by *P. basalis* varied from 26.66 to 73.00 .The lowest damage was noticed during the second fortnight of July, first fortnight of August and first fortnight of December 2004. Seventy three per cent of plants were infested during the second fortnight of April 2004. The extent of damage decreased after second fortnight of April 2004 and reached a minimum in first fortnight of August 2004. Afterwards, there was an increase in damage and upto 50 per cent of plants were damaged during second fortnight of October 2004.Thereafter the plant damage declined and reached 26.66 per cent in first fortnight of December 2004. The damage gradually increased during the next fortnights and peaked at 60.00 per cent during the first fortnight of April 2005.

Table 2. Seasonal occurrence of infestation by pests on amaranthus (from April 2004 to April 2005)

Fortnight number	*P. basalis*		*H. recurvalis*		*A. crenulata*		*S. lutura*		*L. trifolii*		Percentage plant infestation by *A.craccivora*
	*Percentage infestation		*Percentage infestation		*Percentage infestation		*Percentage infestation		*Percentage infestation		
	Plants	Leaves	Plants	Leaves	Plants	Leaves	Plants	Leaves	Plants	Leaves	
2004 April 2	73.00	13.80	26.67	3.30	23.34	0.98	30.00	1.20	10.00	0.71	0.00
May 1	62.22	10.37	28.89	4.36	37.78	1.15	31.11	1.31	20.00	1.08	2.22
May 2	40.00	10.20	40.00	9.45	36.67	1.78	20.00	1.20	13.34	0.67	10.00
June 1	30.00	7.25	66.66	17.90	30.00	1.17	20.00	1.18	3.34	0.10	3.34
June 2	36.67	6.56	90.00	25.47	26.67	1.18	23.33	1.02	0.00	0.00	0.00
July 1	30.00	5.32	76.67	21.43	20.00	0.91	40.00	1.74	0.00	0.00	0.00
July 2	26.66	4.87	90.00	21.03	20.0	0.60	46.66	1.70	0.00	0.00	0.00
Aug 1	26.66	4.68	60.00	15.55	36.67	1.59	30.00	1.14	10.00	0.48	0.00
Aug 2	28.78	6.01	42.22	9.24	57.78	1.83	24.44	0.92	13.33	0.37	0.00
Sept 1	43.00	6.29	36.67	6.10	53.33	2.06	30.00	0.88	10.00	0.22	0.00
Sept 2	46.67	5.43	20.00	2.82	50.00	2.03	36.67	1.22	0.00	0.00	0.00
Oct. 1	49.99	5.70	23.33	3.06	50.00	2.65	30.00	1.06	0.00	0.00	3.34
Oct. 2	50.00	4.63	33.33	8.96	50.00	1.96	30.00	0.98	0.00	0.00	13.34
Nov. 1	40.00	4.19	80.00	19.80	64.44	1.95	26.66	0.98	0.00	0.00	11.11
Nov. 2	30.00	3.45	93.00	25.33	76.67	2.94	26.66	1.03	0.00	0.00	0.00
Dec. 1	26.66	3.44	86.50	21.14	46.66	2.31	26.66	0.94	0.00	0.00	0.00
Dec. 2	29.83	4.99	73.33	14.28	46.66	2.42	30.00	1.22	0.00	0.00	0.00
2005 Jan 1	31.11	6.14	71.11	11.03	48.88	2.35	30.00	0.89	4.44	0.34	0.00
Jan 2	33.33	6.05	83.33	9.50	56.67	2.31	43.33	0.89	16.60	0.70	0.00
Feb 1	33.33	6.33	70.00	6.79	43.33	2.31	30.00	1.17	6.67	0.56	0.00
Feb 2	53.33	8.99	56.67	5.56	36.67	2.16	30.00	1.48	10.00	0.42	0.00
Mar 1	56.67	10.62	56.67	4.50	30.00	1.65	20.00	0.90	16.66	0.84	0.00
Mar 2	56.67	12.32	46.67	5.09	33.33	1.68	23.33	0.96	6.66	0.23	0.00
April 1	60.00	15.02	40.00	4.32	33.33	1.64	23.33	0.92	13.33	0.48	6.66

*Mean of observation on 15 plants

The percentage of leaves damaged by *P. basalis* was high during the first fortnight of April 2005 (15.02) and second fortnight of April 2005 (13.80). The leaf damage was below 10.00 per cent from first fortnight June 2004 to February 2005. The leaf damage recorded was low during the first fortnight of December 2004 (3.44) and during the first (4.19) and second (3.45) fortnight of November 2004 .

4.1.1.2 Leaf Webber H. recurvalis

The mean population of larvae per plant ranged from 0.17 during second fortnight of September 2004 to 2.27 during second fortnight of June 2004. The population of larvae was considerably lower during the months of April and May 2004. Thereafter the population showed a sharp increase and reached a maximum of 2.27 per plant during the second half of June and then declined and reached a minimum of 0.17 by the second half of September 2004. Again the population increased and reached a peak of 1.87 during second fortnight of November 2004. Thus there were two peaks with regard to the population of *H. recurvalis* larvae from April 2004 to April 2005.

Adults of *H. recurvalis* were present in the field throughout the year. The mean population of moths per sweep was the highest during second fortnight of November 2004 (1.50) followed by second fortnight of May 2004, first and second fortnight of June 2004 and second fortnight of July 2004 (1.10). The lowest mean population was observed during the second fortnight of April and the first and second fortnight of September 2004 (0.10).

The percentage of plants infested ranged from 20.00 during the second fortnight of September 2004 to 93.00 during the second fortnight of November 2004.The infestation was considerably low during the months of April, May, August and September 2004.This pest caused more than 50 per cent plant damage during the months of June, July, November and December 2004 as well as January and February 2005.

Larvae

Adult

Infestation on plant

Plate 3. Leaf webber (*H. recurvalis*) of amaranthus

The leaf damage by *H. recurvalis* was higher during the second fortnight of June 2004 (25.47 per cent) and second fortnight of November 2004 (25.33 per cent). The leaf damage was low during the second fortnight of September 2004 (2.82) and first fortnight of October 2004 (3.06).

4.1.1.3 Green Grasshopper A. crenulata

The green grasshopper (*A. crenulata*) was observed in the field throughout the year. However the population was low. Comparatively higher population was observed during the first fortnight of October 2004 (0.87) and first fortnight of November 2004 (0.73). Mean population of grasshopper was low during the second fortnight of April, first fortnight of July (0.17), second fortnight of June 2004 and first fortnight of April 2005 (0.20).

The percentage of plants infested by grasshopper was high and ranged from 20.00 to 76.67 among the different fortnights. The maximum damage was recorded during the month of November 2004 (76.67 and 64.44 in second and first fortnights respectively). Lowest grasshopper damage was observed during the month of July 2004.

In general, the percentage of leaves damaged per plant by the grasshopper was low. The leaf damage ranged from 0.60 per cent in the second fortnight of July 2004 to 2.94 per cent in the second fortnight of November 2004. Leaf damage of 2.65 per cent was recorded during the first fortnight of October 2004.

4.1.1.4 Tobacco Caterpillar S. litura

The infestation by *S. litura* was observed throughout the year. The percentage plant infestation by the pest was high during the second fortnight of July 2004 (46.66) and second fortnight of January 2005 (43.33). The lowest plant damage was noticed during second fortnight of May 2004, first fortnight of June 2004 and first fortnight of March 2005 (20.00).

Green grasshopper *A. crenulata*

Tobacco caterpillar *S. litura*

Aphid *A. craccivora*

Infestation by *L. trifolii*

Plate 4. Pests of amaranthus

The percentage of leaves damaged per plant by *S. litura* was low and ranged from 0.88 to 1.74 among the different fortnights. The highest leaf damage was recorded during first fortnight of July 2004 (1.74) .The lowest percentage of leaf damage was observed during the first fortnight of September 2004 (0.88).

4.1.1.5 American Serpentine Leaf Miner (ASLM) L. trifolii

The percentage of plants damaged by ASLM was maximum during the first fortnight of May 2004 (20.00) followed by damage in the first fortnight of March 2005 (16.66). Infestation by ASLM was low during the first fortnight of June 2004 (3.34) and the first fortnight of January 2005 (4.44). The damage by the pest was not observed during the months of July, October and November 2004.

The extent of leaf damage caused by ASLM was very low. The leaf damage was high during first fortnight of May 2004 (1.08 per cent) and first fortnight of March 2005 (0.84 per cent).

4.1.1.6 Aphid A. craccivora

Aphid population was found during the months of May, October and November 2004 and April 2005 only. However the population per plant was low. The mean population was the highest during second fortnight of October 2004 (5.14) followed by second fortnight of May 2004 (3.93).

Highest percentage of plants infested by aphid was observed during second fortnight of October 2004 (13.34) and first fortnight of November 2004 (11.11).

4.1.2 Seasonal Incidence of Natural Enemies of Pests of Amaranthus

Parasitoid of *H. recurvalis*

A braconid parasitoid *Apanteles opacus* (Ashmead) was observed on leaf webber *H. recurvalis* larvae. The distribution of the parasitoid was in general low during the period of study. The mean count of pupae of

Table 3. Seasonal occurrence of natural enemies of pests and leaf blight disease on amaranthus (from April 2004 to April 2005)

Fortnight number	*Mean population		*Percentage disease index (PDI)
	Spiders	Parasitoid pupae	
2004 April 2	1.20	0.03	7.32
May 1	1.38	0.00	12.90
May 2	1.07	0.03	4.57
June 1	0.83	0.20	13.79
June 2	0.73	0.40	14.66
July 1	0.80	0.70	14.41
July 2	0.40	0.57	19.13
Aug 1	0.66	0.22	13.13
Aug 2	1.00	0.03	9.06
Sept 1	1.03	0.00	7.53
Sept 2	1.50	0.00	4.13
Oct. 1	1.07	0.00	7.59
Oct. 2	0.70	0.07	11.90
Nov. 1	1.33	0.27	14.09
Nov. 2	1.14	0.47	16.86
Dec. 1	0.96	0.30	18.82
Dec. 2	1.43	0.20	22.21
2005 Jan 1	1.30	0.20	19.47
Jan 2	1.40	0.15	17.68
Feb 1	0.80	0.23	16.36
Feb 2	1.17	0.00	15.10
Mar 1	1.29	0.00	14.01
Mar 2	1.37	0.17	10.16
April 1	1.20	0.23	10.71

*Mean of observation on 15 plants

Parasitoid of *H. recurvalis* (*A. opacus*)

***Oxyopes* sp.**

***Cheiracanthium* sp.**

***Phidippus* sp.**

***Tetragnatha* sp.**

Plate 5. Natural enemies of pests of amaranthus

the parasitoid per plant was the maximum during first (0.70) and second fortnight (0.57) of July 2004. The second fortnight of November 2004 recorded a mean population of 0.47. Two hyper parasitoids *viz.*, *Tetrastichus* sp. and *Telenomus* sp. were found parasitising the pupae of *A. opacus*.

Population of spider predators

The spiders were observed during all the fortnights from April 2004 to April 2005. There was no distinct seasonal variation in the number of spiders per plant. The highest population was observed during second fortnight of September 2004 (1.50 per plant) and lowest during the second fortnight of July 2004 (0.40 per plant).

The spider fauna identified were

1) *Oxyopes* sp. (Oxyopidae)
2) *Cheiracanthium* sp. (Miturgidae)
3) *Phidippus* sp. (Salticidae)
4) *Tetragnatha* sp. (Tetragnathidae)

4.1.3 Incidence of Leaf Blight

Leaf blight disease caused by *Rhizoctonia solani* Kuhn. was observed in the field throughout the year. The percentage disease index (PDI) ranged from 4.03 to 22.21 among the various fortnights. PDI was maximum during the second fortnight of December 2004 (22.21). The lowest PDI was observed during the second fortnight of September 2004 (4.03).

4.1.4 Correlation between Incidence of Pests, their natural enemies and Disease with Weather Parameters

Correlation coefficients between the incidence of pests, their natural enemies and disease in amaranthus and weather parameters are presented in Table 4.

Table 4 Correlation coefficients between pests, their natural enemies and leaf blight disease with weather parameters

Parameters	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Number of rainy days
	Maximum	Minimum			
Y_1	0.6474*	0.5229*	-0.4215*	-0.0428	-0.1556
Y_2	0.5218*	0.5469*	-0.4059*	-0.0391	0.0959
Y_3	0.4039*	0.5262*	-0.3315	0.2832	0.2133
Y_4	0.5279*	0.5823*	-0.5029*	0.2084	0.0364
Y_5	-0.2628	-0.4211*	0.3498	-0.0182	-0.0939
Y_6	-0.1174	-0.4019*	0.4114*	-0.2161	-0.2897
Y_7	0.0483	-0.2235	0.2021	-0.1745	-0.2039
Y_8	-0.4197*	-0.4349*	0.3474	-0.1445	-0.1587
Y_9	-0.1851	-0.3619*	0.1965	-0.2980	-0.1467
Y_{10}	-0.1264	-0.4597*	0.2822	-0.3148	-0.2929
Y_{11}	0.0795	-0.3936*	0.2437	-0.3419	-0.3791*
Y_{12}	-0.2206	-0.0796	0.2412	0.2091	0.1642
Y_{13}	-0.2377	0.1399	-0.0309	0.3656*	0.2822
Y_{14}	0.2552	0.0977	-0.0430	0.2897	0.0867
Y_{15}	-0.1251	-0.1869	0.1497	-0.1719	-0.2440
Y_{16}	0.4552*	-0.1409	-0.0457	0.0333	-0.1251
Y_{17}	0.0522	-0.4598*	0.4477*	-0.1962	-0.3559*

*Significant at 1 per cent : 0.3541

Parameters

Y_1 Mean population of *P. basalis* (moths per sweep)
Y_2 Mean population of *P. basalis* (larvae per plant)
Y_3 Percentage of plants damaged by *P. basalis*
Y_4 Percentage of leaves damaged by *P. basalis*
Y_5 Mean population of *H. recurvalis* (moths per sweep)
Y_6 Mean population of *H. recurvalis* (larvae per plant)
Y_7 Percentage of plants damaged by *H. recurvalis*
Y_8 Percentage of leaves damaged by *H. recurvalis*
Y_9 Mean population of *A.crenulata* (per plant)
Y_{10} Percentage of plants damaged by *A.crenulata*
Y_{11} Percentage of leaves damaged by *A.crenulata*
Y_{12} Percentage of plants damaged by *S. litura*
Y_{13} Percentage of leaves damaged by *S. litura*
Y_{14} Percentage of leaves damaged by *L.trifolii*
Y_{15} Mean population of parasitoid pupae (number per plant)
Y_{16} Mean population of spider predators per plant
Y_{17} Percentage disease index (PDI) of leaf blight

The adult population of leaf webber *P. basalis* had significant positive correlation with maximum temperature (r value = 0.6474) as well as minimum temperature (r value = -0.5229) and had significant negative correlation with relative humidity (r value = -0.4205). The rainfall and number of rainy days were also negatively correlated with the population of moths but the relationship was not significant. Mean population of *P. basalis* larvae per plant also showed a significant positive correlation with maximum and minimum temperature (r values being 0.6474 and 0.5224 respectively) and negative correlation with relative humidity (-0.5229). The larval population was negatively correlated with rainfall and number of rainy days. The percentage of plants and leaves damaged by *P. basalis* were also positively correlated with maximum and minimum temperature and negatively correlated with relative humidity, rainfall and number of rainy days.

The mean moth population of leaf webber *H. recurvalis* had a significant negative correlation with minimum temperature (r value = -0.4211). The population was positively correlated with relative humidity and negatively correlated with maximum temperature, rainfall and number of rainy days. The mean population of *H. recurvalis* larvae per plant had a significant positive correlation with relative humidity (r value = 0.4114) and negative correlation with minimum temperature (r value = -0.4019). It was also negatively correlated with maximum temperature, rainfall and number of rainy days though the relationships were not significant.

The percentage of plants infested by *H. recurvalis* did not show any significant relationship with any of the weather parameters. The percentage of leaves infested by *H. recurvalis* per plant had a significant negative correlation with maximum temperature (r value = -0.4197) and minimum temperature (r value = -0.4349).

The mean population of *A. crenulata* per plant showed a significant negative correlation with minimum temperature (r = -0.3619). The population also showed positive correlation with relative humidity and negative correlation with maximum temperature, rainfall and number of rainy days, though the relationships were not significant. The percentage of plants infested and the percentage of leaves infested per plant by grasshopper showed a significant negative correlation with minimum temperature (r = -0.4597 and - 0.3936 respectively).

The percentage of plants damaged by *S. litura* was negatively correlated with maximum and minimum temperature and positively correlated with relative humidity, rainfall and number of rainy days. The percentage of leaves infested by tobacco caterpillar was significantly and positively correlated with rainfall (r = 0.3646).

The percentage leaf damage by ASLM had positive correlation with maximum temperature, minimum temperature, rainfall and number of rainy days and negative correlation with relative humidity.

The count of parasitoid pupae per plant was negatively correlated with maximum temperature, minimum temperature, rainfall, number of rainy days and positively correlated with relative humidity.

The population of spider predators per plant had a significant positive correlation with maximum temperature (r value = 0.4552) and negative correlation with minimum temperature, relative humidity and number of rainy days.

The percentage disease index (PDI) showed a significant positive correlation with relative humidity (r value = 0.4477), significant negative correlation with minimum temperature (r value = -0.4598) and number of rainy days (r value = - 0.3559). The PDI was positively correlated with maximum temperature and negatively correlated with rainfall.

4.2 ANTIFEEDANT EFFECT OF BOTANICALS ON PESTS OF AMARANTHUS

The results of the study are presented in Table 5.

Leaf protection against:

P. basalis

Twenty four hours after feeding, percentage leaf protection was significantly higher in azadirachtin 0.0025 per cent (97.49 per cent) compared to all the other treatments. Among the other treatments, cow's urine 10 per cent + NSKE five per cent (91.66) and NSKE five per cent (89.07) were on par. This was followed by the other treatments. Significantly lower percentage of leaf protection was observed in annona seed extract treated leaves (54.19) compared to all the other treatments.

The percentage leaf protection was significantly higher in azadirachtin 0.0025 per cent (75.50) when compared with the other treatments. Among the other treatments, pongamia oil soap emulsion two per cent gave 69.44 per cent protection. The percentage of leaf protected in NSKE five per cent (61.17) was on par with cow's urine 10 per cent + NSKE five per cent (62.94). Significantly lower leaf protection was recorded in annona seed extract treatment (28.89) per cent compared to all the other treatments.

H.recurvalis

The percentage leaf protection ranged from 44.88 in annona seed extract to 84.21 in azadirachtin 0.0025 per cent, 24 hours after feeding. The treatment azadirachtin 0.0025 percent was statistically similar to NSKE five per cent (86.85) and these treatments were significantly superior to the other treatments. The protection provided by NCE 10 per cent (77.44), cow's urine 10 per cent + NSKE five per cent (77.44) and pongamia oil soap emulsion two per cent (75.19) were also on par.

Table 5 Antifeedant effect of various botanicals on major pests of amaranthus

Treatments	Percentage of leaves protected from *P. basalis*		Percentage of leaves protected from *H. recurvalis*		Percentage of leaves protected from *A. crenulata*		Percentage of leaves protected from *S. litura*	
	24 h	48 h	24 h	48 h	24 h	48 h	24 h	48 h
Neem seed kernel extract (NSKE) five per cent	89.07	61.17	86.85	57.13	89.94	89.64	87.60	66.57
Neem extract 10 per cent spray	76.59	44.44	77.44	47.94	65.14	73.10	69.34	37.50
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	97.49	75.50	84.21	67.19	100.00	94.90	87.80	89.67
Cow's urine 10 per cent + NSKE five per cent	91.66	62.94	77.44	58.31	90.05	90.08	87.29	65.48
Pongamia oil soap emulsion two per cent	87.79	69.44	75.19	54.19	66.89	72.37	76.90	55.83
Annona seed extract soap emulsion two per cent	54.19	28.89	44.88	19.80	46.70	48.02	53.85	25.00
CD (0.05)	2.66	2.16	3.22	1.29	4.62	3.16	2.23	5.49

Forty eight hours after feeding, significantly higher leaf protection was provided by azadirachtin 0.0025 per cent (67.19 per cent) compared to all the other treatments. The percentage leaf protected by cow's urine 10 per cent + NSKE five per cent (58.31) and NSKE five per cent (57.13) were statistically on par. Pongamia oil soap emulsion two per cent and NCE 10 per cent resulted in 54.19 and 47.94 per cent leaf protection respectively. Annona seed extract two per cent provided only 19.80 per cent protection which was significantly lower than all the other treatments.

A. crenulata

Cent per cent protection was observed in azadirachtin 0.0025 per cent treated leaves, 24 hours after feeding. This treatment was significantly superior to all the other treatments. Protection provided by cow's urine 10 per cent + NSKE five per cent (90.05 per cent) and NSKE five per cent (89.94 per cent) were statistically similar. The percentage of leaf protection was significantly lowest in annona seed extract treated leaves (46.70).

Forty eight hours after feeding, azadirachtin 0.0025 percent (94.91) provided significantly higher protection compared to all the other treatments. The treatments, cow's urine 10 per cent + NSKE five per cent (90.08) and NSKE five per cent (89.64) were statistically on par. Pongamia oil soap emulsion two per cent (66.89 per cent) was on par with NCE 10 per cent(65.14 per cent). Significantly lowest leaf protection was obtained in annona seed extract treatment.

S. litura

Twenty four hours after feeding, the percentage leaf protected by the treatments, azadirachtin 0.0025 per cent (87.80), NSKE five per cent (87.60) and cow's urine 10 per cent + NSKE five per cent (87.29) were statistically on par. These three treatments were significantly superior to all

the other treatments. Annona seed extract treatment provided significantly the lowest leaf protection.

The percentage leaf protected was significantly the highest in azadirachtin 0.0025 per cent (89.67) treatment, 48 hours after feeding. The treatments, NSKE five per cent (66.57) and cow's urine 10 per cent + NSKE five per cent (65.48) also afforded better protection and these treatments were statistically on par. Pongamia oil soap emulsion two per cent and NCE 10 per cent gave 55.83 and 37.50 per cent protection respectively. Annona seed extract two per cent (25.00) treated leaves were least protected form *S. litura*.

4.3. FIELD EVALUATION OF DIFFERENT BOTANICALS FOR THE MANAGEMENT OF PESTS OF AMARANTHUS

The results of the field trial conducted for the evaluation of different botanicals are presented here.

4.3.1 Population of Leaf Webber *P. basalis* and its Extent of Damage on Amaranthus Treated with Different Botanicals

The effect of different treatments after the first spray is presented in Table 6

Population of larvae

One day after the first spray, the mean population of *P. basalis* larvae ranged from 0.30 to 0.32 per plant. The larval population did not vary significantly among the treatments and control

Three days after the first spray, the mean population of larvae was significantly lower in all the treatments compared to control (0.49). Azadirachtin 0.0025 per cent (0.25) gave significantly higher effect than all the other treatments and the effect was statistically similar to that of check, malathion 0.10 per cent. The treatments, cow's urine 10 per cent + NSKE five per cent (0.31), NSKE five per cent (0.33) and pongamia oil soap emulsion two per cent (0.33) were on par.

Table 6. Population of *P. basalis* and its extent of damage on amaranthus treated with different botanicals (after first spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.30 (0.55)	0.33 (0.58)	0.33 (0.58)	0.06 (1.03)	0.33 (1.15)	0.40 (1.18)	14.97 (3.87)	17.75 (4.21)	19.44 (4.41)	2.68 (1.64)	3.17 (1.78)	3.47 (1.86)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.31 (0.56)	0.36 (0.60)	0.43 (0.66)	0.26 (1.12)	0.38 (1.18)	0.46 (1.20)	15.52 (3.94)	18.30 (4.28)	21.58 (4.65)	2.78 (1.67)	3.27 (1.81)	3.85 (1.96)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.30 (0.55)	0.25 (0.50)	0.27 (0.52)	0.06 (1.03)	0.19 (1.09)	0.33 (1.15)	14.43 (3.80)	15.55 (3.94)	17.18 (4.15)	2.68 (1.64)	2.78 (1.67)	3.07 (1.75)
Cow's urine 10 per cent + NSKE five per cent	0.30 (0.55)	0.31 (0.56)	0.32 (0.56)	0.19 (1.09)	0.26 (1.12)	0.32 (1.15)	14.97 (3.87)	16.10 (4.01)	18.31 (4.28)	2.68 (1.64)	2.78 (1.67)	3.27 (1.81)
Pongamia oil soap emulsion two per cent	0.31 (0.56)	0.33 (0.58)	0.42 (0.65)	0.33 (1.15)	0.33 (1.15)	0.53 (1.24)	15.49 (3.94)	17.75 (4.21)	21.65 (4.65)	2.78 (1.67)	3.17 (1.78)	3.86 (1.97)
Annona seed extract soap emulsion two per cent	0.31 (0.56)	0.38 (0.62)	0.50 (0.70)	0.53 (1.24)	0.60 (126)	0.60 (1.26)	16.64 (4.08)	19.97 (4.47)	26.62 (5.16)	2.78 (1.67)	3.57 (1.89)	4.74 (2.18)
Malathion 0.10 per cent	0.30 (0.55)	0.22 (0.47)	0.20 (0.45)	0.13 (1.06)	0.25 (1.12)	0.46 (1.21)	13.84 (3.72)	15.00 (3.87)	16.10 (4.01)	2.67 (1.63)	2.68 (1.64)	2.88 (1.70)
Control	0.32 (0.57)	0.49 (0.70)	0.64 (0.80)	0.77 (1.33)	1.06 (1.44)	1.19 (1.48)	16.04 (4.01)	24.40 (4.94)	32.19 (5.67)	2.88 (1.70)	4.22 (2.06)	5.75 (2.40)
CD (0.05)	NS	(0.04)	(0.05)	(0.16)	(0.19)	(0.17)	NS	(0.22)	(0.39)	NS	(0.13)	(0.16)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

Seven days after the first spray also. the mean population of larvae was significantly lower in all the treatments compared to control (0.64). Azadirachtin 0.0025 per cent treatment recorded a mean population of 2.27 which was statistically similar to that of cow's urine 10 per cent + NKSE five per cent (0.32). All the other treatments recorded significantly higher population of larvae.

Population of moths

One day after the first spray, the mean population of moths in treatments, azadirachtin 0.0025 per cent (0.06), NSKE five per cent (0.06) cow's urine 10 per cent + NSKE five per cent (0.19) and pongamia oil soap emulsion two per cent (0.33) were statistically similar to that of malathion treatment (0.13) and were significantly superior to annona seed extract two per cent (0.53) and control(0.77)

Three days after application of treatments, moth population in all the botanicals was significantly lower than control (1.06) and all these treatments recorded statistically similar population as that of malathion check. The same trend was observed seven days after treatment also.

Infestation on plants

One day after first spray, there was no significant difference among treatments and control in the percentage of plants infested by *P.basalis*

Three days after the first spray, the percentage of plants infested in all the treatments were significantly lower compared to control (24.40) The treatments, azadirachtin 0.0025 per cent (15.55) and cow's urine 10 per cent + NSKE five per cent (16.10) were significantly superior to the other treatments and were on par with malathion 0.10 per cent(15.00) . The infestation was of a higher magnitude in the other treatments. However all of them recorded a significantly lower percentage of pest infestation compared to control.

A comparable trend was observed seven days after the first spray also. The percentage plant damage in azadirachtin 0.0025 per cent (17.18) and cow's urine 10 per cent + NSKE five per cent (18.31) were statistically similar to that of malathion check. Significantly higher percentage of plant damage was recorded in the control (32.19) compared to all the treatments..

Infestation on leaves

One day after first spray, the percentage of leaves damaged by *P. basalis* did not differ significantly among the treatments. Three days after the first spray, all the treatments were significantly superior to control (4.22 per cent) in reducing the leaf damage. leaf damage in treatments, azadirachtin 0.0025 per cent and cow's urine 10 per cent + NSKE five per cent (2.78) were statistically similar to that of malathion 0.10 per cent (2.68). All the treatments recorded significantly higher leaf damage compared to the malathion check.

Seven days after treatment also, all the treatments were significantly superior to control which recorded a leaf damage of 5.75 per cent. Leaf damage percentage in treatments, azadirachtin 0.0025 per cent (3.07) and cow's urine 10 per cent + NSKE five per cent (3.27) and NSKE five per cent (3.47) was on par with malathion.

The effect of different treatments after the second spray is presented in Table 7.

Population of larvae

One day after the second spray, the mean population of *P. basalis* larvae in all the treatments except annona seed extract two per cent (0.55). were significantly lower compared to control (0.23).The treatment azadirachtin 0.0025 per cent (0.20) was significantly superior to all the other treatments and malathion 0.10 per cent. This was followed by NSKE

Table 7. Population of *P. basalis* and its extent of damage on amaranthus treated with different botanicals (after second spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.32 (0.57)	0.33 (0.57)	0.34 (0.59)	0.13 (1.06)	0.27 (1.12)	0.40 (1.18)	19.98 (4.47)	21.06 (4.59)	21.65 (4.65)	3.33 (1.83)	3.51 (1.87)	3.61 (1.90)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.46 (0.67)	0.48 (0.69)	0.44 (0.66)	0.33 (1.15)	0.32 (1.14)	0.40 (1.18)	22.75 (4.77)	23.31 (4.83)	24.42 (4.94)	3.79 (1.95)	3.97 (1.99)	4.06 (2.01)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.20 (0.45)	0.19 (0.43)	0.15 (0.39)	0.06 (1.03)	0.07 (1.03)	0.19 (1.09)	17.18 (4.15)	17.77 (4.22)	18.31 (4.28)	2.87 (1.69)	2.97 (1.72)	3.05 (1.75)
Cow's urine 10 per cent + NSKE five per cent	0.32 (0.57)	0.32 (0.57)	0.32 (0.57)	0.07 (1.03)	0.26 (1.12)	0.26 (1.12)	19.34 (4.40)	19.91 (4.46)	20.50 (4.53)	3.21 (1.79)	3.31 (1.82)	3.42 (1.85)
Pongamia oil soap emulsion two per cent	0.43 (0.66)	0.46 (0.67)	0.45 (0.67)	0.40 (1.18)	0.19 (1.09)	0.60 (1.26)	21.65 (4.65)	22.75 (4.77)	23.31 (4.83)	3.47 (1.86)	3.79 (1.95)	3.89 (1.97)
Annona seed extract soap emulsion two per cent	0.55 (0.75)	0.58 (0.76)	0.58 (0.76)	0.38 (1.18)	0.40 (1.18)	0.66 (1.29)	27.76 (5.27)	28.88 (5.37)	29.42 (5.42)	4.61 (2.15)	4.81 (2.19)	4.91 (2.22)
Malathion 0.10 per cent	0.23 (0.48)	0.11 (0.32)	0.10 (0.32)	0.13 (1.06)	0.13 (1.06)	0.18 (1.09)	16.64 (4.08)	17.21 (4.15)	18.31 (4.28)	2.78 (1.67)	3.10 (1.76)	3.05 (1.75)
Control	0.61 (0.78)	0.79 (0.89)	0.92 (0.96)	1.06 (1.44)	1.00 (1.41)	1.06 (1.44)	32.76 (5.72)	40.53 (6.37)	47.64 (6.90)	5.44 (2.33)	6.56 (2.56)	7.72 (2.78)
CD (0.05)	(0.11)	(0.04)	(0.05)	(0.16)	(0.18)	(0.17)	(0.38)	(0.37)	(0.36)	(0.17)	(0.18)	(0.12)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

five per cent (0.32) and cow's urine 10 per cent + NSKE five per cent (0.32) which were statistically on par.

Three days after the second spray also, all the treatments were significantly superior to control (0.79) in reducing the population of larvae. Among the treatments, azadirachtin 0.0025 per cent (0.19) was significantly superior to all the others. This was followed by cow's urine 10 per cent + NSKE five per cent (0.32) and NSKE five per cent(0.33). respectively. These two treatments were significantly superior compared to the other botanical treatments.

Significantly higher mean population of larvae was observed in control (0.92) compared to all the treatments, seven days after treatment. Azadirachtin 0.0025 per cent was significantly superior to all other treatments. This was followed by cow's urine 10 per cent + NSKE five per cent (0.32) and NSKE five per cent (0.34) which were significantly superior to the other botanical treatments.

Population of moths

One day after the second spray, the mean population of moths were significantly lower in all the treatments compared to control (1.06).All the treatments recorded statistically similar population as that of malathion check. The same trend was observed three days after the second spray also. Seven days after the second spray, the moth population in all the treatments except annona seed extract treatment (0.66) was significantly lower than control (1.06). The mean population in treatments, azadirachtin 0.0025 per cent (0.19), cow's urine 10 per cent + NSKE five per cent and NSKE five per cent and NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray and pongamia oil soap emulsion two per cent (0.60) were statistically on par with malathion 0.10 per cent (0.18).

Infestation on plants

One day after second spray, the percentage of plants damaged by *P.basalis* in all the treatments were significantly superior to control (32.76). The treatments, azadirachtin 0.0025 per cent (17.18) produced statistically similar effect as that of in malathion 0.10 per cent treatment (16.61). All the other treatments were significantly inferior to the insecticide check.

Three days after second spray, the percentage plant infestation in treatment azadirachtin 0.0025 per cent (17.77 per cent) was significantly superior to all the other treatments and was on par with malathion 0.10 per cent (17.21 per cent). All the treatments were significantly superior to control (40.53) in reducing the plant damage.

Seven days after treatment, all the treatments were significantly superior to control in reducing the plant damage. The plant damage in treatment, azadirachtin 0.0025 per cent (18.31) was on par with malathion 0.10 per cent. The treatments, cow's urine 10 per cent + NSKE five percent (20.50), NSKE five per cent (21.65) and pongamia oil soap emulsion (23.31) were on par and superior to the other treatments.

Infestation on leaves

One day after the second spray, all the treatments recorded a significantly lower leaf damage compared to control (5.44). The percentage leaf infestation in azadirachtin 0.0025 per cent (2.87), cow's urine 10 per cent + NSKE five per cent (3.21) and NSKE five per cent (3.33) were on par with malathion 0.10 per cent (2.78). The same trend was observed three days after the second spray.

Seven days after the second spray also, the leaf damage in all the treatments was significantly lower than control (7.27 per cent). Percentage leaf damage in azadirachtin 0.0025 per cent (3.05) and cow's urine 10 per cent + NKSE five per cent (3.42) was on par with malathion 0.10 per cent

treated plots (3.05). NSKE five per cent (3.61) and pongamia oil soap emulsion two per cent (3.89) were statistically on par.

The effect of different treatments after the third spray is presented in Table 8.

Population of larvae

One day after the third spray, the mean population of *P.basalis* larvae was significantly lower in azadirachtin 0.0025 per cent (0.20) compared to control (0.26) and was on par with malathion 0.10 per cent (0.17). All the other treatments did not exhibit any significant difference among themselves and control.

Three days after treatment, all the treatments were significantly superior to control (0.44) in reducing the population of larvae. The population in azadirachtin 0.0025 per cent (0.18) was significantly lower compared to all the other treatments and was on par with malathion.

Seven days after the third spray also, a similar trend was observed. Larval population in azadirachtin 0.0025 per cent (0.20) was significantly lower than all the other treatments and was on par with malathion 0.10 per cent (0.17). This was followed by the treatments, cow's urine 10 per cent + NSKE five per cent (0.26), NSKE five per cent (0.28) which recorded significantly lower population compared to the remaining treatments.

Population of moths

All the treatments recorded significantly lower moth population compared to control (0.93). The population in all the treatments except annona seed extract two per cent (0.53) were statistically similar to that of malathion 0.10 per cent (0.13).

Three days after the third spray, all the treatments except annona seed extract two per cent (0.53) recorded significantly lower moth population compared to control (1.00) and the population in the treatments were on par with that of malathion 0.10 per cent (0.19).

Table 8. Population of *P. basalis* and its extent of damage on amaranthus treated with different botanicals (after third spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.26 (0.51)	0.27 (0.52)	0.28 (0.53)	0.13 (1.06)	0.27 (1.12)	0.39 (1.18)	12.76 (3.57)	14.36 (3.79)	16.10 (4.01)	2.28 (1.51)	2.57 (1.60)	2.59 (1.61)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.24 (0.49)	0.31 (0.56)	0.37 (0.61)	0.20 (1.10)	0.40 (1.18)	0.47 (1.21)	12.17 (3.49)	14.98 (3.87)	18.83 (4.34)	2.17 (1.47)	2.67 (1.63)	3.14 (1.77)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.20 (0.45)	0.18 (0.43)	0.20 (0.45)	0.07 (1.03)	0.13 (1.06)	0.13 (1.06)	11.10 (3.33)	12.18 (3.49)	13.84 (3.72)	2.08 (1.44)	2.18 (1.48)	2.31 (1.52)
Cow's urine 10 per cent + NSKE five per cent	0.23 (0.48)	0.26 (0.51)	0.26 (0.51)	0.13 (1.06)	0.25 (1.12)	0.27 (1.12)	11.63 (3.41)	12.75 (3.57)	14.97 (3.87)	2.08 (1.44)	2.18 (1.48)	2.49 (1.58)
Pongamia oil soap emulsion two per cent	0.26 (0.51)	0.27 (0.52)	0.35 (0.59)	0.33 (1.15)	0.46 (1.21)	0.40 (1.18)	12.76 (3.57)	14.44 (3.80)	18.31 (4.28)	2.08 (1.44)	2.57 (1.60)	3.05 (1.75)
Annona seed extract soap emulsion two per cent	0.23 (0.48)	0.31 (0.56)	0.44 (0.66)	0.53 (1.24)	0.53 (1.24)	0.47 (1.21)	12.17 (3.49)	16.65 (4.08)	23.28 (4.82)	2.17 (1.47)	2.97 (1.72)	3.88 (1.97)
Malathion 0.10 per cent	0.17 (0.41)	0.18 (0.43)	0.17 (0.41)	0.13 (1.06)	0.19 (1.09)	0.26 (1.12)	12.18 (3.49)	12.18 (3.49)	12.76 (3.57)	2.18 (1.48)	2.18 (1.48)	2.13 (1.46)
Control	0.26 (0.51)	0.44 (0.66)	0.58 (0.76)	0.93 (1.39)	1.00 (1.41)	0.86 (1.36)	13.30 (3.65)	21.07 (4.59)	28.85 (5.37)	2.37 (1.54)	3.77 (1.94)	4.81 (2.19)
CD (0.05)	(0.05)	(0.04)	(0.04)	(0.13)	(0.17)	(0.10)	NS	(0.34)	(0.39)	NS	(0.14)	(0.16)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

Seven days after the third spray, moth population observed in azadirachtin 0.0025 per cent (0.13) and and cow's urine 10 per cent + NSKE five per cent (0.27) were on par with malathion 0.10 per cent (0.26). The moth population in all the treatments was significantly lower than control (0.86).

Infestation on plants

One day after the third spray, the percentage of plants damaged by *P.basalis* ranged from 11.10 per cent in azadirachtin 0.0025 per cent to 13.30 in control. There was no significant difference among the treatments and control.

Three days after spray, the percentage plant damage in azadirachtin 0.0025 per cent (12.18), cow's urine 10 per cent + NSKE five per cent (14.36) and pongamia oil soap emulsion two per cent (14.44) were statistically on par with malathion 0.10 per cent (12.18) and were superior to the other treatments. Percentage of plants infested was significantly higher in control (21.07 per cent) compared to all other treatments..

Seven days after the third spray, significantly highest plant damage was observed in control (28.55 per cent.) Among the botanicals, the percentage infestation in azadirachtin 0.0025 per cent (13.84) and cow's urine 10 per cent + NSKE five per cent (14.97) were on par with malathion 0.10 (12.76) per cent and were superior to all the other treatments.

Infestation on leaves

The percentage leaf damage by *P. basalis* larvae ranged from 2.08 per cent to 2.37 per cent among the various treatments and there were no significant difference among treatments and control, one day after the third spray.

Three days after the third spray, the leaf damage in all the treatments was significantly lower than control (3.77 per cent). The

percentage infestation in treatments, azadirachtin 0.0025 per cent, cow's urine 10 per cent + NSKE five per cent (2.18 per cent), NSKE five per cent (2.57) and pongamia oil soap emulsion two per cent (2.57 per cent damage) were on par with malathion 0.10 per cent (2.18).

Seven days after the third spray also, significantly lowest leaf damage was observed in control (4.81 per cent). The percentage leaf damage in treatments, azadirachtin 0.0025 per cent (2.31), cow's urine 10 per cent + NSKE five per cent (2.49) and NSKE five per cent (2.51) were statistically similar with that of malathion 0.10 per cent (2.13).

4.3.2 Population of Leaf Webber *H. recurvalis* and its Extent of Damage on Amaranthus Treated with Different Botanicals

The effect of different treatments after the first spray is presented in Table 9.

Population of larvae

The mean population of *H. recurvalis* larvae did not differ significantly among the treatments and control, one day after the first spray.

Three days after the first spray, mean population of larvae was significantly lower in all the treatments compared to control (0.95). The botanicals, azadirachtin 0.0025 per cent and cow's urine 10 per cent + NSKE five per cent recorded mean populations of 0.52 and 0.57 respectively. These treatments were on par and significantly superior to the other botanicals. All the treatments were significantly inferior to malathion in reducing the population of larvae.

All the treatments recorded significantly lower mean population of larvae compared to control(1.20), seven days after the first spray. The population was significantly lower in azadirachtin 0.0025 per cent compared to the other treatments. Malathion 0.10 per cent was

Table 9. Population of *H. recurvalis* and its extent of damage on amaranthus treated with different botanicals (after first spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.62 (0.79)	0.61 (0.78)	0.50 (0.71)	0.13 (1.06)	0.33 (1.15)	0.40 (1.18)	20.55 (4.53)	22.77 (4.77)	24.98 (5.00)	5.87 (2.42)	6.50 (2.55)	6.66 (2.58)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.60 (0.77)	0.80 (0.87)	0.84 (0.92)	0.40 (1.18)	0.46 (1.21)	0.46 (1.21)	19.98 (4.47)	24.98 (5.00)	28.99 (5.38)	5.71 (2.39)	7.13 (2.67)	7.71 (2.78)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.63 (0.80)	0.52 (0.72)	0.36 (0.60)	0.07 (1.03)	0.13 (1.06)	0.19 (1.09)	21.06 (4.59)	21.65 (4.65)	22.78 (4.77)	6.02 (2.45)	6.18 (2.49)	6.07 (2.46)
Cow's urine 10 per cent + NSKE five per cent	0.63 (0.80)	0.57 (0.75)	0.47 (0.69)	0.13 (1.06)	0.18 (1.09)	0.26 (1.12)	21.06 (4.59)	22.77 (4.77)	24.44 (4.94)	6.02 (2.45)	6.50 (2.55)	6.52 (2.55)
Pongamia oil soap emulsion two per cent	0.60 (0.77)	0.70 (0.84)	0.73 (0.86)	0.38 (1.18)	0.32 (1.15)	0.40 (1.18)	19.94 (4.47)	23.31 (4.83)	26.62 (5.16)	5.71 (2.39)	6.66 (2.58)	7.10 (2.66)
Annona seed extract soap emulsion two per cent	0.63 (0.80)	0.82 (0.90)	0.86 (0.92)	0.53 (1.24)	0.47 (1.21)	0.46 (1.21)	21.06 (4.59)	27.22 (5.22)	32.20 (5.68)	6.64 (2.58)	7.78 (2.79)	8.58 (2.93)
Malathion 0.10 per cent	0.49 (0.70)	0.40 (0.63)	0.30 (0.55)	0.13 (1.06)	0.13 (1.06)	0.33 (1.15)	20.31 (4.51)	21.06 (4.59)	21.06 (4.59)	5.87 (2.42)	6.01 (2.45)	6.37 (2.52)
Control	0.65 (0.81)	0.95 (0.97)	1.20 (1.09)	1.13 (1.46)	1.13 (1.46)	1.00 (1.41)	21.65 (4.65)	31.65 (5.63)	39.97 (6.32)	6.19 (2.49)	9.04 (3.01)	10.62 (3.26)
CD (0.05)	NS	(0.04)	(0.03)	(0.14)	(0.17)	(0.16)	NS	(0.30)	(0.35)	NS	(0.16)	(0.26)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

significantly superior to all the treatments in reducing the population of larvae.

Population of moths

The mean population of *H. recurvalis* moths was significantly the highest in control compared to the other treatments, one day after the first spray. The population in treatments, azadirachtin 0.0025 per cent (0.07), NSKE five per cent and cow's urine 10 per cent + NSKE five per cent (0.13) were on par with malathion 0.10 per cent.

Three days after the first spray, the population of moths ranged from 0.13 in azadirachtin 0.0025 per cent to 1.13 in control. However, all the treatments were on par and significantly superior to control (1.13) with regard to the population of moths. The same trend was observed seven days after treatment also.

Infestation on plants

The percentage of plants infested by *H. recurvalis* ranged from 19.94 in pongamia oil soap emulsion two per cent treatment to 21.65 in control, one day after the first spray. There were no significant difference among the treatments and control.

Three days after the third spray, the plant infestation in all the treatments was significantly lower when compared to control (31.65 per cent).The treatments, azadirachtin 0.0025 per cent (21.65), NSKE five per cent, cow's urine 10 per cent + NSKE five per cent (22.77) and pongamia oil soap emulsion two per cent (23.31) were statistically on par with malathion 0.10 per cent(21.06 per cent).

Seven days after the first spray, the percentage infestation on plants in azadirachtin 0.0025 per cent (22.78) and cow's urine 10 per cent + NSKE five per cent (24.98) were on par with that of malathion 0.10 per cent (21.06). All the treatments were significantly superior to control.

Infestation on leaves

The percentage of leaves damaged by *H. recurvalis* did not vary among treatments and control , one day after the first spray.

Three days after the first spray, significantly highest percentage of plant damage was observed in control (9.04 per cent) compared to the treatments. The treatments, azadirachtin 0.0025 per cent (6.18), NSKE five per cent, cow's urine 10 per cent + NSKE five per cent (6.50) and pongamia oil soap emulsion two per cent (6.66) and pongamia oil soap emulsion two per cent (7.10) recorded statistically similar leaf damage as that of malathion 0.10 per cent (6.01 per cent). A similar trend was observed seven days after spray also.

The effect of different treatments after the second spray is presented in Table 10.

Population of larvae

One day after the second spray, the mean population of *H. recurvalis* larvae in all the treatments were significantly lower compared to control (1.22). Among the botanicals, azadirachtin 0.0025 recorded a significantly lower population of 0.34 compared to all the other treatments. However all the treatments were significantly inferior to malathion 0.10 per cent.

The mean population of larvae was significantly the lowest in all the treatments compared to control (1.43), three days after the second spray. Azadirachtin 0.0025 per cent recorded a population of 0.19 which was significantly lower than that of all the other treatments. Malathion 0.10 per cent (0.14) was significantly superior to the botanical treatments.

The mean population of larvae in the different treatment plots varied significantly among themselves and control, seven days after the second spray. The population in treatments varied from 0.16 in

Table 10. Population of *H. recurvalis* and its extent of damage on amaranthus treated with different botanicals (after second spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.47 (0.69)	0.38 (0.62)	0.33 (0.58)	0.13 (1.06)	0.33 (1.15)	0.40 (1.18)	26.07 (5.11)	28.27 (5.32)	29.41 (5.42)	6.95 (2.64)	7.54 (2.75)	7.49 (2.74)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.73 (0.86)	0.78 (0.89)	0.68 (0.83)	0.40 (1.18)	0.32 (1.15)	0.60 (1.26)	29.98 (5.48)	34.39 (5.86)	37.20 (6.10)	8.00 (2.83)	9.17 (3.03)	9.60 (3.10)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.34 (0.59)	0.19 (0.44)	0.16 (0.40)	0.07 (1.03)	0.13 (1.06)	0.18 (1.09)	23.31 (4.83)	23.86 (4.89)	24.98 (5.00)	6.22 (2.50)	6.36 (2.52)	6.45 (2.54)
Cow's urine 10 per cent + NSKE five per cent	0.47 (0.68)	0.33 (0.58)	0.28 (0.53)	0.13 (1.06)	0.19 (1.09)	0.33 (1.15)	24.44 (4.94)	26.65 (5.16)	28.28 (5.32)	6.48 (2.51)	7.11 (2.67)	7.20 (2.68)
Pongamia oil soap emulsion two per cent	0.70 (0.84)	0.68 (0.83)	0.62 (0.79)	0.46 (1.21)	0.60 (1.26)	0.53 (1.24)	27.74 (5.27)	30.52 (5.52)	33.30 (5.77)	7.4 (2.72)	8.14 (2.85)	8.59 (2.93)
Annona seed extract soap emulsion two per cent	0.85 (0.92)	0.82 (0.91)	0.77 (0.88)	0.52 (1.23)	0.52 (1.23)	0.67 (1.29)	32.74 (5.72)	38.25 (6.18)	42.17 (6.49)	8.73 (2.95)	10.20 (3.19)	10.88 (3.30)
Malathion 0.10 per cent	0.27 (0.52)	0.14 (0.37)	0.11 (0.32)	0.13 (1.06)	0.19 (1.09)	0.26 (1.12)	21.65 (4.65)	22.73 (4.77)	23.86 (4.89)	5.92 (2.43)	6.06 (2.46)	6.12 (2.47)
Control	1.22 (1.10)	1.43 (1.20)	1.62 (1.27)	1.06 (1.44)	1.00 (1.41)	1.13 (1.46)	40.54 (6.37)	49.97 (7.07)	58.33 (7.64)	10.80 (3.29)	13.33 (3.65)	15.49 (3.94)
CD (0.05)	(0.03)	(0.02)	(0.03)	(0.16)	(0.15)	(0.17)	(0.36)	(0.47)	(0.40)	(0.19)	(0.24)	(0.21)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

azadirachtin 0.0025 per cent to 0.77 in annona seed extract two per cent. Control plots recorded a mean population of 1.62.

Population of moths

Mean population of *H. recurvalis* moths per sweep ranged from 0.07 in azadirachtin 0.0025 per cent to 1.06 in control, one day after the second spray. All the treatments were significantly superior to control in reducing the population of moths.

Three days after the second spray, all the treatments except annona seed extract recorded significantly lower population compared to control (1.42). Treatments, azadirachtin 0.0025 per cent (0.13) and cow's urine 10 per cent + NSKE five per cent (0.19) were significantly superior to the other treatments and were on par with malathion 0.10 per cent (0.19).

Seven days after the second spray, the mean population of *H. recurvalis* moths in all the treatments except annona seed extract (0.67) was significantly lesser compared to control (1.13).The population in treatments ranged from 0.18 in azadirachtin 0.0025 per cent to 0.60 in NC soil application @250 kg.ha-1 at planting +NCE 10 per cent spray. All the botanical treatments were statistically similar to that of malathion 0.10 per cent (0.26).

Infestation on plants

One day after the second spray, the percentage of plants infested by *H. recurvalis* was significantly highest in control (40.54). Among the botanicals, azadirachtin 0.0025 per cent (23.31) and cow's urine 10 per cent + NSKE five per cent (24.44) were significantly superior to the other treatments and were statistically similar to malathion check (21.65).

Three days after the second spray also, all the treatments recorded significantly lesser plant infestation compared to control (49.97 per cent). Azadirachtin 0.0025 per cent (23.86) and cow's urine 10 per cent + NSKE five per cent (26.65) were on par with malathion 0.10 per cent (22.73).

The plant damage was significantly highest in control (58.33 per cent) compared to all other treatments, seven days after the second spray. The percentage plant infestation in treatment azadirachtin 0.0025 per cent (24.98 per cent) was statistically similar to that of malathion 0.10 per cent (23.86 per cent).

Infestation on leaves

The percentage of leaves infested by *H. recurvalis* was significantly low in all the treatments compared to control (10.80), one day after the second spray. Treatment azadirachtin 0.0025 per cent and cow's urine 10 per cent + NSKE five per cent (6.48), were on par with malathion 0.10 per cent (5.92).

The same trend was observed three days after the second spray. Control plots recorded significantly highest percentage of leaf damage compared to all the treatments. Among the treatments, azadirachtin 0.0025 per cent (6.22) and cow's urine 10 per cent + NSKE five per cent(6.48) recorded statistically similar effect as that of malathion 0.10 per cent (5.92).

Seven days after the second spray, significantly highest leaf damage was observed in control (15.49). Among the botanicals, azadirachtin 0.0025 per cent recorded significantly lower leaf damage (6.45) which was on par with cow's urine 10 per cent +NSKE five per cent (4.49) and malathion 0.10 per cent. The leaf damage was higher in the other botanical treatments.

The effect of different treatments after the third spray is presented in Table 11.

Population of larvae

The mean population of *H. recurvalis* larvae per plant ranged from 0.35 in malathion 0.10 per cent to 0.53 in control, one day after third

Table 11. Population of *H. recurvalis* and its extent of damage on amaranthus treated with different botanicals (after third spray)

Treatments	*Population of larvae (DAT)			**Population of moths (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.52 (0.72)	0.53 (0.73)	0.55 (0.74)	0.07 (1.03)	0.26 (1.12)	0.40 (1.18)	17.22 (4.15)	19.45 (4.41)	21.62 (4.65)	3.68 (1.92)	4.04 (2.01)	4.16 (2.04)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.49 (0.70)	0.53 (0.73)	0.79 (0.89)	0.19 (1.09)	0.40 (1.18)	0.47 (1.21)	16.65 (4.08)	21.62 (4.65)	25.60 (5.06)	3.57 (1.89)	4.45 (2.11)	5.20 (2.28)
Azadirachtin 0.0025 per cent (Neem Azal I % TS @ 2.5 ml/litre)	0.40 (0.63)	0.40 (0.63)	0.35 (0.59)	0.13 (1.06)	0.13 (1.06)	0.13 (1.06)	17.72 (4.21)	18.32 (4.28)	18.32 (4.28)	3.57 (1.89)	3.57 (1.89)	3.72 (1.93)
Cow's urine 10 per cent + NSKE five per cent	0.50 (0.71)	0.49 (0.70)	0.49 (0.70)	0.07 (1.03)	0.33 (1.15)	0.27 (1.12)	17.72 (4.21)	19.45 (4.41)	21.07 (4.59)	3.57 (1.89)	4.12 (2.03)	4.41 (2.10)
Pongamia oil soap emulsion two per cent	0.52 (0.72)	0.55 (0.74)	0.69 (0.83)	0.25 (1.12)	0.19 (1.09)	0.46 (1.21)	17.22 (4.15)	19.98 (4.47)	23.33 (4.83)	3.50 (1.87)	4.28 (2.07)	4.88 (2.21)
Annona seed extract soap emulsion two per cent	0.53 (0.73)	0.74 (0.86)	0.85 (0.92)	0.67 (1.30)	0.53 (1.24)	0.67 (1.29)	17.72 (4.21)	25.00 (5.00)	28.84 (5.37)	3.69 (1.92)	5.24 (2.29)	6.10 (2.47)
Malathion 0.10 per cent	0.35 (0.59)	0.27 (0.52)	0.21 (0.46)	0.19 (1.09)	0.25 (1.12)	0.25 (1.12)	17.22 (4.15)	17.72 (4.21)	17.72 (4.21)	3.35 (1.83)	3.69 (1.92)	3.69 (1.92)
Control	0.53 (0.73)	0.85 (0.92)	1.00 (1.00)	1.26 (1.50)	1.06 (1.44)	0.86 (1.36)	17.72 (4.21)	28.30 (5.32)	36.12 (6.01)	3.80 (1.95)	6.05 (2.46)	7.56 (2.75)
CD (0.05)	(0.06)	(0.04)	(0.05)	(0.16)	(0.18)	(0.13)	NS	(0.32)	(0.39)	NS	(0.12)	(0.17)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants ** Mean of five random sweeps
Transformed values are given in parenthesis (population of moths : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

spray. Azadirachtin 0.0025 per cent recorded a mean population of 0.40 and was on par with malathion 0.10 per cent. All the other treatments were on par with control.

Three days after the third spray, the mean population of *H. recurvalis* larvae was significantly lowest in treatment azadirachtin 0.0025 per cent (0.40) which was significantly superior to all the other botanicals. Malathion 0.10 per cent (0.27) was significantly superior to all the treatments.

Seven days after the third spray, the mean population of *H. recurvalis* larvae in all the treatments were significantly lower than control. The most effective botanical was azadirachtin 0.0025 per cent (0.35) followed by cow's urine 10 per cent + NSKE five per cent (0.49) and NSKE five per cent (0.55) which were statistically on par.

Population of moths

One day after the third spray, the mean population of *H. recurvalis* moths was significantly lower in NSKE five per cent (0.07) and cow's urine 10 per cent + NSKE five per cent (0.07) compared to control (1.26). All the treatments except annona seed extract two per cent were on par.

Three days after third spray, all the botanical treatments were statistically on par with malathion 0.10 per cent (0.25) and were superior to control (1.06).

Seven days after the third spray, all the treatments were significantly superior to control (0.86) in reducing the population of moths. Treatments, azadirachtin 0.0025 per cent (0.13), cow's urine 10 per cent + NSKE five per cent and NSKE five per cent (0.40) were on par with malathion 0.10 per cent (0.25).

Infestation on plants

The percentage of plants damaged ranged from 17.22 in malathion 0.10 per cent to 17.72 in control one day after the third spray. There were no significant difference among treatments and control.

Three days after third spray, the percentage of plants infested was significantly lower than control (28.30) in all the treatments except annona seed extract two per cent (25.00). Treatments, azadirachtin 0.0025 per cent (8.32), NSKE five per cent (19.45) and cow's urine 10 per cent + NSKE five per cent (19.45) were on par and were statistically similar to malathion 0.10 per cent (17.72).

Seven days after the third spray, the percentage plant infestation was significantly higher in the control plots (36.12) compared to the treatment plots. Treatments, azadirachtin 0.0025 per cent (18.32) and cow's urine 10 per cent + NSKE five per cent (21.07) were on par with malathion 0.10 per cent (17.72)

Infestation on leaves

One day after the third spray, the damage to leaf did not vary significantly among treatments.

Three days after third spray, significantly highest leaf damage of 6.05 per cent was observed in control. The extent of damage in treatments, azadirachtin 0.0025 per cent (3.57 per cent) and NSKE five per cent (4.04 percent) were statistically similar to malathion 0.10 per cent (3.69 per cent). The effect of these treatments were significantly superior to that of the remaining treatments.

4.3.3 Population of the Green Grasshopper *A. crenulata* and its Extent of Damage on Amaranthus Treated with Different Botanicals

The effect of different treatments after the first spray is presented in Table 12.

Population of grasshopper

One day after the first spray, the mean population of *A.crenulata* per plant was generally low and ranged from 0.02 in treatments to 0.19 (control). The treatments, cow's urine 10 per cent + NSKE five per cent (0.02), azadirachtin 0.0025 per cent (0.02), NSKE five per cent (0.03)

Table 12. Population of *A. crenulata* and its extent of damage on amaranthus treated with different botanicals (after first spray)

Treatments	*Population of *A. crenulata* (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.03 (1.01)	0.02 (1.01)	0.05 (0.22)	11.09 (3.33)	12.75 (3.57)	14.44 (3.80)	1.17 (1.08)	1.25 (1.12)	1.44 (1.20)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.08 (1.04)	0.11 (1.05)	0.10 (0.32)	10.50 (3.24)	13.32 (3.65)	17.14 (4.14)	1.17 (1.08)	1.42 (1.19)	1.72 (1.31)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.02 (1.01)	0.03 (1.01)	0.05 (0.23)	9.99 (3.16)	11.09 (3.33)	12.75 (3.57)	1.04 (1.02)	1.19 (1.09)	1.39 (1.18)
Cow's urine 10 per cent + NSKE five per cent	0.02 (1.01)	0.03 (1.01)	0.03 (0.17)	9.99 (3.16)	11.63 (3.41)	13.32 (3.65)	1.06 (1.03)	1.25 (1.12)	1.44 (1.20)
Pongamia oil soap emulsion two per cent	0.09 (1.04)	0.11 (1.05)	0.10 (0.31)	10.43 (3.23)	13.32 (3.65)	16.65 (4.08)	1.17 (1.08)	1.42 (1.19)	1.66 (1.29)
Annona seed extract soap emulsion two per cent	0.11 (1.05)	0.14 (1.07)	0.11 (0.33)	9.86 (3.14)	14.98 (3.87)	21.62 (4.65)	1.21 (1.10)	1.61 (1.27)	2.19 (1.48)
Malathion 0.10 per cent	0.03 (1.01)	0.04 (1.02)	0.14 (0.38)	10.56 (3.25)	10.56 (3.25)	12.11 (3.48)	1.12 (1.06)	1.15 (1.07)	1.21 (1.10)
Control	0.19 (1.09)	0.18 (1.09)	0.17 (0.41)	11.63 (3.41)	19.98 (4.47)	27.14 (5.21)	1.25 (1.12)	2.13 (1.46)	2.72 (1.65)
CD (0.05)	(0.02)	(0.02)	(0.07)	NS	(0.34)	(0.44)	NS	(0.10)	(0.13)

NS – Not significant, DAT – Days after treatment * Mean of observation on 15 plants
Transformed values are given in parenthesis (population of *A. crenulata* : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

were on par with malathion 0.10 per cent (0.03). The population was significantly higher in control compared to all other treatments.

Three days after the first spray, the highest population of grasshoppers was observed in control (0.18) and the lowest in NSKE five per cent (0.02). The population in NSKE five per cent treatment was on par with azadirachtin 0.0025 per cent (0.03), cow's urine 10 per cent + NSKE five per cent (0.03) and malathion 0.10 per cent (0.04).

Seven days after the first spray, the population of grasshoppers was the lowest in cow's urine 10 per cent + NKE five per cent (0.03) followed by NSKE five per cent (0.05) and azadirachtin 0.0025 per cent (0.05). These treatments were on par. A significantly higher grasshopper population was observed in control (0.17) compared to all the treatments.

Infestation on plants

One day after the first spray, the percentage of plants damaged by *A.crenulata* ranged from 9.86 to 11.63 among the treatments which were on par.

The plant damage was significantly higher in the control plot (19.98 per cent) compared to all the other treatments, three days after the first spray. Percentage damage in treatments, azadirachtin 0.0025 per cent (11.09), cow's urine 10 per cent + NSKE five per cent (11.63) and NSKE five per cent (12.75) were on par with malathion 0.10 per cent (10.56 per cent).

Seven days after the first spray, azadirachtin 0.0025 per cent (12.75), cow's urine 10 per cent + NSKE five per cent (13.32) and NSKE five per cent (14.44) recorded lesser plant damage and were on par with chemical check. All the botanical treatments resulted in a significant reduction in plant damage compared to control (27.14 per cent).

Infestation on leaves

The percentage of leaves damaged by *A.crenulata* was closely related to the percentage of plants infested. In general, percentage of leaves infested was low. The leaf damage did not vary significantly among treatments, one day after the first spray.

The leaf damage was significantly the highest in control (2.13 per cent) three days after the first spray. The botanicals, azadirachtin 0.0025 per cent (1.19), NSKE five per cent (1.25) and cow's urine 10 per cent + NSKE five per cent (1.25) were on par with malathion 0.10 per cent.

Seven days after the first spray, the least leaf damage was observed in malathion 0.10 per cent (1.21), azadirachtin 0.025 per cent (1.39), NSKE five per cent (1.44) and cow's urine 10 per cent + NSKE five per cent (1.44); these treatments were on par. The other botanical treatment also recorded a significantly lower leaf damage compared to control (2.72).

The effect of different treatments after the second spray is presented in Table 13.

Population of grasshopper

One day after the second spray, the population of *A.crenulata* per plant was low and ranged from 0.01 (NSKE five per cent) to 0.07 (control). The population was on par among all the treatments except annona seed extract two per cent. All the treatments were significantly superior to control (0.16).

Three days after first spray, the grasshopper population was significantly lower in all the treatments compared to control (0.16). The lowest population was observed in cow's urine 10 per cent + NSKE five per cent (0.01) and azadirachtin 0.0025 per cent (0.02). The population in the other treatments was slightly higher and the highest was observed in

Table 13. Population of *A. crenulata* and its extent of damage on amaranthus treated with different botanicals (after second spray)

Treatments	*Population of *A. crenulata* (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.01 (1.01)	0.02 (1.01)	0.04 (0.20)	14.98 (3.87)	14.98 (3.87)	16.65 (4.08)	1.49 (1.22)	1.44 (1.20)	1.56 (1.25)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.05 (1.02)	0.06 (1.03)	0.07 (0.26)	17.72 (4.21)	18.84 (4.34)	18.84 (4.34)	1.74 (1.32)	1.82 (1.35)	1.77 (1.33)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.02 (1.01)	0.02 (1.01)	0.03 (0.18)	12.74 (3.57)	12.74 (3.57)	12.74 (3.57)	1.28 (1.13)	1.25 (1.12)	1.19 (1.09)
Cow's urine 10 per cent + NSKE five per cent	0.03 (1.01)	0.01 (1.01)	0.02 (0.15)	13.84 (3.72)	13.84 (3.72)	14.44 (3.80)	1.39 (1.18)	1.35 (1.16)	1.32 (1.15)
Pongamia oil soap emulsion two per cent	0.07 (1.03)	0.04 (1.02)	0.08 (0.29)	16.65 (4.08)	17.72 (4.21)	18.32 (4.28)	1.66 (1.29)	1.72 (1.31)	1.72 (1.31)
Annona seed extract soap emulsion two per cent	0.10 (1.05)	0.09 (1.04)	0.10 (0.32)	23.33 (4.83)	23.33 (4.83)	25.00 (5.00)	2.25 (1.50)	2.19 (1.48)	2.34 (1.53)
Malathion 0.10 per cent	0.02 (1.01)	0.01 (1.01)	0.03 (0.16)	12.11 (3.48)	12.11 (3.48)	12.11 (3.48)	1.37 (1.17)	1.17 (1.08)	1.15 (1.07)
Control	0.16 (1.08)	0.16 (1.08)	0.15 (0.39)	27.77 (5.27)	33.87 (5.82)	35.28 (5.94)	2.69 (1.64)	2.92 (1.71)	3.10 (1.76)
CD (0.05)	(0.02)	(0.02)	(0.07)	(0.39)	(0.47)	(0.56)	(0.16)	(0.14)	(0.13)

DAT – Days after treatment * Mean of observation on 15 plants

Transformed values are given in parenthesis (population of *A. crenulata* : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation)

the control plot (0.16). All the treatments except annona seed extract were on par.

The mean population of grasshopper was low and ranged from 0.02 in cow's urine 10 per cent + NSKE five per cent to 0.15 in control, seven days after second spray. The treatments, azadirachtin 0.0025 per cent (0.02) and NSKE five per cent (0.04) were on par with malathion 0.10 per cent (0.03).

Infestation on plants

The percentage of plants damaged was significantly highest in control (27.77) compared to all the treatments, one day after second spray. Treatments, azadirachtin 0.0025 per cent (12.74), cow's urine 10 per cent + NSKE five per cent (13.84) and NSKE five per cent (14.98) were on par with malathion 0.10 per cent (12.11)

Three days after the second spray also, the above trend was observed. Lowest plant damage was observed in control (33.87). Among the botanicals, azadirachtin 0.0025 per cent (12.74), cow's urine 10 per cent + NSKE five per cent (13.84), NSKE five per cent (14.98) were on par with malathion 0.10 per cent. The other botanical treatments also recorded a significantly lower plant damage compared to control.

Seven days after the second spray, the percentage of plants damaged ranged from 12.11 in malathion 0.10 per cent to 35.28 in control. Among the botanicals, azadirachtin 0.0025 per cent (12.74) was the best, followed by cow's urine 10 per cent + NSKE five per cent (14.44) and NSKE five per cent (16.65) and these treatments were on par. Pongamia oil soap emulsion two per cent (18.32) and NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray were also significantly better than control.

Infestation on leaves

The percentage of leaves damaged by *A.crenulata* in the infested plants was in general, low one, three and seven days after the second spray. One day after the second spray, the percentage of leaves damaged was on par in treatments, cow's urine 10 per cent + NSKE five per cent (1.39), NSKE five per cent (1.49) and pongamia oil soap emulsion two per cent (1.66) with malathion 0.10 per cent (1.37).Significantly higher leaf damage was observed in control (2.69) than all the treatments.

Three days after the second spray, all the treatments were significantly superior to control in reducing the plant damage. The treatments, azadirachtin 0.0025 per cent (1.25), cow's urine 10 per cent + NSKE five per cent (1.35) and NSKE five per cent (1.44) were on par with malathion 0.10 per cent (1.17).

Seven days after the second spray, the leaf damage by the grasshopper was significantly low in azadirachtin 0.0025 per cent (1.19) and cow's urine 10 per cent + NSKE five per cent (1.32); these treatments were statistically similar to malathion 0.10 per cent (1.15). The botanicals, NSKE five per cent (1.56), pongamia oil soap emulsion two per cent (1.72), NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (1.77) significantly lowered plant damage by grasshopper compared to annona seed extract two per cent (2.34) and control (3.10).

The effect of different treatments after the third spray is presented in Table 14.

Population of grasshopper

The population of grasshopper was low one, three and seven days after the third spray. One day after the third spray, the mean population of grasshoppers was significantly lower in treatments azadirachtin 0.0025 per cent (0.01), cow's urine 10 per cent + NSKE five per cent (0.02), NSKE five per cent (0.02) and these treatments were on par with malathion 0.10

Table 14. Population of *A. crenulata* and its extent of damage on amaranthus treated with different botanicals (after third spray)

Treatments	*Population of *A. crenulata* (DAT)			*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7	1	3	7
NSKE five per cent	0.02 (1.01)	0.02 (1.01)	0.04 (0.21)	9.42 (3.07)	11.09 (3.33)	12.75 (3.57)	1.02 (1.01)	1.19 (1.09)	1.37 (1.17)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.07 (1.04)	0.11 (1.05)	0.10 (0.32)	9.00 (3.00)	11.63 (3.41)	15.52 (3.94)	0.92 (0.96)	1.25 (1.12)	1.66 (1.29)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.01 (1.01)	0.02 (1.01)	0.05 (0.23)	8.29 (2.88)	9.43 (3.07)	11.09 (3.33)	0.88 (0.94)	0.98 (0.99)	1.19 (1.09)
Cow's urine 10 per cent + NSKE five per cent	0.02 (1.01)	0.03 (1.01)	0.03 (0.17)	8.29 (2.88)	9.99 (3.16)	11.63 (3.41)	0.88 (0.94)	1.06 (1.03)	1.21 (1.10)
Pongamia oil soap emulsion two per cent	0.07 (1.04)	0.10 (1.05)	0.09 (0.30)	8.76 (2.96)	11.63 (3.41)	12.67 (3.56)	0.94 (0.97)	1.25) (1.12	1.61 (1.27)
Annona seed extract soap emulsion two per cent	0.11 (1.05)	0.13 (1.06)	0.10 (0.32)	8.76 (2.96)	13.32 (3.65)	20.07 (4.48)	0.94 (0.97)	1.42) (1.19	2.20 (1.48)
Malathion 0.10 per cent	0.02 (1.01)	0.04 (1.02)	0.12 (0.34)	8.88 (2.98)	8.88 (2.98)	10.43 (3.23)	0.96 (0.98)	0.94) (0.97)	1.12 (1.06)
Control	0.18 (1.08)	0.17 (1.08)	0.17 (0.41)	9.99 (3.16)	18.32 (4.28)	25.50 (5.05)	1.06 (1.03)	1.96 (1.40)	2.69 (1.64)
CD (0.05)	(0.02)	(0.02)	(0.06)	NS	(0.36)	(0.52	NS	(0.12)	(0.14)

DAT – Days after treatment * Mean of observation on 15 plants
Transformed values are given in parenthesis (population of *A. crenulata* : $\sqrt{x+1}$ transformation, all other values $\sqrt{x}$ transformation

per cent (0.02). The population was also significantly lower in the other plots compared to control (0.18).

Three days after the third spray, significantly highest grasshopper population was observed in control (0.17). The population was lesser in NSKE five per cent (0.02), azadirachtin 0.0025 per cent (0.02), cow's urine 10 per cent + NSKE five per cent (0.02) and malathion 0.10 per cent (0.02). The population was significantly higher in the other botanical treatments.

Seven days after the third spray also significantly higher grasshopper population was observed in control (0.17) compared to the other treatments. The population was significantly lesser in NSKE five per cent (0.02), azadirachtin 0.0025 per cent (0.02) and cow's urine 10 per cent + NSKE five per cent (0.03). These were on par with malathion 0.10 per cent (0.04).

Infestation on plants

The percentage of plants infested did not vary among treatments, one day after the third spray.

Three days after the third spray, the plant damage was significantly higher in control (18.32) compared to the treatments. All the botanicals recorded a significantly higher plant damage compared to malathion 0.10 per cent.

Seven days after the third spray, the percentage of plants damaged in azadirachtin 0.0025 per cent (11.09), cow's urine 10 per cent + NSKE five per cent (11.63), pongamia oil soap emulsion two per cent (12.67) and NSKE five per cent (12.75) treatments were on par. Significantly highest percentage of plant damage was recorded in control (25.50).

Infestation on leaves

The percentage of leaves infested was low at one, three and seven days after the third spray. The percentage of leaves damaged did not differ significantly among the treatments, one day after third spray.

Three days after the third spray, the percentage of leaves damaged was significantly higher in control (1.96) compared to the treatments. Leaf damage in azadirachtin 0.0025 (0.98), cow's urine 10 per cent + NSKE five per cent (1.06) and NSKE five per cent (1.19) were on par with malathion 0.10 per cent (0.94).

The same trend was observed seven days after the third spray. The percentage of leaves damaged ranged from 1.12 per cent in malathion 0.10 per cent to 2.69 in control. The botanicals, azadirachtin 0.0025 per cent (1.19), cow's urine 10 per cent + NSKE five per cent (1.37) were on par with malathion 0.10 per cent.

4.3.4 Extent of of Damage Caused by Tobacco Caterpillar *S.litura* on Amaranthus Treated with Different Botanicals

The effect of different treatments after the first spray is presented in Table 15.

Infestation on plants

The percentage of plants infested was the least in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (2.72) and was superior to all the other treatments and malathion, one day after the first spray. This was followed by azadirachtin 0.0025 per cent (6.60) and cow's urine 10 per cent + NSKE five per cent (6.61).

Three days after first spray also, the percentage of plants infested was significantly lesser in all the treatments compared to control (16.65). Among the treatments, NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (2.72) was significantly superior to the other treatments and malathion check. This was followed by azadirachtin 0.0025

Table 15. Extent of damage caused by *S. litura* on amaranthus treated with different botanicals (after first spray)

Treatments	*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7
NSKE five per cent	7.78 (2.79)	9.36 (3.06)	11.09 (3.33)	0.55 (0.74)	0.66 (0.81)	0.79 (0.89)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	2.72 (1.65)	2.72 (1.65)	2.72 (1.65)	0.18 (0.42)	0.19 (0.44)	0.19 (0.44)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	6.60 (2.57)	7.78 (2.79)	9.43 (3.07)	0.48 (0.69)	0.53 (0.73)	0.67 (0.82)
Cow's urine 10 per cent + NSKE five per cent	6.61 (2.57)	8.29 (2.88)	9.99 (3.16)	0.45 (0.67)	0.58 (076)	0.69 (0.83)
Pongamia oil soap emulsion two per cent	7.08 (2.66)	9.99 (3.16)	13.32 (3.65)	0.53 (0.73)	0.71 (0.84)	0.92 (0.96)
Annona seed extract soap emulsion two per cent	7.08 (2.66)	11.63 (3.41)	18.23 (4.27)	0.49 (0.70)	0.81 (0.90)	1.30 (1.14)
Malathion 0.10 per cent	7.18 (2.68)	7.18 (2.68)	8.76 (2.96)	0.49 (0.70)	0.49 (0.70)	0.49 (0.70)
Control	8.29 (2.88)	16.65 (4.08)	23.80 (4.88)	0.59 (0.77)	1.19 (1.09)	1.66 (1.29)
CD (0.05)	(0.59)	(0.44)	(0.50)	(0.15)	(0.11)	(0.10)

DAT – Days after treatment * Mean of observation on 15 plants
Values given in parenthesis are after $\sqrt{x}$ transformation

per cent (7.78), cow's urine 10 per cent + NSKE five per cent (8.29) and NSKE five per cent (9.36) which were on par with malathion 0.10 per cent (7.18).

The same trend in infestation was observed seven days after first spray. The percentage of plants infested was significantly less in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (2.72) compared to all the other treatments and malathion 0.10 per cent (8.76). However all the treatments recorded a significantly lower plant damage compared to control (23.80 per cent).

Infestation on leaves

The percentage of leaves infested by *S.litura* was low at one, three and seven days after first spray. The percentage of leaves infested one day after first spray was significantly lower in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.18) compared to all the other treatments which were on par among themselves and with control.

Three days after the first spray, the percentage of leaves infested ranged from 0.19 in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray to 1.19 in control. Treatments, azadirachtin 0.0025 per cent (0.53), cow's urine 10 per cent + NSKE five per cent (0.58) and NSKE five per cent (0.66) were on par with malathion 0.10 per cent (0.49). All the treatments recorded a significantly lower leaf damage compared to control.

A similar trend was observed seven days after first spray. Control plots recorded a significantly higher percentage of leaf infestation (1.66) compared to all the treatments. The percentage of leaves infested in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.19) and malathion 0.10 per cent (0.49) was significantly lesser than all the other treatments. This was followed by azadirachtin 0.0025 per cent

(0.67), cow's urine 10 per cent + NSKE five per cent (0.69) and NSKE five per cent (0.79) and these treatments were on par.

Effect of different treatments after the second spray is presented in Table 16.

Infestation on plants

The percentage of plants infested by *S. litura* was significantly lowest in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (3.35) one day after second spray compared to all the other treatments and control (24.40 per cent). This was followed by azadirachtin 0.0025 per cent (9.42), and cow's urine 10 per cent + NSKE five per cent (11.63); these three treatments were on par with malathion 0.10 per cent (8.76).

Three days after second spray, the percentage of plants infested was the least in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (3.84); this was significantly superior to all the other treatments. The treatments, azadirachtin 0.0025 per cent (9.43), cow's urine 10 per cent + NSKE five per cent (10.46) and NSKE five per cent (11.63) were on par with malathion 0.10 per cent (8.76).

Seven days after second spray, the infestation in treatments, NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (3.84), azadirachtin 0.0025 per cent (9.43) and in cow's urine 10 per cent + NSKE five per cent (11.09) were on par with malathion 0.10 per cent. This was followed by NSKE five per cent (13.32) and pongamia oil soap emulsion two per cent (14.98); these two treatments were also on par. Control plots recorded a significantly higher plant damage (33.87) compared to all the treatments.

Infestation on leaves

The percentage of leaves infested was very low one, three and seven days after the second spray. However all the treatments were

Table 16. Extent of damage caused by *S. litura* on amaranthus treated with different botanicals (after second spray)

Treatments	*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7
NSKE five per cent	11.63 (3.41)	11.63 (3.41)	13.32 (3.65)	0.77 (0.88)	0.77 (0.88)	0.88 (0.94)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	3.35 (1.83)	3.84 (1.96)	3.84 (1.96)	0.22 (0.47)	0.24 (0.49)	0.26 (0.51)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	9.42 (3.07)	9.43 (3.07)	9.43 (3.07)	0.62 (0.79)	0.61 (0.78)	0.61 (0.78)
Cow's urine 10 per cent + NSKE five per cent	10.56 (3.25)	10.56 (3.25)	11.09 (3.33)	0.72 (0.85)	0.74 (0.86)	0.74 (0.86)
Pongamia oil soap emulsion two per cent	13.32 (3.65)	14.44 (3.80)	14.98 (3.87)	0.92 (0.96)	0.96 (0.98)	1.00 (1.00)
Annona seed extract soap emulsion two per cent	19.98 (4.47)	19.98 (4.47)	21.62 (4.65)	1.32 (1.15)	1.28 (1.13)	1.44 (1.20)
Malathion 0.10 per cent	8.76 (2.96)	8.76 (2.96)	8.76 (2.96)	0.58 (0.76)	0.59 (0.77)	0.56 (0.75)
Control	24.40 (4.94)	29.38 (5.42)	33.87 (5.82)	1.64 (1.28)	1.96 (1.40)	2.25 (1.50)
CD (0.05)	(0.42)	(0.48)	(0.38)	(0.10)	(0.12)	(0.10)

DAT – Days after treatment * Mean of observation on 15 plants
Values given in parenthesis are after $\sqrt{x}$ transformation

superior to control. One day after second spray, significantly lowest percentage of leaf damage was observed in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray to (0.22). The leaf damage in treatments, malathion 0.10 per net (0.58), azadirachtin 0.0025 per cent (0.62) and cow's urine 10 per cent + NSKE five per cent (0.72) were on par. NSKE five per cent (0.77) was on par with pongamia oil soap emulsion two per cent (0.92).

The percentage of leaves infested was significantly lesser in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.24), three days after the second spray. This was followed by malathion 0.10 per cent (0.59), azadirachtin 0.0025 per cent (0.61), cow's urine 10 per cent + NSKE five per cent (0.74) and NSKE five per cent (0.77); these treatments were on par. All the insecticide treatments recorded a significantly lesser leaf damage compared to control (1.96).

Seven days after the second spray, the percentage of leaves damaged in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent per cent spray (0.26) was on par with malathion 0.10 per cent (0.56). These treatments were significantly superior to all the other treatments. This was followed by azadirachtin 0.0025 per cent (0.61), NSKE five per cent (0.88) and cow's urine 10 per cent + NSKE five per cent (0.74), these treatments were on par. However the percentage of leaves infested in plants treated with annona seed extract two per cent (1.44) and control (2.25) were significantly higher compared to the other botanical treatments.

Effect of different treatments after third spray is presented in Table 17.

Infestation on plants

The percentage of plants infested ranged from 2.16 in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray to 9.99 in

Table 17. Extent of damage caused by *S. litura* on amaranthus treated with different botanicals (after third spraying)

Treatments	*Percentage of plants infested (DAT)			*Percentage of leaves infested (DAT)		
	1	3	7	1	3	7
NSKE five per cent	9.42 (3.07)	11.09 (3.33)	11.09 (3.33)	0.72 (0.82)	0.81 (0.90)	0.76 (0.87)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	2.16 (1.47)	2.16 (1.47)	2.72 (1.65)	0.25 (0.50)	0.18 (0.42)	0.22 (0.47)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	8.29 (2.88)	9.42 (3.07)	10.56 (3.25)	0.61 (0.78)	0.67 (0.82)	0.71 (0.84)
Cow's urine 10 per cent + NSKE five per cent	7.08 (2.66)	9.99 (3.16)	11.63 (3.41)	0.53 (0.73)	0.71 (0.84)	0.77 (0.88)
Pongamia oil soap emulsion two per cent	8.76 (2.96)	11.63 (3.41)	14.98 (3.87)	0.64 (0.80)	0.83 (0.91)	1.00 (1.00)
Annona seed extract soap emulsion two per cent	8.76 (2.96)	13.32 (3.65)	19.89 (4.46)	0.69 (0.83)	0.94 (0.97)	1.35 (1.16)
Malathion 0.10 per cent	8.29 (2.88)	8.88 (2.98)	10.43 (3.23)	0.59 (0.77)	0.67 (0.82)	0.71 (0.84)
Control	9.99 (3.16)	18.84 (4.34)	22.75 (4.77)	0.74 (0.86)	1.35 (1.16)	1.51 (1.23)
CD (0.05)	(0.60)	(0.37)	(0.52)	(0.15)	(0.10)	(0.12)

DAT – Days after treatment * Mean of observation on 15 plants
Values given in parenthesis are after $\sqrt{x}$ transformation

control one day after third spray. All the treatments were significantly superior to control in reducing the plant damage. The treatments, cow's urine 10 per cent + NSKE five per cent (7.08), azadirachtin (8.29), malathion 0.10 per cent (8.29), annona seed extract soap emulsion, pongamia oil soap emulsion two per cent and NSKE five per cent (9.42) were on par.

Three days after third spray, also the percentage of plants damaged significantly the least in NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (2.16) compared to all the other treatments. The extent of infestation was higher in the other botanical treatments. The percentage of plants infested was significantly higher in control (18.84) compared to all the treatments.

The treatments, NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray was the best treatment with significantly lesser plant damage (2.72), seven days after third spray. Azadirachtin 0.0025 per cent (10.56), NSKE five per cent (11.09), cow's urine 10 per cent + NSKE five per cent (11.63) also recorded lower plant damage and these treatments were on par with malathion 0.10 per cent (10.42 per cent.). All the treatments except annona seed extract two per cent (19.89) recorded significantly lower plant damage compared to control.

Infestation on leaves

The percentage of leaves infested was very low one, three and seven days after the third spray. The percentage of leaves infested ranged from 0.25 in NC soil application 250 kg ha^{-1} at planting + NC extract 10 per cent spray to 0.74 in control. All the treatments except NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray were on par.

The treatment, NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.18) recorded significantly the lowest leaf damage three days after third spray. This was followed by azadirachtin

0.0025 per cent (0.67), cow's urine 10 per cent + NSKE five per cent (0.71), NSKE five per cent (0.81) and pongamia oil soap emulsion two percent (0.83); these treatments were on par with malathion 0.10 per cent (0.67). Highest leaf damage was observed in control (1.35). The same trend was observed seven days after treatment also.

4.3.5 Mean Effect of Three Sprays of Botanicals on Pests of Amaranthus and their Damage

The effect of all the three sprays of botanicals on the population of pests and their extent of damage on amaranthus are presented in Table 18.

The mean effect of all the three sprays on the population of *P. basalis* revealed that all the botanicals were significantly superior to control in reducing the population of the pest and its damage. The mean population of *P. basalis* per plant was significantly lower in azadirachtin 0.0025 (0.21) treatment compared to the other treatments. This was followed by the treatments cow's urine 10 per cent + NSKE five per cent and NSKE five per cent (0.30). These two treatments were on par. All other treatments recorded higher populations than the above treatments and their effects were also superior to control (0.56).

The mean population of *P. basalis* moths in all the treatments was significantly lower than control (1.02). The treatments, azadirachtin 0.0025 per cent (0.12), cow's urine 10 per cent + NSKE five per cent (0.25), NSKE five per cent (0.28), pongamia oil soap emulsion (0.32) and NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.37) recorded a statistically similar moth population as that of malathion check.

The percentage of plants infested was significantly lower in all the treatments compared to control (29.91). The damage ranged from 15.40 per cent to 22.52 per cent among the treatments. A significantly lower plant damage was observed in azadirachtin 0.0025 per cent (15.40) which

Table 18 Mean effect of three sprays of botanicals on pests of amaranthus and their damage

Treatments	*P. basalis*				*H. recurvalis*				*A. crenulata*			*S. litura*	
	Population of		Percentage infestation on		Population of		Percentage infestation on		Population of plant^{-1}	Percentage infestation on		Percentage infestation on	
	Larvae plant^{-1}	Moths sweep^{-1}	Plants	Leaves	Larvae plant^{-1}	Moths sweep^{-1}	Plants	Leaves		Plants	Leaves	Plants	Leaves
NSKE five per cent	0.30 (1.14)	0.28 (1.13)	18.10 (4.37)	3.08 (2.02)	0.51 (1.23)	0.30 (1.14)	23.40 (4.94)	5.97 (2.64)	0.02 (1.01)	12.91 (3.73)	1.31 (1.52)	10.69 (3.42)	0.74 (1.32)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	0.39 (1.18)	0.37 (1.17)	19.25 (4.50)	3.29 (2.07)	0.69 (1.30)	0.39 (1.18)	26.77 (5.27)	6.78 (2.79)	0.10 (1.05)	15.44 (3.93)	1.50 (1.58)	2.88 (1.97)	0.21 (1.10)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	0.21 (1.10)	0.12 (1.06)	15.40 (4.05)	2.65 (1.91)	0.37 (1.17)	0.12 (1.06)	21.18 (4.71)	5.30 (2.51)	0.02 (1.01)	11.04 (3.47)	1.13 (1.46)	8.86 (3.14)	0.61 (1.27)
Cow's urine 10 per cent + NSKE five per cent	0.30 (1.14)	0.25 (1.12)	16.89 (4.23)	2.76 (1.94)	0.46 (1.21)	0.23 (1.1)	22.91 (4.89)	5.86 (2.62)	0.02 (1.01)	11.74 (3.57)	1.25 (1.50)	9.56 (3.25)	0.66 (1.29)
Pongamia oil soap emulsion two per cent	0.35 (1.16)	0.32 (1.15)	20.16 (4.49)	3.16 (2.04)	0.64 (1.28)	0.39 (1.18)	24.40 (5.04)	6.29 (2.70)	0.08 (1.04)	14.13 (3.89)	1.47 (1.57)	11.96 (3.60)	0.82 (1.35)
Annona seed extract soap emulsion two per cent	0.42 (1.19)	0.51 (1.23)	22.52 (4.85)	3.75 (2.18)	0.79 (1.34)	0.51 (1.23)	29.91 (5.56)	7.64 (2.94)	0.12 (1.06)	16.81 (4.22)	1.72 (1.65)	14.60 (3.95)	1.02 (1.42)
Malathion 0.10 per cent	0.17 (1.08)	0.19 (1.09)	15.48 (4.06)	2.65 (1.91)	0.28 (1.13)	0.19 (1.09)	20.44 (4.63)	5.20 (2.49)	0.04 (1.02)	10.49 (3.39)	1.10 (1.45)	8.30 (3.05)	0.59 (1.26)
Control	0.56 (1.25)	1.02 (1.42)	29.91 (5.56)	4.81 (2.41)	1.07 (1.44)	1.07 (1.44)	36.09 (6.09)	9.24 (3.20)	0.17 (1.08)	23.60 (4.96)	2.35 (1.83)	21.28 (4.72)	1.50 (1.58)
CD (0.05)	(0.01)	(0.11)	(0.29)	(0.10)	(0.01)	(0.01)	(0.30)	(0.13)	(0.01)	(0.33)	(0.30)	(0.30)	(0.10)

DAT – Days after treatment
Values given in parenthesis are after $\sqrt{x+1}$ transformation

was statistically on par with cow's urine 10 per cent + NSKE five per cent (16.69) and malathion check (15.48).

The leaf damage percentage by this pest was also significantly higher in control (4.81 per cent) compared to all the botanical treatments. Azadirachtin 0.0025 per cent recorded a significantly lower leaf damage of 2.65 per cent which was statistically similar to cow's urine 10 per cent + NSKE five per cent (2.76) and malathion check (2.65).

The mean population of *H. recurvalis* larvae was significantly lesser in all the treatments compared to control (1.07). Lowest larval population was observed in azadirachtin 0.0025 per cent (0.37). All the treatments differed significantly among themselves. Malathion 0.10 per cent recorded a mean population of 0.28 per plant.

The mean population of *H. recurvalis* moths per sweep was significantly higher in control (1.07) compared to all the treatments. Among the treatments, azadirachtin 0.0025 per cent (0.12) and cow's urine 10 per cent + NSKE five per cent (0.23) recorded statistically similar population as that of malathion 0.10 per cent (0.19).

The percentage of plants infested by *H. recurvalis* was significantly lower in all the treatments compared to control (36.09). The treatments azadirachtin 0.0025 per cent (21.18), malathion check and other NSKE containing treatments also recorded statistically similar effects as that of azadirachtin.

The percentage leaf damage by *H. recurvalis* was significantly higher in control (9.24). The damage varied from 5.30 to 7.64 per cent in the other treatments. Among the treatments, significantly lower leaf damage was recorded in azadirachtin 0.0025 per cent which was statistically on par with cow's urine 10 per cent + NSKE five per cent and malathion check.

The population of *A. crenulata* per plant was significantly lesser in treatments compared to 'control (0.17). Among the treatments, the population in azadirachtin 0.0025 per cent, NSKE five per cent and cow's urine 10 per cent + NSKE five per cent (0.02) were statistically similar to that of malathion check. These treatments were significantly superior to all the other treatments.

The percentage of plants damaged by *A. crenulata* were significantly higher in control (23.60) compared to the treatments. The damage ranged from 11.04 to 16.81 in the treatments. The treatments. azadirachtin 0.0025 per cent was statistically on par with cow's urine 10 per cent + NSKE five per cent (11.74) and NSKE five per cent (12.91) and also with the chemical check. The percentage leaf damage was also significantly higher in control (2.35) compared to the treatments. Among the treatments, the leaf damage in azadirachtin 0.0025 per cent (1.13), cow's urine 10 per cent + NSKE five per cent (1.25) and NSKE five per cent (1.31) were statistically similar to malathion check.

The percentage of plants damaged by *S. litura* was significantly lower in all the treatments compared to control (21.28 per cent). Among the treatments, NC soil application @ 250 kg ha^{-1} + NCE 10 per cent spray recorded significantly lower plant damage (2.88 per cent) compared to the other treatments. NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (0.21) was significantly superior to the other treatments in reducing the damage to leaves. All the other treatments except annona seed extract two per cent were statistically on par. All the treatments were significantly superior to control.

4.3.6 Population of Spider Predators

The results are presented in Table.19

Table 19 Population of spider predators observed at different intervals after spray

Treatments	First spray (DAT)			Second spray (DAT)			Third spray (DAT)		
	1	3	7	1	3	7	1	3	7
NSKE five per cent	1.21 (1.10)	1.25 (1.12)	1.25 (1.12)	1.15 (1.07)	1.23 (1.11)	1.23 (1.11)	1.21 (1.10)	1.15 (1.07)	1.23 (1.11)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	1.23 (1.11)	1.23 (1.11)	1.19 (1.09)	1.15 (1.07)	1.21 (1.10)	1.19 (1.09)	1.23 (1.11)	1.15 (1.07)	1.19 (1.09)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	1.23 (1.11)	1.23 (1.11)	1.17 (1.08)	1.15 (1.07)	1.23 (1.11)	1.15 (1.07)	1.23 (1.11)	1.21 (1.10)	1.17 (1.08)
Cow's urine 10 per cent + NSKE five per cent	1.17 (1.08)	1.23 (1.11)	1.17 (1.08)	1.15 (1.07)	1.17 (1.08)	1.21 (1.10)	1.17 (1.08)	1.15 (1.07)	1.23 (1.11)
Pongamia oil soap emulsion two per cent	1.21 (1.10)	1.19 (1.09)	1.19 (1.09)	1.15 (1.07)	1.21 (1.10)	1.28 (1.13)	1.21 (1.10)	1.15 (1.07)	1.15 (1.07)
Annona seed extract soap emulsion two per cent	1.21 (1.10)	1.21 (1.10)	1.19 (1.09)	1.17 (1.08)	1.21 (1.10)	1.15 (1.07)	1.25 (1.12)	1.23 (1.11)	1.10 (1.05)
Malathion 0.10 per cent	0.56 (0.75)	0.71 (0.84)	0.59 (0.77)	0.52 (0.72)	0.44 (0.66)	0.44 (0.66)	0.46 (0.68)	0.44 (0.66)	0.56 (0.75)
Control	0.90 (0.95)	1.30 (1.14)	1.15 (1.07)	1.42 (1.19)	1.23 (1.11)	1.15 (1.07)	1.23 (1.11)	1.28 (1.13)	1.30 (1.14)
CD (0.05)	(0.22)	(0.15)	NS	(0.18)	(0.18)	(0.18)	(0.14)	(0.18)	(0.18)

DAT – Days after treatment * Mean of observation on 15 plants
Values given in parenthesis are after $\sqrt{x+1}$ transformation

After first spray

The mean population of spiders was significantly higher in control and botanical treatment plots compared to malathion treated plots, one, three and seven days after first spray. One day after the first spray, the highest population of spiders was observed in azadirachtin 0.0025 per cent (1.23), NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray (1.23), NSKE five per cent (1.21), pongamia oil soap emulsion two per cent (1.21) and annona seed extract two per cent. The mean population of spiders was significantly the lowest in malathion 0.10 per cent (0.56).

Three days after the first spray, highest spider population was observed in control (1.30) and NSKE five per cent (1.25). All the treatments recorded a significantly lower population of spiders compared to malathion 0.10 per cent.

Seven days after treatment, the spider population did not vary significantly among the treatments, eventhough malathion 0.10 per cent (0.59) recorded the lowest mean population.

After second spray

One, three and seven days after the second spray, the population of spiders was significantly lower in insecticide (malathion) treated plots compared to control and botanical treatments. The mean population in control and malathion 0.10 per cent were 1.42 and 0.52 respectively, at one day after second spray. All the treatments were on par with control.

The population of spiders was 1.23 in the three treatments *viz.*, NSKE five per cent, azadirachtin 0.0025 per cent and in control three days after second spray. All the botanicals recorded a significantly higher population compared to malathion 0.10 per cent (0.44).

Seven days after the second spray also, the spider population in all the botanical treatments were on par with control (1.23) and significantly lower population was recorded in malathion 0.10 per cent (0.44).

Table 20 Percentage disease index (PDI) at different intervals after spray

Treatments	First spray		Second spray		Third spray	
	Before treatment	7 DAT	Before treatment	7 DAT	Before treatment	7 DAT
NSKE five per cent	24.40 (4.94)	24.40 (4.94)	25.00 (5.00)	25.40 (5.04)	25.4 (5.04)	25.30 (5.03)
NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	24.01 (4.90)	24.31 (4.92)	24.01 (4.90)	24.50 (4.95)	26.94 (5.19)	27.78 (5.27)
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	25.00 (5.00)	25.3 (5.03)	25.30 (5.03)	25.40 (5.04)	25.71 (5.07)	26.11 (5.11)
Cow's urine 10 per cent + NSKE five per cent	26.21 (5.12)	26.11 (5.11)	26.11 (5.11)	25.20 (5.02)	24.4 (4.94)	24.50 (4.95)
Pongamia oil soap emulsion two per cent	31.92 (5.65)	25.50 (5.05)	25.71 (5.07)	25.60 (5.06)	24.90 (4.99)	24.90 (4.99)
Annona seed extract soap emulsion two per cent	24.30 (4.93)	24.50 (4.95)	24.30 (4.93)	25.40 (5.04)	25.80 (5.08)	25.81 (5.08)
Malathion 0.10 per cent	24.40 (4.94)	24.60 (4.96)	25.10 (5.01)	24.80 (4.98)	25.20 (5.02)	25.40 (5.04)
Control	25.20 (5.02)	25.30 (5.03)	25.10 (5.01)	25.91 (5.09)	26.42 (5.14)	26.42 (5.14)
CD (0.05)	NS	NS	NS	NS	NS	NS

DAT – Days after treatment * Mean of observation on 15 plants
Values given in parenthesis are after $\sqrt{x+1}$ transformation

After third spray

One day after third spray, the spider population in all the botanical treatments were on par with control (1.23). Significantly lower mean population was recorded in malathion 0.10 per cent (0.46). The same trend was observed three and seven days after application of treatments.

The observations on the effect of treatments on spider fauna indicated that botanical pesticides were benign to the spiders compared to chemical insecticide *viz.*, malathion.

4.3.7 Disease Intensity at Different Intervals Before and After Spraying

The effect of different treatments on leaf blight disease caused by *R. solani* is presented in Table 20.

The percentage disease index (PDI) did not have any significant difference among treatments. The PDI in different treatments before spray and seven days after each spray were similar and there was no significant variation among treatments.

4.3.8 Leaf Yield of Amaranthus and Benefit: Cost Ratio of the Treatments in Field Experiment

The results are presented in Table 21.

All the treatments recorded significantly higher yield compared to control (3.53 t ha^{-1}). The highest yield of amaranthus leaves was recorded in azadirachtin 0.0025 per cent (8.90 t ha^{-1}) treated plots and the yield was statistically similar to that of malathion 0.10 per cent treated plots (9.22 t ha^{-1}). This was followed by cow's urine 10 per cent + NSKE five per cent (7.35), NSKE five per cent (7.27) and pongamia oil soap emulsion two per cent (6.85), these treatments were on par. The treatment, NC soil application @ 250 kg ha^{-1} at planting + NC extract 10 per cent spray (6.27) was on par with pongamia oil soap emulsion two per cent.

Table 21 Yield and benefit : cost ratio obtained in various treatments in field experiment

Treatments	Yield (t ha^{-1})	B : C ratio
Neem seed kernel extract (NSKE) five per cent	7.27	2.01
Neem cake soil application @ 250 kg ha^{-1} at planting + neem cake extract 10 per cent spray	6.27	1.13
Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	8.90	3.20
Cow's urine 10 per cent + NSKE five per cent	7.35	2.12
Pongamia oil soap emulsion two per cent	6.85	1.90
Annona seed extract soap emulsion two per cent	5.30	1.00
Malathion 0.1 per cent	9.22	1.61
Control	3.53	
CD (0.05)	0.80	

annona seed extract two per cent (5.30) recorded the lowest yield among the botanicals.

The benefit: cost ratio was the highest in azadirachtin 0.0025 per cent treated plots (3.20) followed by cow's urine 10 per cent + NSKE five per cent (2.12) and NSKE five per cent (2.01). The B:C ratio ranged from 1.00 to 1.90 among the other treatments.

Discussion

5. DISCUSSION

Vegetables occupy an exalted position in the average Indian diet. The cultivation of vegetables including leafy species is fraught with the dangers of infestation by pests. Crops and pests co-evolve and pests quickly adapt to changing cropping patterns. Insect pests infest leafy vegetable crops like amaranthus which adversely affect the yield. Plant protection especially in commercial olericulture is largely chemical pesticide based. The use of short duration vegetables as salads or as partially cooked food aggravates the hazards of pesticide residues. The indiscriminate use of chemicals also causes a host of other problems like pest resurgence, mortality of natural enemies besides environmental pollution. The limitations of chemical control calls for the imperative exploration of other viable methods of pest control. One approach is the use of phytochemicals or botanicals like neem in vegetable plant protection which are benign to the agroecosystems. Amaranthus is a short duration crop raised throughout the year in Kerala and is infested by pests like leaf webbers. The antifeedant and other effects of neem can be utilized successfully to ward off the pests whenever abundant.

5.1 SEASONAL INCIDENCE OF PESTS, NATURAL ENEMIES AND DISEASE OF AMARANTHUS

The population of important pests and the damage caused by the pests and disease in amaranthus were assessed at fortnightly intervals for an year from April 2004 to April 2005 in the Instructional Farm, College of Agriculture, Vellayani.

The seasonal occurrence studies revealed that the pests *P. basalis*. *H. recurvalis* and *A. crenulata* and leaf blight disease was present throughout the year in varying intensities. The infestation of *S. litura* was observed at a lesser degree compared to the other pests. Among the

different pests observed, the leaf webbers *P. basalis* and *H. recurvalis* were the major pests of amaranthus. The larvae of both these are almost similar in appearance. However the feeding habits of the two species were different. The *P. basalis* larvae feed on new flushes and cause crinkling of the new leaves, arrests the apical dominance and thus the growth of the crop is reduced. The larvae of *H. recurvalis* feed on the underside of mature leaves and skeletonise them.

From the results of para.4.1.1.1, it was inferred that the population and extent of damage by the pest was the highest during summer months (April and May 2004, March and April 2005), which were characterised by high temperature, low relative humidity and low rainfall. Since summer season is preferred for the cultivation of this crop in Kerala, infestation by this pest causes considerable yield reduction and reduced market value for the produce.

However the lowest mean population and damage by this pest was recorded during the months of July 2004 and December 2004. These months were characterized by high rainfall and low temperature respectively. *P. basalis* moths lay eggs on the upper surface of leaves. Washing off of these eggs during heavy rains might have been a major factor for lower incidence of this pest during the rainy months (Fig. 1).

The population and extent of damage by *P. basalis* showed significant positive correlation with maximum and minimum temperature and negative correlation with relative humidity. The mean population of *P. basalis* moths was negatively correlated with rainfall and number of rainy days.

The mean population of *H. recurvalis* larvae was the highest during the second fortnight of June 2004. This period coincided with low temperature and high relative humidity. The lowest larval population was observed during second fortnight of September 2004 (0.17).

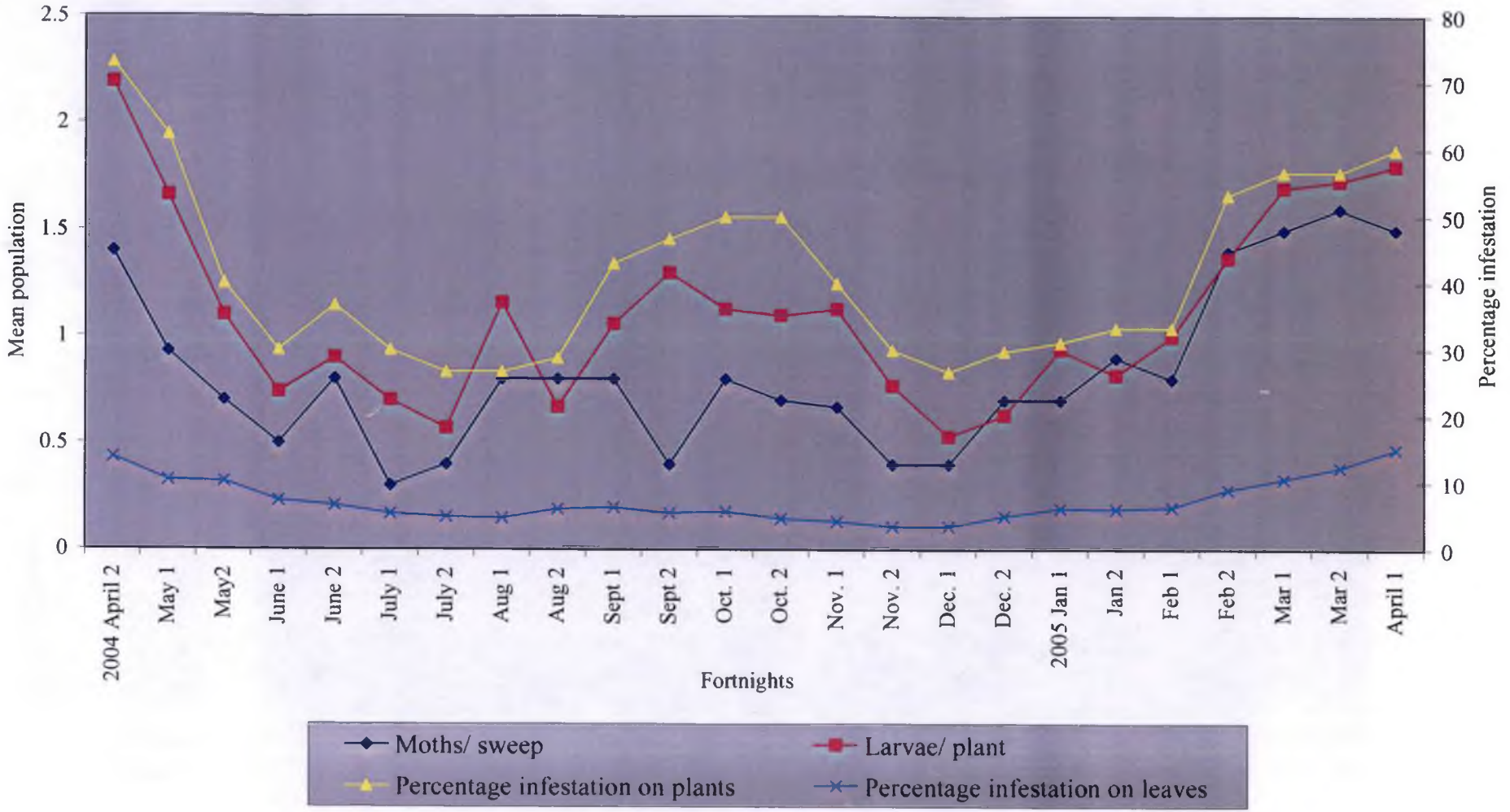


Fig. 1. Population and damage of leaf webber *P. basalis* from April 2004 to April 2005

The highest mean population of *H. recurvalis* moths was observed during the second fortnight of November 2004 and lowest during second fortnight of April 2004 and first and second fortnight of September 2004 . Similar observations were made by Bhattacherjee and Menon (1964) who reported that the moths were found in large numbers from July to October. As the severity of winter increased, their number gradually dwindled and they became very scarce in January and February.

The percentage of plants infested by *H. recurvalis* was the highest during second fortnight of November 2004. The highest percentage of leaves damaged was observed during the second fortnight of November 2004. A higher population of larvae was counted during these periods. The lowest mean population of the larvae was recorded during the second fortnight of September 2004. The lowest percentage of plant and leaf damage was also recorded during this period. This reduction in pest population and damage would have resulted due to the washing off of eggs and early instar larvae by the heavy rain (141 mm in seven days) received during the first fortnight of September 2004 (Fig. 2).

The mean population and extent of damage by *H. recurvalis* was positively correlated with minimum temperature and relative humidity and negatively correlated with maximum temperature, rainfall and number of rainy days.

The green grasshopper *A. crenulata* was observed in the field throughout the year. Highest population per plant was observed during the first fortnight of October 2004. The highest percentage of infestation on plants and leaves were recorded during the second fortnight of November 2004. However studies conducted by Reddy and Kumar (2004) on tomato in Karnataka revealed that this grasshopper was most active from July to September during which they caused the maximum damage. The lowest mean population of the grasshopper was observed during the second fortnight of April 2004 and first fortnight of July 2004. The lowest

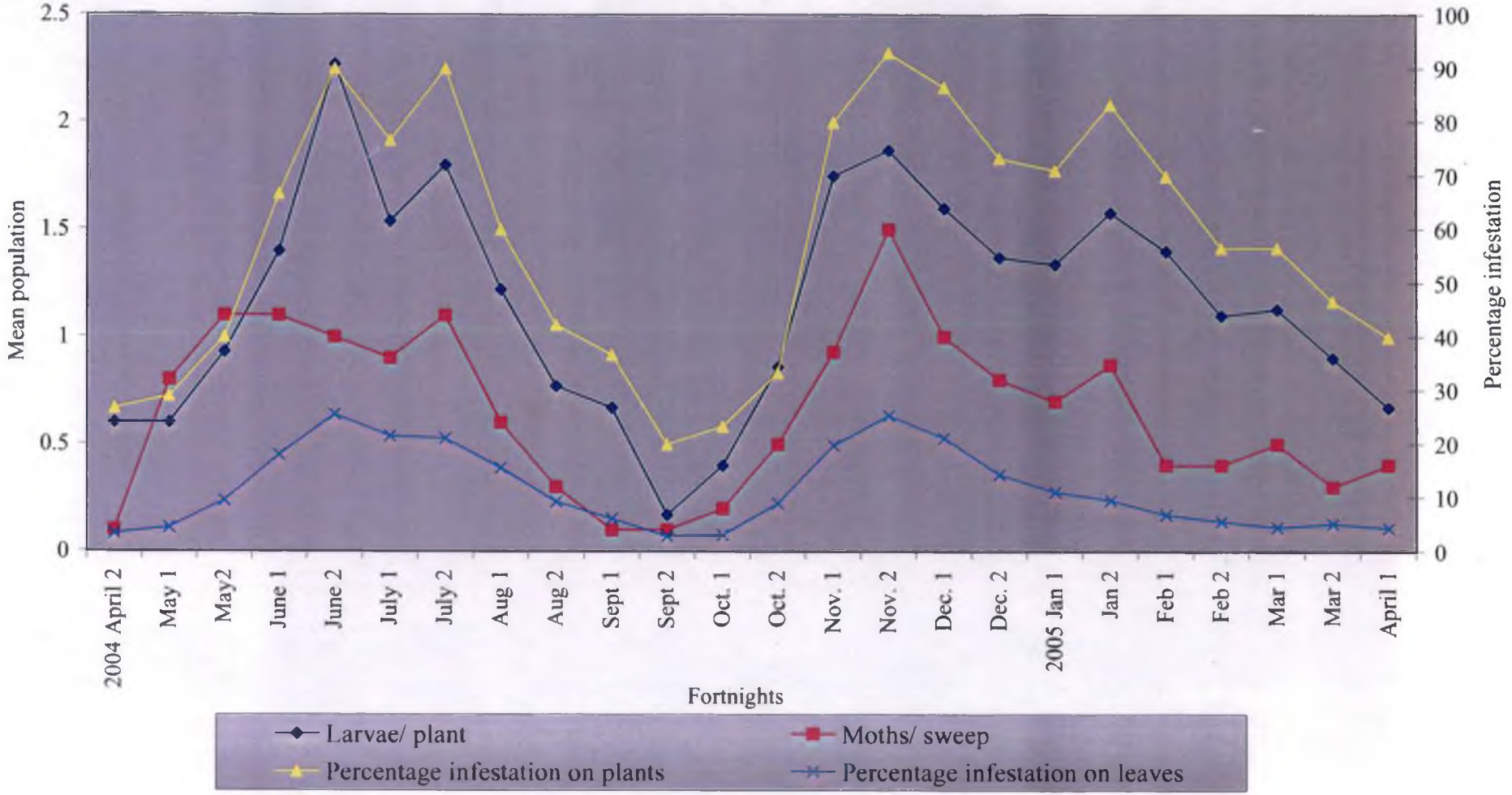


Fig. 2. Population and damage of leaf webber *H. recurvalis* from April 2004 to April 2005

percentage of plant damage was observed during the two fortnights of July 2004 and leaf damage was recorded during second fortnight of July 2004. These periods were characterized by low temperature, high relative humidity and high rainfall. This observation was in agreement with the findings of Nair (1998) and Reddy and Kumar (2004) who reported that the population of the green grasshopper reduced as the temperature fell. The population of green grasshopper and its extent of damage showed significant negative correlation with minimum temperature.

The damage by tobacco caterpillar *S. litura* was observed in the field throughout the year. The percentage of plants infested by this pest was maximum during the second fortnight of July 2004 and the percentage of leaves damaged was maximum during the first fortnight of July 2004. This concurred with the observations of Reddy and Kumar (2004) who recorded the highest population of *S. litura* during the months of May and July in Karnataka. The lowest percentage of leaves damaged by *S. litura* was observed during the first fortnight of September 2004. Similar observations were recorded by Butani (1977) and Reddy and Kumar (2004).

The percentage of plants damaged and leaves damaged by *S. litura* was positively correlated with relative humidity, rainfall and number of rainy days and negatively correlated with maximum temperature. Similar findings were reported by Palande *et al.* (2004).

The percentage of plants damaged by American serpentine leaf miner (ASLM) *L. trifolii* was high during the first fortnight of May 2004 and first fortnight of March 2005. The highest percentage of leaf damage was also recorded during this period. The infestation by ASLM was not observed during the months of July, October and November of 2004. Similar observations were made by Jayakumar and Uthamasamy (2000). Reji (2002) and Reddy and Kumar (2004).The percentage of leaf damage by ASLM was positively correlated with maximum and minimum

temperature and negatively correlated with relative humidity. The peak incidence of this pest was found during May 2004 and March 2005 (summer). The present observations were in line with the findings of Reddy and Kumar (2004).

The aphid *A. craccivora* population was found during the months of May, October and November 2004 and April 2005. However the aphid population per plant was considerably low.

5.1.1 Incidence of Natural Enemies

A braconid parasitoid *A. opacus* was found parasitising the early instars of *H. recurvalis* larvae. Invariably a single cocoon was found emerging from each infested larvae which indicated that it was a solitary endoparasite. Earlier, 11.43 per cent natural parasitisation of *H. recurvalis* larvae by *A. delhiensis* was reported by Bhattacherjee and Menon (1964). The mean population of parasitoid pupae per plant was high when the population of larvae of the pest were more. Two hyper parasitoids *viz.*, *Tetrastichus* sp. and *Telenomus* sp. were found parasitising the pupae of *A. opacus*. This finding was in line with that of Krishnamoorthy (2000) who reported that *Apanteles* sp. produced 60 per cent parasitism on leaf webber, *H. recurvalis*. However the effectiveness of many parasites was drastically reduced by the attack of eight different species of hyper-parasitoids. The count of parasitoid pupae of leaf webber per plant was positively correlated with relative humidity and negatively correlated with the other weather parameters.

The spider predators were present in the field throughout the year and there were no distinct seasonal variation in their population. The population of spiders in second fortnight of July 2004 was very low. This period was characterized by heavy rain (168.6 mm in 12 days).

The most abundant spider was *Oxyopes* sp. Debnath and Borah (2002) reported that *Oxyopes shweta* Tikader was an important natural enemy of

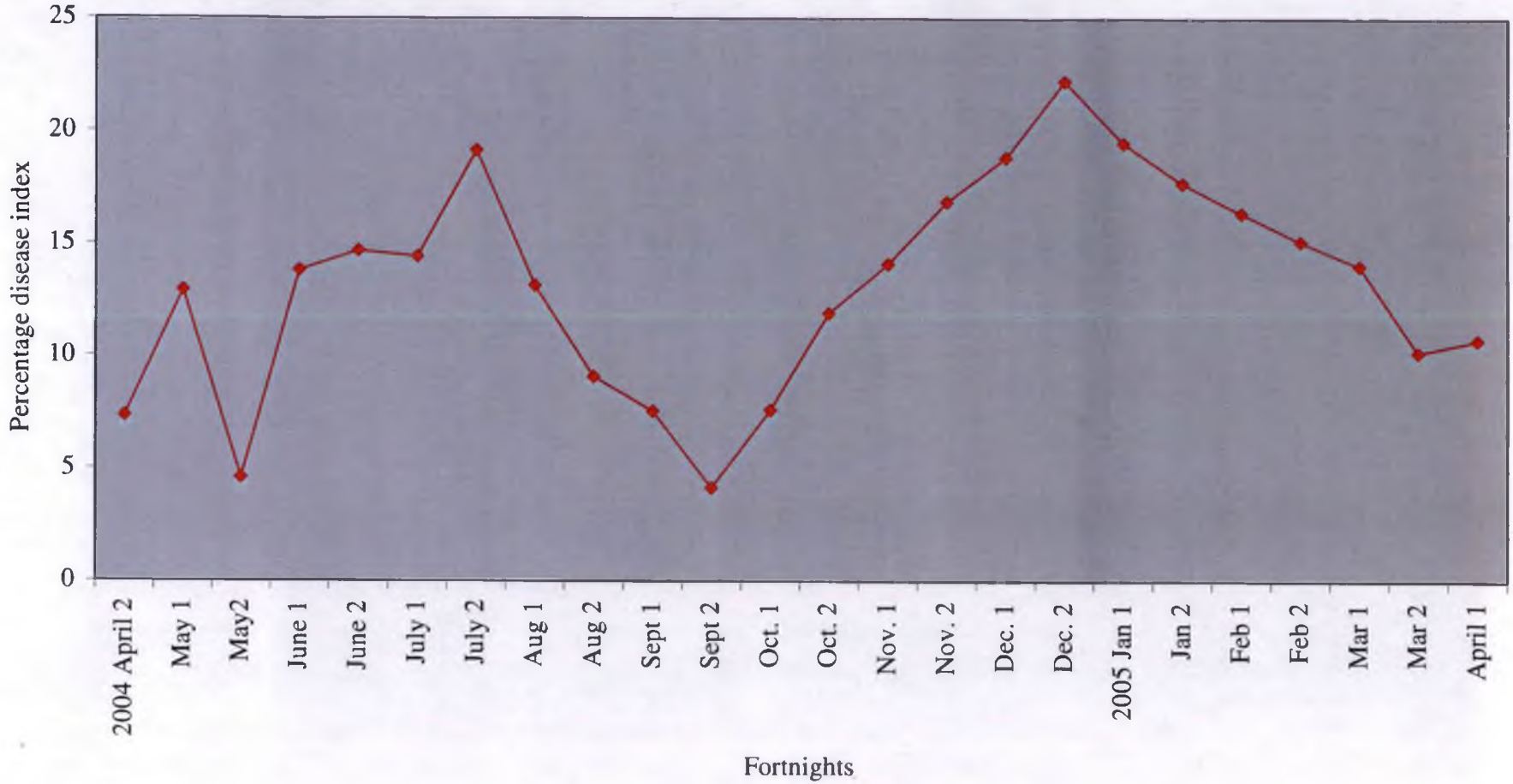


Fig. 3. Percentage disease index (PDI) of leaf blight from April 2004 to April 2005

of potato tuber moth. The occurrence of spiders *Oxyopes* sp. and *Tetragnatha* sp. in bhindi fields was reported by Thamilvel (2004).

The population of spider predators was significantly and positively correlated with maximum temperature and negatively correlated with minimum temperature, relative humidity and number of rainy days. However Nandakumar (1999) revealed that the population of spiders was negatively correlated with maximum and minimum temperature and positively correlated with rainfall and number of rainy days. The higher population of spiders coincided with the population of the prey *P. basalis* larvae during the summer months. The activity of spiders was limited during the rainy season.

5.1.2 Incidence of Leaf Blight Disease

Leaf blight caused by *R solani* was observed in the field throughout the year. The percentage disease index (PDI) was maximum during the second fortnight of December 2004. This period was characterized by high relative humidity which was congenial for spore germination and aerial spread of the fungus. The lowest PDI was observed during the second fortnight of September 2004 (Fig.3).

The PDI showed significant positive correlation with relative humidity and significant negative correlation with minimum temperature and number of rainy days. The conidiospores of *R. solani* spread through air. Continuous rainfall hampered the aerial movement of spores which resulted in reduced incidence of disease during periods of heavy rainfall.

5.2 ANTIFEDANT EFFECT OF BOTANICALS AGAINST IMPORTANT PESTS OF AMARANTHUS

The antifeedant study (Para 4.2. of results) against the leaf webber *P. basalis* revealed that azadirachtin 0.0025 per cent was the best botanical treatment. Twenty four hours after feeding, azadirachtin 0.0025 per cent was the best antifeedant and was significantly superior to the

other treatments. This was followed by cow's urine 10 per cent + NSKE five per cent and NSKE five per cent. Forty eight hours after feeding also, azadirachtin 0.0025 per cent was the best treatment which provided 75.50 per cent protection against the pest. Thus neem formulations (azadirachtin 0.0025 per cent and NSKE five per cent) proved to be the best treatments against *P. basalis* larvae. The antifeedant effect of four per cent of neem leaf extract against *P. basalis* has been reported by Srinath (1990).

The study on antifeedant effect of botanicals against the leaf webber *H. recurvalis* revealed that NSKE five per cent and azadirachtin 0.0025 per cent were the most effective treatments. The treatment NSKE five per cent afforded 86.85 per cent protection against the pest. This was followed by azdirachtin treatment which provided 84.21 per cent protection. Forty eight hours after feeding, azadirachtin treated leaves recorded the maximum protection (67.19 per cent) against the pest. This treatment was significantly superior to all the other botanicals. Similar observations were made by Singh and Sharma (1987) using azadirachtin at nine ml a.i. per litre on *P. xylostella* of cabbage.

Twenty four hours after feeding, azadirachtin 0.0025 per cent provided cent per cent protection against *A. crenulata*. The grasshopper did not feed on the azadirachtin treated leaves. This was followed by treatments cow's urine 10 per cent +NSKE five per cent and NSKE five per cent. Forty eight hours after feeding also, azadirachtin 0.0025 per cent was the best botanical treatment which provided 94.90 per cent protection. This endorsed the antifeedant action of neem against the grasshopper. Similar observations were made by Narayanaswamy and Ramegowde (1999). Leaf area protection of 72.86 to 93.84 per cent was achieved against mulberry wingless grasshopper *Neorthacris acuticeps nilgirensis* Uvarov by using Neemark (azadirachtin 0.03 % EC) at 0.50 and 3.00 per cent concentrations.

The study on antifeedant effect of botanicals against the tobacco caterpillar *S. litura* revealed that azadirachtin 0.0025 per cent and NSKE five per cent were the best botanical treatments. Twenty four hour after feeding azadirachtin treatment provided 87.80 per cent protection. This was followed by NSKE five per cent which provided 67.60 per cent leaf protection. Maximum leaf consumption was recorded in control (1.37 g). The antifeedant and repellent effect of neem kernel extract on tobacco caterpillar was reported earlier by Joshi and Ramaprasad (1975) and Rao *et al.* (1996). Forty eight hours after feeding, azadirachtin 0.0025 per cent was the best treatment which recorded 89.67 per cent protection against the larvae. Chari *et al.* (1996) reported that neem formulations (Repelin, Neemgold, Navneem) containing azadirachtin above 0.003 per cent concentration were highly effective in protecting the tobacco foliage from *S. litura* damage.

The studies on the antifeedant effect of botanicals indicated that azadirachtin 0.0025 per cent was the most effective antifeedant against the major pests of amaranthus *viz.*, leaf webbers, green grasshopper and tobacco caterpillar followed by NSKE five per cent and cow's urine 10 per cent + NSKE five per cent treatments. Similar findings were obtained by Leena (2001) who observed that neem pesticides *viz.*, Econeem and NeemAzal were effective in controlling leaf webbers of amaranthus. Reghunath *et al.* (2001) also advocated the application of a combination of cow's urine 10 per cent + 10 g bird chilli per litre of water as a non-chemical measure against leaf webbers of amaranthus.

5.3 FIELD EVALUATION OF DIFFERENT BOTANICALS FOR THE MANAGEMENT OF PESTS OF AMARANTHUS

A field experiment was conducted in the Instructional Farm, College of Agriculture, Vellayani to evaluate the efficacy of different botanicals and one chemical pesticide as check against the major pests of amaranthus. Three sprays were given to the crop starting from two weeks

after transplanting. The sprays were given at fortnightly intervals. The observations on pests, their extent of damage and natural enemies of pests were recorded one, three and seven days after each spraying. The incidence of leaf blight disease as well as the yield was assessed.

5.3.1 Population of Leaf Webber *P. basalis* and its Extent of Damage on Amaranthus Treated with Different Botanicals

The effect of different treatments on population of *P. basalis* and its extent of damage indicated that all the treatments were effective in deterring the pest compared to control. Perusal of the effect of the three sprays of the treatments (results of para.4.3.5 and Fig.4) indicated that azadirachtin 0.0025 per cent was the best botanical treatment in containing the population of *P. basalis* larvae. This was followed by cow's urine 10 per cent + NSKE five per cent and NSKE five per cent.

The population of *P. basalis* moths was significantly lesser in all the treatments compared to control. The treatments, azadirachtin 0.0025 per cent, cow's urine 10 per cent + NSKE five per cent, NSKE five per cent, Pongamia oil soap emulsion two per cent and NC soil application @ 250 $kg.ha^{-1}$ at planting + NCE 10 per cent spray showed statistically similar effect as malathion check. When the overall impact of three sprays of treatments on the population of moths was assessed, the best treatment turned out to be azadirachtin 0.0025 per cent. The repellent and ovipositional deterrent effect of azadirachtin had limited the population of moths.

The percentage of plants and leaves infested was significantly lesser in all the treatments compared to control (Fig.5). The overall effect of the three sprays on the level of plant and leaf damage was assessed. The antifeedant effect of neem pesticides had plausibly reduced the extent of damage by *P. basalis*. Similar observations were made by Chakraborti (2001) who reported that azadirachtin at nine ml a.i per litre was effective against caterpillars of diamond back moth in cabbage. In the present

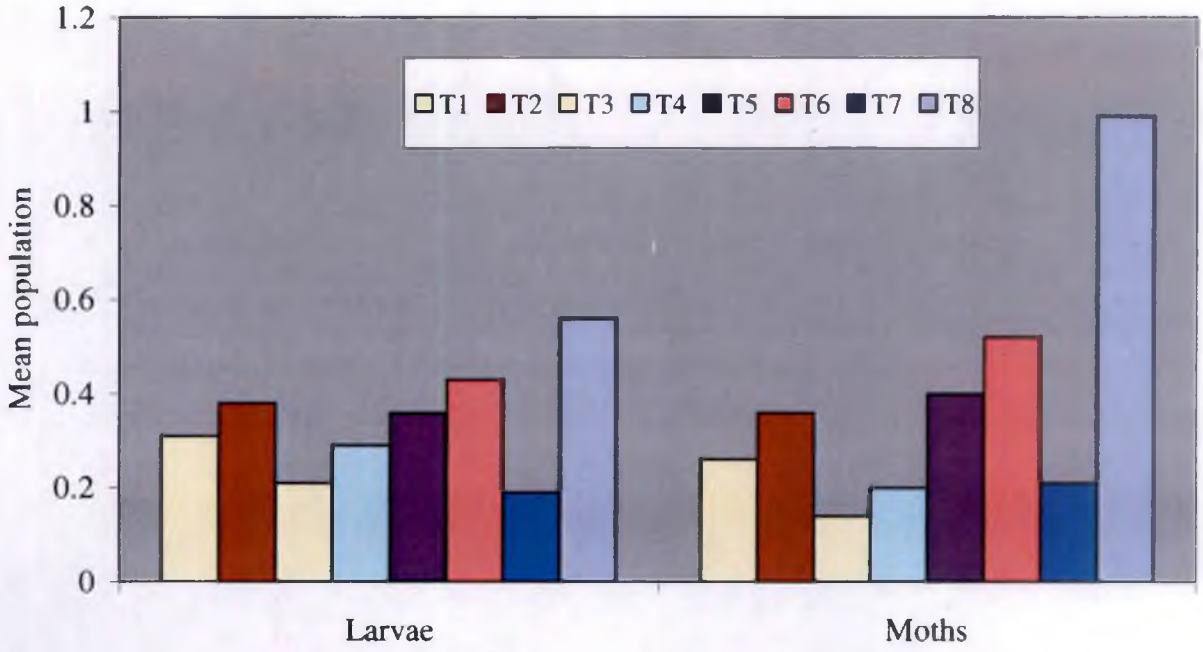


Fig. 4. Mean effect of three sprays on population of *P. basalis*

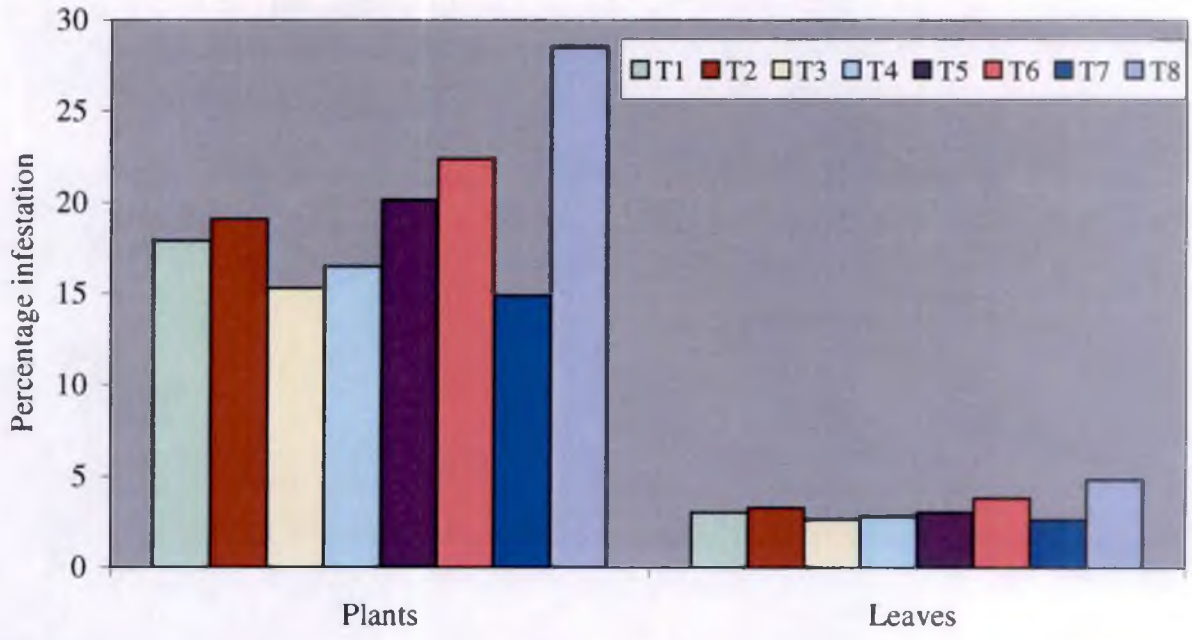


Fig. 5. Mean effect of three sprays on extent of damage by*P. basalis*

T_1 NSKE 5 per cent
T_2 NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray
T_3 Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)
T_4 Cow's urine 10 per cent + NSKE 5 per cent
T_5 Pongamia oil soap emulsion 2 per cent
T_6 Annona seed extract soap emulsion 2 per cent
T_7 Malathion 0.10 per cent
T_8 Control

study, cow's urine 10 per cent + NSKE five per cent was also effective in reducing the extent of damage to plant and leaf. This observation was in tune with that of Purwar and Yadav (2002) who reported that soybean treated with 20 per cent cow's urine was free from infestation by leaf folders *Nacoleia* spp., three and seven days after treatment.

Thus it could be concluded that azadirachtin containing formulations were effective botanical treatments in controlling *P. basalis*.

5.3.2 Population of Leaf Webber *H. recurvalis* and Extent of Damage on Amaranthus Treated with Different Botanicals

All the treatments were significantly superior to control in reducing the population of *H. recurvalis* larvae (results of para.4.3.5). Among the treatments, azadirachtin 0.0025 per cent was the best. The effectiveness of azadirachtin on pigeon pea pod borer *H. armigera* was reported earlier by Chakraborthi and Chatterjee (1999). However malathion 0.10 per cent was significantly superior to all the treatments. The effectiveness of malathion against this pest was reported earlier by Bhattacherjee and Menon (1964) and Grubben (1976).

The mean population of *H. recurvalis* adults per sweep was the lowest in azadirachtin 0.0025 per cent three and seven days after first spray, one and seven days after second spray and three and seven days after third spray (Fig.6). One day after third spray, the adult population per sweep was the lowest in treatments, NSKE five per cent and cow's urine 10 per cent + NSKE five per cent. The analysis of the mean population of *H. recurvalis* moths after three sprays of the different treatments indicated that the treatments azadirachtin 0.0025 per cent and cow's urine 10 per cent + NSKE per cent were statistically similar to that of malathion check. The repellent and ovipositional deterrent effects of neem had acted against *H. recurvalis*. Similar effect of NSKE on *P. brassicae* of cabbage was reported by Singh and Sharma (1987).

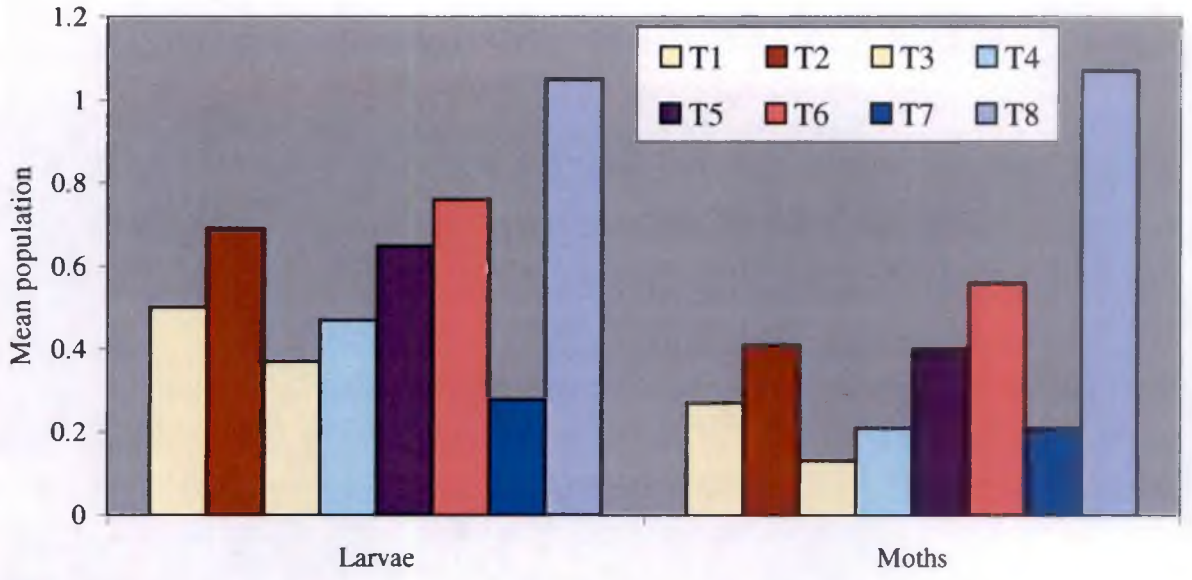


Fig. 6. Mean effect of three sprays on population of *H. recurvalis*

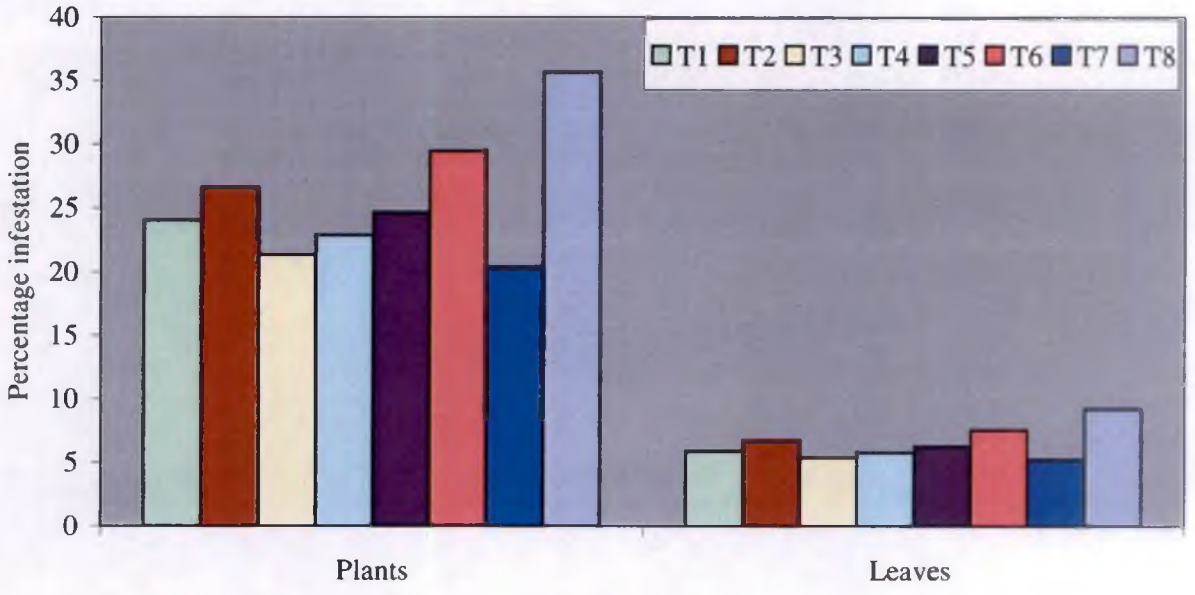


Fig. 7. Mean effect of three sprays on extent of damage by*H. recurvalis*

T_1	NSKE 5 per cent
T_2	NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray
T_3	Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)
T_4	Cow's urine 10 per cent + NSKE 5 per cent
T_5	Pongamia oil soap emulsion 2 per cent
T_6	Annona seed extract soap emulsion 2 per cent
T_7	Malathion 0.10 per cent
T_8	Control

Azadirachtin 0.0025 per cent was the best botanical treatment in reducing the percentage of plant and leaf infestation (Fig.7). This treatment was statistically similar to that of malathion 0.10 per cent. This was followed by cow's urine 10 per cent + NSKE five per cent treatment.

It was obvious that the antifeedant, repellent and oviposition deterrent effects of the neem treatments came into play against the leaf webbers. Thus it could be concluded indubitably that botanicals *viz*..azadirachtin 0.0025 per cent and cow's urine 10 per cent + NSKE five per cent were effective against the leaf webbers. The findings were in unison with those of Leena (2001) and Reghunath *et al.* (2001).

5.3.3 Population of Grasshoppers *A. crenulata* and its Extent of Damage on Amaranthus Treated with Different Botanicals

All the treatments were effective in reducing the population and damage of green grasshopper *A. crenulata* in amaranthus compared to control (4.3.5 of results).

The population of grasshopper per plant was low in treatments. cow's urine 10 per cent + NSKE five per cent, NSKE five per cent. azadirachtin 0.0025 per cent and on par with malathion 0.10 per cent at different intervals after spray. This underscored the strong antifeedant and repellent action of neem against pests like grasshoppers. Pradhan *et al.* (1963) reported that the locust *Schistocerca gregaria* Forskl. Swarms could not feed on crops sprayed with 0.10 per cent neem seed kernel suspension.

Analysis of the damage by the grasshopper after all the three sprays revealed that the treatments azadirachtin 0.0025 per cent, cow's urine 10 per cent + NSKE five per cent and NSKE five per cent were statistically similar to malathion check. Similar observations were made by Ascher *et al.* (1989) who reported that 10^{-4} per cent azadirachtin exhibited 100 per cent phagodeterrence against fourth instar nymphs of the acridid

Euprepocnemis sp. on broadbean. Srinath (1990) found that four per cent neem leaf extract protected the amaranthus crop from *A. crenulata* for 14 days after spraying and reduced the damage by this pest.

5.3.4 Extent of Damage Caused by Tobacco Caterpillar *S. litura* on Amaranthus Treated with Different Botanicals

The percentage of plants and leaves damaged was significantly lesser in all the treatments compared to control.

Among the different treatments, NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray recorded the least damage at different intervals after spraying. The pooled data on extent of damage by the pest (4.3.5 of results) revealed that NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray was the best treatment against *S. litura* in amaranthus. When neem cake was applied in the soil and raked around the base of amaranthus plants, the volatiles emanating from neem cake deterred the *S. litura* larvae from infesting the plants. Krishnamoorthy *et al.* (2001) reported that neem cake soil application was effective in reducing the attack of *H. armigera* in tomato.

Assessment of the impact of three sprays of the different treatments on the four major pests of amaranthus revealed that most effective treatment was azadirachtin 0.0025 per cent (NeemAzal 1% TS@ 2.5 ml per litre). The second and third best treatments were cow's urine 10 per cent + NSKE five per cent and NSKE five per cent respectively.

5.3.5 Mean Population of Spider Predators in Amaranthus Plots Treated with Different Botanicals

The mean population of spider predators per plant was significantly the lowest in malathion 0.10 per cent treated plots at different intervals after spraying whereas the spider population among the botanical treated plots and control was on par. In a few instances, botanical treated plots recorded higher mean population of spiders compared to control. These

findings validated the statement that botanicals were benign to natural enemies like spiders. Similar observations were made by Nandakumar and Saradamma (1996) and Thamilvel (2004).

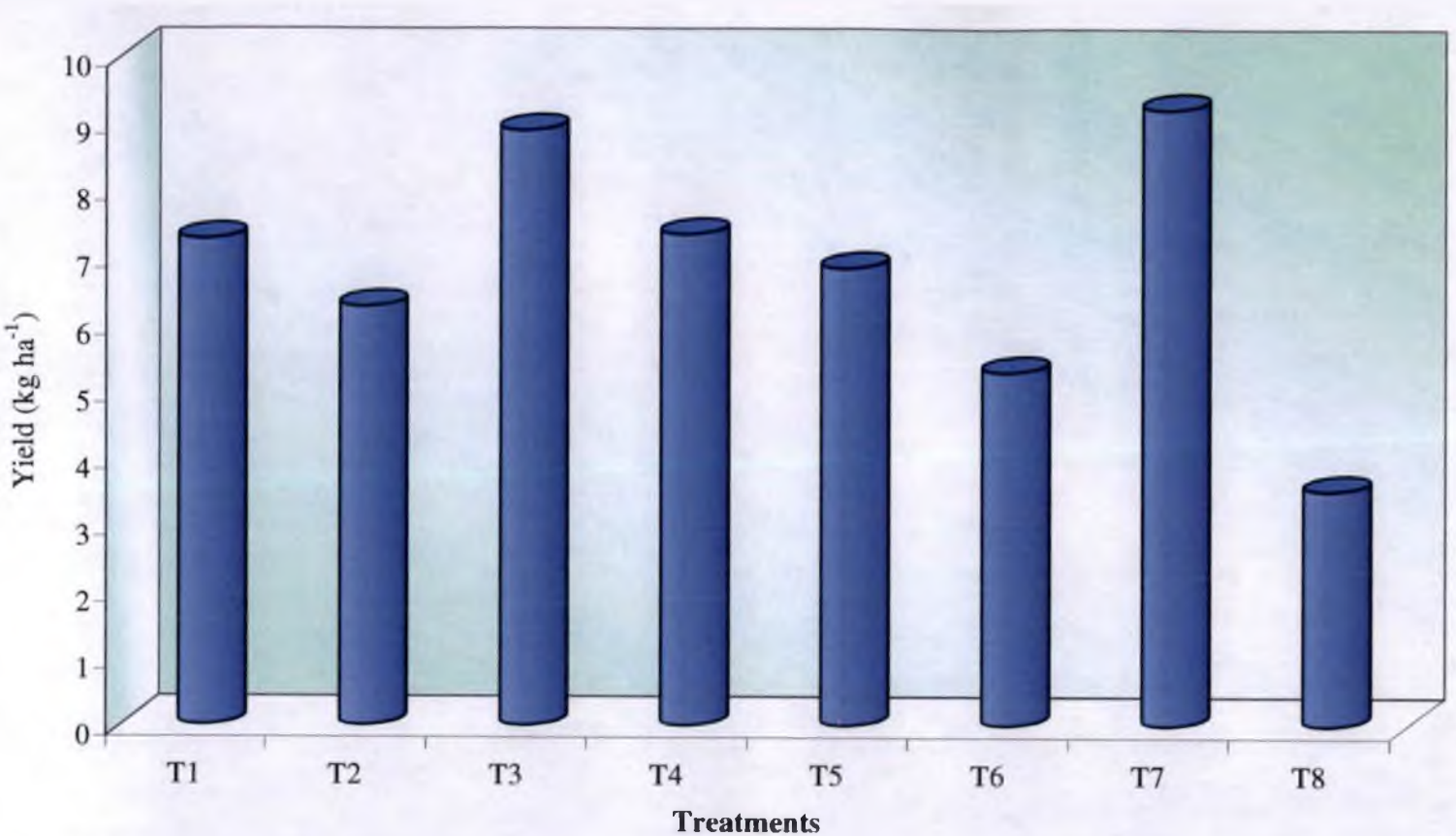
5.3.6 Intensity of Leaf Blight Disease at Different Intervals before and after Spraying

The percentage disease index calculated before spraying and seven days after spraying varied from 24.01 to 26.42 and it did not vary significantly among treatments and control. The botanical treatments were not very effective in controlling the leaf blight disease of amaranthus caused by *R. solani*. However complete inhibition of growth of *R. solani* was reported Dhanpal *et al.*, (1996) using 30 per cent neem seed extract. in a laboratory experiment.

5.3.7 Yield of Amaranthus and Benefit : Cost Ratio of the Treatments in Field Experiment

The treatment, azadirachtin 0.0025 per cent (NeemAzal 1 per cent T/S @ 2.5 ml l^{-1}) gave an yield of 8.90 t ha^{-1} which was statistically similar to the yield obtained in malathion treated plots (9.22 $t.ha^{-1}$) (Fig.8) However the B :C ratio was highest for this treatment (3.20) as a value addition of fifty per cent for yield was given for botanical treatments over malathion treatment. This was followed by cow's urine 10 per cent + NSKE five per cent combination (yield = 7.35 $t.ha^{-1}$ and B:C ratio = 2.12) and NSKE five per cent (yield = 7.27 t ha^{-1} and B : C ratio = 2.08). However Srinath (1990) reported an yield of 8.96 $t.ha^{-1}$ from amaranthus var. Kannara Local by using four per cent neem leaf extract.

Hence it could be concluded that the pests of amaranthus could be controlled in an ecofriendly manner by the application of azadirachtin 0.0025 per cent (NeemAzal 1 % TS @ 2.5 ml l^{-1}), cow's urine 10 per cent + NSKE five per cent or NSKE five per cent. Three sprays of any of the above botanical treatments could be recommended at two weeks interval



T1	Neem seed kernel extract (NSKE) five per cent	T5	Pongamia oil soap emulsion two per cent
T2	NC soil application @ 250 kg ha^{-1} at planting + NCE 10 per cent spray	T6	Annona seed extract soap emulsion two per cent
T3	Azadirachtin 0.0025 per cent (Neem Azal 1 % TS @ 2.5 ml/litre)	T7	Malathion 0.1 per cent
T4	Cow's urine 10 per cent + NSKE five per cent	T8	Control

Fig. 8. Effect of different treatments on yield of amaranthus

starting from two weeks after transplanting in cases of severe pest infestation.

Amaranthus is being raised not only on a commercial basis but is also grown in the homesteads and kitchen gardens by the consumers themselves. Its successful cultivation is beset by problem pests like leaf webbers. The utilization of plant products or botanicals like neem for pest management offsets the hazards of synthetic pesticide use. In this context, the recommendation of use of azadirachtin 0.0025 per cent (NeemAzal 1 % TS @ 2.5 ml l^{-1}), cow's urine 10 per cent + NSKE five per cent or NSKE five per cent will be of unfeigned help in amaranthus crop husbandry.

The future line of work could include the survey and evaluation of botanicals and their combinations for their efficacy against pests of leafy vegetables. Traps and poison baits to capture pests like *S. litura* larvae have to be designed. Another aspect would be to assess the efficacy of microbial pesticides and their combinations with phytochemicals in IPM of leaf vegetables.

Summary

6. SUMMARY

The present study entitled "Seasonal occurrence and ecofriendly management of pests of amaranthus (*A. tricolor* L.) was conducted from April 2004 to April 2005 in the Instructional Farm, College of Agriculture, Vellayani. The main objectives were to study the seasonal occurrence of the pests of amaranthus, their natural enemies and to evolve an ecofriendly management strategy against the pests. The intensity of leaf blight disease was also assessed.

Seasonal occurrence studies revealed that the leaf webbers *P. basalis* and *H .recurvalis* were major pests of amaranthus. Leaf blight disease caused by *R. solani* was the major disease.

The leaf webber *P. basalis* was present in the field throughout the year. The population and extent of damage caused by the pest was maximum during the summer months. The highest mean population of larvae per plant was observed during second fortnight of April 2004 (2.19). Maximum mean population of *P. basalis* moths per sweep was observed during the second fortnight of March 2005 (1.60).

The percentage of plants infested by *P. basalis* was the highest (73.00) during the second fortnight of April 2004. Highest percentage of leaf damage was observed during the first fortnight of April 2005 (15.02). The population and extent of damage by *P. basalis* exhibited significant positive correlation with maximum and minimum temperature.

The mean population of *H. recurvalis* larvae per plant ranged from 0.17 during second fortnight of September 2004 to 2.27 during the second fortnight of June 2004. The population was considerably lower during the summer months (April and May 2004). The population of larvae showed significant negative correlation with minimum temperature (r value = -0.4211). *H. recurvalis* moths were present in the field throughout the year. The mean population of moths per sweep was the highest during the second fortnight of November 2004 (1.50). The

population of moths showed significant negative correlation with minimum temperature (r value = -0.4019) and positive correlation with relative humidity (r value = 0.4114).

The percentage of plants damaged by *H. recurvalis* ranged from 20.00 during second fortnight of September 2004 to 93.00 during second fortnight of November 2004. The percentage of leaves damaged by *H. recurvalis* was the highest during the second fortnight of June 2004 (25.47). The leaf damage showed significant negative correlation with maximum and minimum temperature with 'r' values being –0.4197 and –0.4349 respectively.

The green grasshopper *A. crenulata* was observed in the field throughout the year. Highest population per plant was observed during the first fortnight of October 2004 (0.87). The population of grasshopper showed significant negative correlation with minimum temperature (r value = -0.3619).

The percentage of plants infested by *A. crenulata* ranged from 20.00 during July 2004 to 76.67 during the second fortnight of November 2004. The plant damage showed significant negative correlation with minimum temperature (r value = -0.4597). The percentage of leaves damaged by the grasshopper was maximum during the second fortnight of November 2004 (2.94). The leaf damage showed significant negative correlation with minimum temperature (r value = -0.3936) and number of rainy days (r value = -0.3791).

The percentage of plants infested by *S. litura* was maximum during the second fortnight of July 2004 (46.66). The percentage of leaves damaged by *S. litura* was low and ranged from 0.88 during the first fortnight of September 2004 to 1.74 during first fortnight of July 2004. The leaf damage caused by the pest showed significant positive correlation with rainfall (r value = 0.3656).

The percentage of plants infested by American serpentine leaf miner (ASLM), *L. trifolii* was maximum during the first fortnight of May 2004 (20.00). The percentage of leaves damaged was the highest during the first fortnight of May 2004 (1.08).

The population of aphid *A. craccivora* was in general, low and the pest was observed during the months of May, October and November 2004 and April 2005 only.

A braconid parasitoid *A. opacus* was found infesting larvae of *H. recurvalis*. The mean population of pupae of the parasitoid per plant was the maximum during the first fortnight of July 2004 (0.70).

Spider predators *Oxyopes* sp., *Cheiracanthium* sp, *Phidippus* sp. and *Tetragnatha* sp. were found in the field throughout the year. The mean population of spiders per plant was maximum during the second fortnight of September 2004 (1.50) and lowest during the second fortnight of July 2004 (0.40). The spider population showed significant positive correlation with maximum temperature (r value = 0.4552).

The leaf blight disease caused by *R. solani* was observed throughout the year. The percentage disease index (PDI) was maximum during the second fortnight of December 2004 (22.21).

The results of the studies on antifeedant effect of botanicals against the major pests of amaranthus revealed that azadirachtin 0.0025 percent was the best botanical treatment which provided maximum percentage of leaf protection. This was followed by NSKE five percent and cow's urine 10 percent + NSKE five percent.

The results of the field experiment revealed that all the treatments were significantly superior to control in reducing the population and damage of leaf webbers *viz.*, *P. basalis* and *H. recurvalis*. Azadirachtin 0.0025 per cent was the best botanical treatment. This was followed by the treatments, cow's urine 10 percent + NSKE five per cent and NSKE five per cent which were also effective against the pests.

The population of *A. crenulata* was low in the treatments, NSKE five per cent, cow's urine 10 per cent + NSKE five per cent, azadirachtin 0.0025 per cent and in malathion 0.10 per cent.. The extent of damage caused by the grasshopper

in azadirachtin 0.0025 per cent was statistically similar to that of malathion 0.10 per cent treated plots. This was followed by cow's urine 10 per cent + NSKE five per cent.

The extent of plant and leaf infestation by the tobacco caterpillar *S. litura* was the lowest in treatment NC soil application @ 250 kg. ha^{-1} at planting + NCE 10 per cent spray.

The population of spider predators in botanical treated plots and in control plots were on par and higher compared to malathion treated plots.

The percentage disease index (PDI) due to leaf blight did not vary significantly among the treatments. Botanical pesticides like neem were not effective in controlling leaf blight disease.

. The treatment, azadirachtin 0.0025 per cent (NeemAzal 1% TS @ 2.5 ml/litre) gave an yield of 8.90 t. ha^{-1} with a B: C ratio of 3.20. This was followed by cow's urine 10 per cent + NSKE five per cent (yield = 7.35 $t.ha^{-1}$ and B:C ratio = 2.12) and NSKE five per cent (yield = 7.27 t. ha^{-1} and B:C ratio = 2.08). The maximum yield of marketable leaves (9.22 $t.ha^{-1}$) was obtained from plots treated with malathion 0.10 per cent with a B : C ratio of 1.61. The lowest yield of amaranthus was recorded in control (3.53 $t.ha^{-1}$)

Based on the results of the studies, the following ecofriendly plant protection measures could be recommended against the pests of amaranthus:

Application of three sprays of azadirachtin 0.0025 per cent (NeemAzal 1% TS @ 2.5 ml/litre) or cow's urine 10 per cent + NSKE five per cent or NSKE five per cent at two weeks interval starting from two weeks after transplanting of amaranthus seedlings for control of major pests.

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* original not seen

Appendix

APPENDIX – I

Weather parameters at Instructional Farm, College of Agriculture, Vellayani from April 2004 to April 2005

Fortnight	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Number of rainy days
	Maximum	Minimum			
April 2	33.15	25.20	76.70	50.50	4
May 1	31.45	23.50	83.33	283.2	12
May 2	30.70	23.95	82.43	173.10	9
June 1	29.75	22.90	86.08	187.40	12
June 2	30.58	23.62	81.58	33.20	4
July 1	30.00	23.20	84.23	151.90	8
July 2	29.60	23.05	84.43	168.60	12
Aug 1	29.85	22.95	83.95	79.60	8
Aug 2	30.46	23.26	78.65	9.80	3
Sept 1	29.70	22.90	82.70	141.00	7
Sept 2	30.25	23.45	84.73	51.70	10
Oct. 1	30.30	22.90	82.25	115.8	8
Oct. 2	30.85	23.15	82.98	64.30	1
Nov. 1	30.40	23.05	84.73	130.20	10
Nov. 2	30.75	23.35	82.24	36.90	6
Dec. 1	30.65	21.00	76.15	16.00	1
Dec. 2	31.40	22.20	76.90	0.00	-
Jan 1	31.65	21.60	76.25	0.00	-
Jan 2	31.80	21.40	77.30	1.00	1
Feb 1	32.00	22.90	76.85	0.20	1
Feb 2	32.20	21.40	74.00	0.00	-
Mar 1	33.00	23.40	76.40	0.30	1
Mar 2	33.10	24.80	76.85	0.80	1
April 1	31.70	23.10	80.45	184.20	3

SEASONAL OCCURRENCE AND ECOFRIENDLY MANAGEMENT OF PESTS OF AMARANTHUS (*Amaranthus tricolor* L.)

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Abstract of the
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ABSTRACT

Seasonal occurrence of pests, their natural enemies and leaf blight disease of amaranthus were studied in the Instructional Farm. College of Agriculture, Vellayani from April 2004 to April 2005.

Leaf webbers *Psara basalis* F. and *Hymenia recurvalis* (F.) were the major pests of amaranthus and leaf blight disease caused by *Rhizoctonia solani* Kuhn. was the major disease.

The leaf webber *P. basalis* was present in the field throughout the year. However the highest population and infestation was observed during the summer months. Maximum population of larvae was observed during the month of April 2004. The population and extent of damage by the pest exhibited significant positive correlation with maximum and minimum temperature.

The leaf webber *H. recurvalis* was also present in the field throughout the year. The population and extent of damage by the pest was maximum during June, July and November 2004 and minimum during the summer months (April and May 2004). The population of the pest showed significant positive correlation with minimum temperature.

The green grasshopper *Atractomorpha crenulata* F. was observed in the field throughout the year. Highest population was observed during the first fortnight of October 2004. The percentage of plants and leaves damaged by the grasshopper was maximum during the second fortnight of November 2004. The population and extent of damage of the grasshopper showed significant negative correlation with minimum temperature.

The percentage of plants damaged by the tobacco caterpillar *Spodoptera litura* (F.) was maximum during the second fortnight of June 2004 and the leaves damaged was the highest during the first fortnight of

June 2004. The leaf damage showed significant positive correlation with rainfall.

A solitary braconid endoparasitoid *Apanteles opacus* (Ashmead) was found infesting the second instar larvae of *H.recurvalis*. The population of pupae of the parasitoid was maximum during the first fortnight of July 2004.

Spider predators *viz.*, *Oxyopes* sp., *Cheiracanthium* sp., *Phidippus* sp. and *Tetragnatha* sp. were found in the field throughout the year. Maximum population of spiders was observed during the second fortnight of September 2004. The population showed significant positive correlation with maximum temperature.

The leaf blight disease caused by *R. solani* was observed throughout the year. The percentage disease index (PDI) was maximum during the second fortnight of December 2004.

Studies on antifeedant effect of botanicals on major pests of amaranthus revealed that azadirachtin 0.0025 per cent was the best phagodeterrent followed by cow's urine 10 per cent + NSKE five per cent and NSKE five per cent.

Six botanical pesticides were evaluated with malathion as check in a field experiment. The treatments included neem seed kernel extract five per cent (NSKE), neem cake (NC) soil application @ 250 $kg.ha^{-1}$ at planting + neem cake extract (NCE) 10 per cent spray, azadirachtin 0.0025 per cent, cow's urine 10 per cent + NSKE five per cent, Pongamia oil soap emulsion two per cent and annona seed extract two per cent. Three sprays of the treatments were applied on the crop during the experiment. The results revealed that all the treatments were significantly superior to control in reducing the population of pests and their damage. Azadirachtin 0.0025 per cent was the most effective treatment against leaf webbers and grasshopper. This was followed by cow's urine 10 per cent + NSKE five

per cent and NSKE five per cent. The extent of damage caused by these pests in azadirachtin treated plots was statistically similar to that of malathion treated plots. .

The extent of damage by the tobacco caterpillar was the lowest in NC soil application @ 250 kg ha^{-1} + NCE 10 per cent spray treatment.

Higher population of spiders was found in botanical treated plots and control plots compared to malathion treated plots. The botanical treatments were not effective in containing the leaf blight disease.

Maximum yield of marketable produce was recorded from malathion treated plots. However the B : C ratio was the highest (3.20) in botanical treatment, azadirachtin 0.0025 per cent (NeemAzal 1% TS @ 2.5 ml/litre) followed by cow's urine 10 percent + NSKE five per cent (2.12) and NSKE five per cent (2.08).

Three sprays of any of these botanicals at fortnightly intervals starting from two weeks after transplanting could manage the pests of amaranthus.