STUDIES ON BIOEFFICACY, SAFETY AND RESIDUES OF FENPYROXIMATE AND FLUFENZIN USED AGAINST RED SPIDER MITE ON BRINJAL

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI- 413 722, DIST. AHMEDNAGAR (M.S.)

By

NAIK RAJIV LAXMAN

Reg. No. 02016

In partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE,
DEPARTMENT OF AGRICULTURAL ENTOMOLOGY,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722 DIST- AHMEDNAGAR (M. S.) INDIA

2005

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RAHURI-413 722 DIST- AHMEDNAGAR (M. S.) INDIA

2005

CANDIDATE'S DECLARATION

I hereby declare that the thesis entitled **"Studies on bioefficacy, safety and residues of fenpyroximate and flufenzin used against red spider mite on brinjal"**, or part thereof has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma.

Place : M. P. K. V., Rahuri

Date : 14/04 / 2005

(R. L. Naik)

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Rahuri-413 722 Dist. Ahmednagar (India).

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This is to certify that the thesis entitled, **"STUDIES ON BIOEFFICACY, SAFETY AND RESIDUES OF FENPYROXIMATE AND FLUFENZIN USED AGAINST RED SPIDER MITE ON BRINJAL"**, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist: Ahmednagar, Maharashtra in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY** embodies the results of a piece of *bona fide* research carried out by **Mr. RAJIV LAXMAN NAIK**, under my guidance and supervision and that no part of the thesis has been submitted to any other University for Degree or Diploma.

The assistance and help rendered during the course of this investigation have been duly acknowledged.

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Place : Place : M. P. K. V., Rahuri
Date : 14/ 04/2005

(D. M. Sawant)

ACKNOWLEDGEMENT

Principally, I take this opportunity to express my deep sense of gratitude to Dr. Dethe, for giving an opportunity to work under his able guidance. My sincere thanks go to him for his constant encouragement, invaluable advice and the expertise, which enabled me in accomplishment of the present investigations. I earnestly extend my sincere thanks to all the advisory committee members for the graciously given advice. Further, I extend my sincere thanks to Dr. Kale for providing all the necessary laboratory facilities and especially, the critical reading of the manuscript with helpful comments.

Completion of this thesis would have been difficult without the close co-operation and efficient endeavors of many faculty and staff members. Special appreciation is extended to Dr. Patil, Prof. Lolage, Prof. Kulkarni, Dr. Mohite, Prof. Tambe, Dr. Nakat, Dr. Shewale, Dr. Jadhav, Dr. Kadam, Mr. Walunj and Mr. Pawar. I gratefully acknowledge Mr. Autade, Mr. Gire and Mr. Adsure who diligently assisted me in both laboratory and field experiments. I also thank Mr. Nadkar for developing and providing the software in respect of the determination of LC_{50} values.

Special thanks are also duly given to the University Authorities, the Associate Dean, College of Agriculture, Pune and especially to Dr. Chandele, Professor of Entomology for granting study leave for the Ph. D. programme.

I owe my gratitude to my father and family members for their endurance and understanding which have been quite overwhelming. Without their persuasion and support, this degree programme would have not been completed.

I fondly dedicate this work to my beloved late mother

(R. L. Naik)

Place : M. P. K. V., Rahuri
Date : 14 / 04 / 2005

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LIST OF ABBREVIATIONS

a. i., AI	:	Active ingredient
BCPC	:	British Crop Protection Council
Conc.	:	Concentration
EC	:	Emulsifiable concentrate
e.g.	:	*Exempli gratia*, for example
et al.	:	*Et alia*, and others
etc.	:	*Et cetera*, and so on
EU	:	European Union
FAO	:	Food and Agriculture Organization
FS	:	Flowable suspension
ha	:	Hectare (s)
hr	:	Hour (s)
i.d.	:	Internal diameter
i.e.	:	*Id est*, that is
kg	:	Kilogram (s)
g	:	Gram (s)
mg	:	Milligram (s)
µg	:	Microgram (s)
ng	:	Nanogram (s)
L	:	Liter (s)
ml	:	Milliliter (s)
µl	:	Micro-liter (s)
LC_{50}	:	Lethal concentration 50, concentration of toxicant that kills 50% of the organisms exposed to it.
LD_{50}	:	Lethal dose 50, the dose of a toxicant that kills 50% of the organisms exposed to it
LT_{50}	:	Lethal time 50, a time period of exposure to obtain 50% kill of the organisms exposed
m	:	Meter (s)
m^2	:	Square meter
cm	:	Centimeter (s)

cm^2	:	Square centimeter
mm	:	Millimeter (s)
nm	:	Nanometer (s)
t		Metric tonne (s)
oz	:	Ounce (1 oz ≡ 30 ml)
pH	:	Measure of the relative acidity of a liquid on a scale ranging from 0 (most acidic) through 7 (neutral) to 14 (most basic): the scale is logarithmic
ppm	:	Parts per million
rpm	:	Revolutions per minute
RH	:	Relative humidity
SC	:	Suspension concentrate
T_{BDL}	:	Time required (for residues) to reach below detectable level
T_{MRL}	:	Time required (for residues) to reach below the maximum residue limit
$T_{1/2}$	:	Time required (for residues) to decrease by half
vis-à-vis	:	In relation to, to or with
viz.,	:	*Vide licet,* namely
WG	:	Wettable granules
WHO	:	World Health Organisation
WS	:	Wettable suspension
@	:	At the rate of
/	:	Per, and
>	:	Greater than
<	:	Less than
≈	:	Equivalent to
≅	:	Approximately equal to
%	:	Per cent
^0C	:	Degree Celsius
√	:	Square root of

ABSTRACT

"STUDIES ON BIOEFFICACY, SAFETY AND RESIDUES OF FENPYROXIMATE AND FLUFENZIN USED AGAINST RED SPIDER MITE ON BRINJAL"

by

NAIK RAJIV LAXMAN

A candidate for the degree

of

DOCTOR OF PHILOSOPHY

(AGRICULTURE)

2005

Research Guide	**: Dr. DETHE M. D.**
Department	**: Agricultural Entomology**

Two new selective acaricides *viz.*, flufenzin 200 SC (20%) and fenpyroximate 5% EC were tested at 60, 80 and 100 g a. i./ha and at 15, 20 and 25 g a. i./ha, respectively alongwith dicofol 18.5% EC at 250 g a. i./ha, as a standard check against the spider mite, *Tetranychus cinnabarinus* (Boisduval). Bioassay conducted by using residual leaf-disc-dip method on each of life-stages of the test mite revealed that dicofol was found fairly good ovicide, larvicide, nymphicide and adulticide. Flufenzin observed to be excellent ovicide, fairly good larvicide and moderate nymphicide however, adults were found less susceptible. Fenpyroximate appeared to be excellent larvicide, nymphicide and adulticide however, showed moderate action as an ovicide. It exhibited quick knockdown effect, adults were found more sensitive than nymphs. LC_{50} values estimated for fenpyroximate, flufenzin and dicofol in respect of larvae were 2.52, 0.57 and 166.25 ppm whereas for adults, the values were 4.37, 1153.57 and 309.19 ppm,respectively.

In field bioefficacy studies although dicofol was found to be efficient, it offered comparatively less protection (88%) for a week period. Flufenzin offered < 95 per cent protection and the efficient kill was noticed in between 13 and 15 DAT. Fenpyroximate

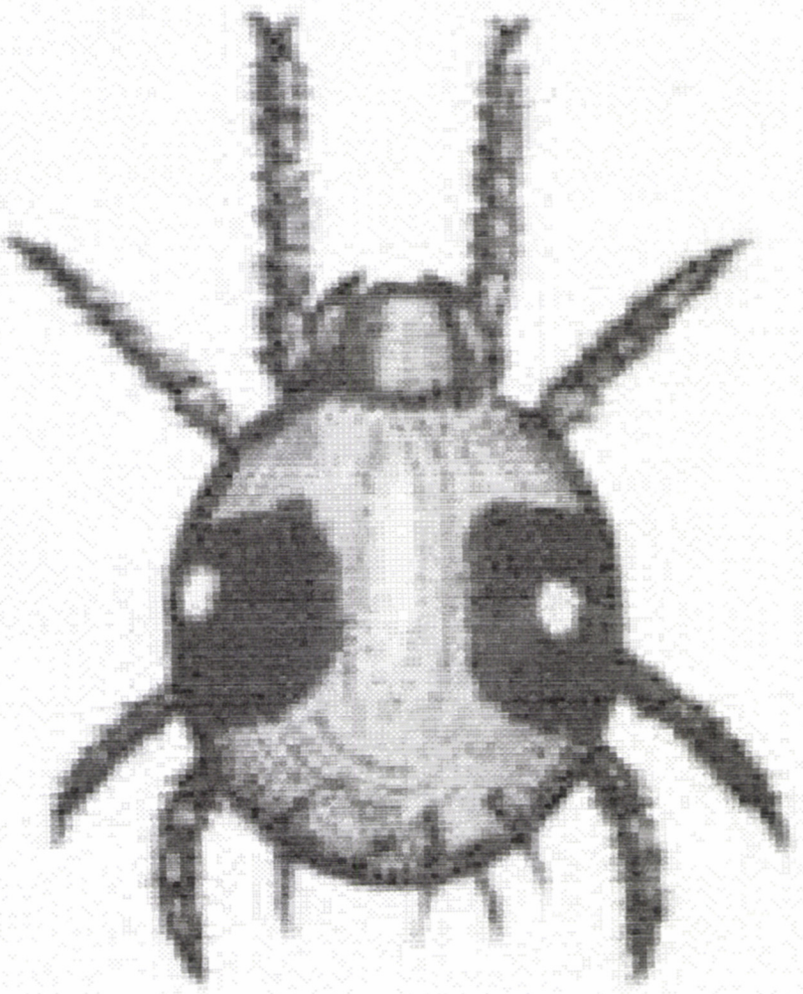
offered > 95 per cent protection, extending the protection in between 15 and 21 DAT. None of the acaricides exhibited any phytotoxicity to brinjal plants. All the three dosages of fenpyroximate and higher dose of flufenzin (100 g a. i./ha) prominently controlled the mite and contributed better returns.

The studies on safety to beneficial arthropods revealed that dicofol, fenpyroximate and flufenzin were harmful, slightly harmful and safe, respectively to the green lacewing, honeybee and earthworm. The data on abundance of phytoseiid mites and the laboratory toxicity to the mite, *Amblyseius* spp. revealed that dicofol, fenpyroximate and flufenzin were harmful, moderately harmful and safe, respectively. However, lesser toxicity was exhibited by fenpyroximate under laboratory conditions than depicted in the field bioassays.

The residue studies indicated that in flufenzin when applied twice at 100 and 200 g a. i./ha, the residue levels were dissipated within 7 and 10 days, respectively. The residue levels were dissipated within 3 and 5 days in fenpyroximate when applied twice at 25 and 50 g a. i./ha, respectively. The residue levels were reduced in the range of 43 to 48 per cent in flufenzin and of 46 to 55.6 per cent in fenpyroximate due to the process of washing. The combine effect of both washing and cooking further reduced the residue levels in the range of 67.6 to 70.0 and 70.0 to 75.0 per cent in the flufenzin and fenpyroximate, respectively. The MRL proposed for flufenzin and fenpyroximate was worked out to be 0.4 and 0.2 ppm, respectively. In studies on dissipation, pre-harvest interval of both the candidate acaricides arrived to be zero days, but one day waiting period is proposed as most practicable for consumers safety. The estimated consumer risk of the flufenzin and fenpyroximate was found to be 0.36 and 1.67 per cent, respectively.

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Chapter One



INTRODUCTION

1. INTRODUCTION

Brinjal, *Solanum melongena* Linnaeus is an important vegetable crop cultivated in India over an area of 2.99 lakh hectares with the yield of 3.12 million tonnes. In the State of Maharashtra, it is mostly grown under irrigated conditions and occupies 31 thousand hectares area with the production of 506 thousand tonnes (Anonymous, 1998).In recent years, the red spider mite has become serious menace for cultivation of the crop. Like spiders, the mites spin webs on the leaves and cover their colonies to protect themselves from natural enemies and also from pesticides. Overcrowding of the mites often occurs on leaf/fruit tip and consequently they migrate to other fields. Besides the brinjal, most of the vegetable crops are subjected to attack of the spider mites and common species prevailing are *Tetranychus cinnabarinus* (Boisduval), *T. neocaledonicus* (Adre), *T. ludeni* (Zacher), and *T. macfarlanei* (Barker and Pritchard). The yield losses due to the mites are about 13 to 31 per cent in brinjal, 23 to 25 per cent in okra and 10 to 15 per cent in other vegetables. Heavy infestation of *T. cinnabarinus* results in shedding of leaves with no fruiting and total failure of crops like brinjal , okra and beans have also been reported. The monetary loss due to the spider mites, in case of brinjal is estimated to be Rs. 8616 /ha (Gupta, 1993).

The mite, *T. cinnabarinus* is soft bodied, 0.5-0.6 mm sized, crimson red coloured, colony forming mite which mostly live on under surface of leaves (Plate 1). The life cycle constitutes the sequential stages *viz.*, egg, larva, nymphochrysalis, protonymph, duetochrysalis, duetonymph, teleiochrysalis and imago (adult). The oviposition occurs on ventral leaf surface along the lateral veins/mid ribs. On an average single female lays about 60 to 70 eggs. Unfertilized egg produces only male-offspring whereas, fertilized egg produces female only. Larva possesses three pairs of

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legs while remaining subsequent developing stages possess four pairs of legs. The normal duration of egg, larval, nymphal and adult stage is 5 to 7, 1 to 2, 3 to 4 and 7 to 9 days, respectively. In general, the duration from eggs to emergence of adult is 9 to 12 days (Bhagat and Singh, 1999). In warmer zone of the State, the mite population starts developing during March, prevails till July and declines thereafter with the start of monsoon rains. However, under climatic conditions of Rahuri (District: Ahmednagar), the peak infestation occurs during August-October and March-May.

The mite feeds by piercing the leaf tissues with chelicerae. Injuries to epidermal and mesophyll layers cause water loss, which reduces the chlorophyll metabolism and photosynthesis. Besides, the damaged cell loose chlorophyll content as a result of which, the normal cell functioning is reduced and the plant growth is affected. Due to mechanical injury, photosynthetic enzymes are influenced which change the pathway of carbon and affect CO_2 intake. All these damages impair the starch synthesis. The feeding also affects transpiration rate due to loss of protective covering and disturbance in stomatal opening, resulting in hydrolysis of protein and starch into amino acids and soluble sugars. This breakdown provides more nutrition to the mites leading to their rapid multiplication. Severely infested leaves become completely yellow to brown and fall off from the plants, plants remain stunted.

Prior to the introduction of broad-spectrum insecticides in the market, the mites assumed a minor pest status and were not reported to cause widespread damage. Moreover, the mite infestations occurred sporadically and were easily controlled with different formulations of sulphur, which did not interfere seriously with ecosystem. This might have been due to undisturbed natural prey-predator relationship.

In Indian literature, spider mites were never reported as a pest of agriculture prior to 1940 (Prasad, 1974). With the introduction of different broad-spectrum

insecticides such as organochlorine and organophosphates for general pest control, the natural enemies of mites were adversely affected. The regular intervention of insect pest populations with chemical insecticides resulted in serious outbreaks of mites. In addition, the deleterious effects of these insecticides caused negative and adverse impact on biodiversity by reducing the overall population of natural enemies and variety of other beneficial, biological species. Thus, mites assumed a status of major pest with recurrent occurrences on many vegetables and other crops.

The intensive year-round cultivation of vegetables often leads to increased flare-ups necessitating more rigid pest control. Use of same chemical repeatedly or increase in dose and frequency of pesticides has unnecessarily led to severe problems such as additional cost of pesticides, elimination of beneficial fauna, unintended pollutive residues and more importantly, the ability of pests to adopt and survive in a high pesticides use environment (resistance). Consequently, major insect pests including mites have acquired resistance to many pesticides. The mites have acquired single/cross/multiple resistance to almost all commonly used acaricides, which may be due to enhanced reproductive potential and detoxification mechanism of mixed function oxidases. Faster degradation of dicofol in R-strains of two spotted spider mite has already been reported. Besides, use of sub-lethal doses of organophosphates also tend to develop resistance in mites. The spider mites have very short life cycle and the number of generations under favourable conditions are very high. Due to very high reproduction rate and ability of quick development of cross- multiple-resistance to different compounds, their field management has become a more difficult task in recent years.

Chemical control of phytophagous mites mostly relies upon three categories *viz.*, 1. Non-selective insecticides/ acaricides like organophosphates, cyclodienes,

pyrethroids and organocholorines (dicofol, tetradifon and endosulfan). 2. The acaricides possessing some degree of mite selectivity like formamidines, benzolureas, thioureas etc. and 3. More specific acaricides like organotins, sulfites, pyrazoles, pyridazinones, carbazates, quinazolines, tetrazines etc. In the recent years, emphasis is being laid on low risk acaricides active at low doses under field conditions, which have a controlled action span and less non-target effect. New generation acaricides with novel chemistries are being developed and investigated for their biological activity, residues and environmental safety. These selective acaricides have little or no effect on beneficials and are efficient in their action against the target mite species, which consequently may fit into the IPM strategies.

Two new molecules *viz.*, Flufenzin 200 SC (20%) and Fenpyroximate 5 EC (5%) claimed to be more selective, potent miticides with minimum impact on beneficial and the environment were chosen to study their performance against the mite, *Tetranychus cinnabarinus* infesting brinjal crop during the present investigations. Contemplating their use on vegetable crops, especially brinjal, the data on magnitude of residues of these compounds after application is of immense importance from the consumer safety point of view. Since these are new compounds, there is a paucity of literature, particularly in India. Keeping the aforesaid facts in view, these two new acaricides along with the recommended conventional acaricide, dicofol as a treated check were evaluated with the following objectives.

i) To determine toxicity by laboratory bioassays
ii) To study the bio-efficacy under field condition
iii) To evaluate safety against beneficials
iv) To study the dissipation of the residues on brinjal fruits
v) To study the effect of home processes such as washing and cooking of fruits on reduction of residues of the test compounds.

Plate 1: RED SPIDER MITE

Leaf Infested with Red Mite

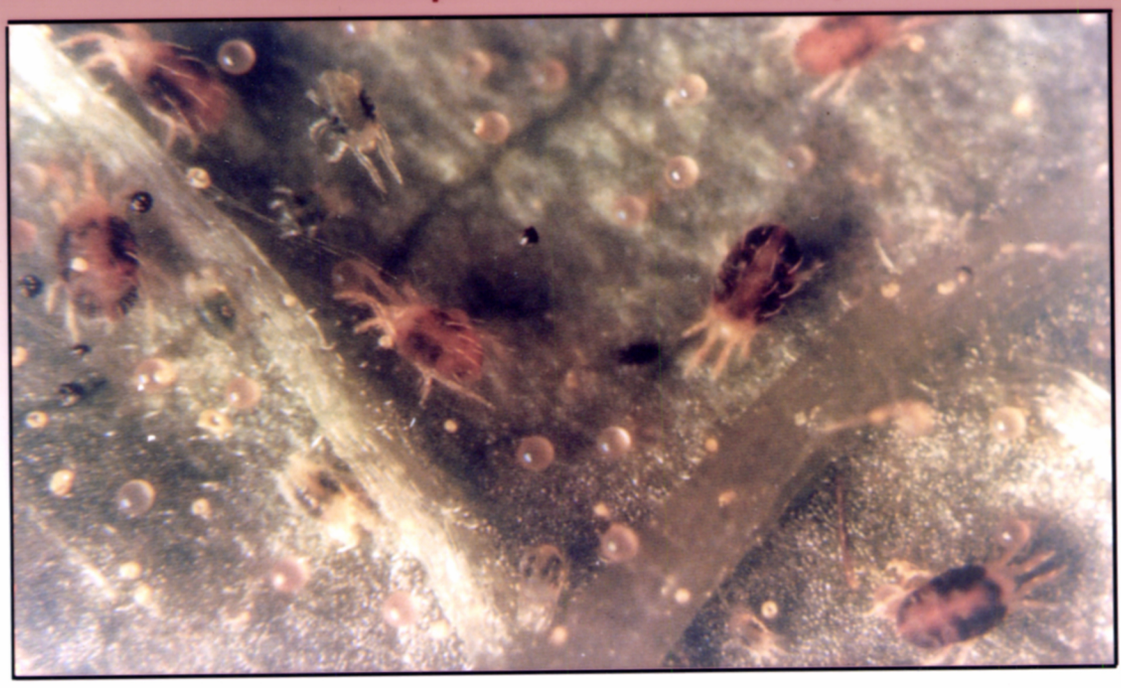


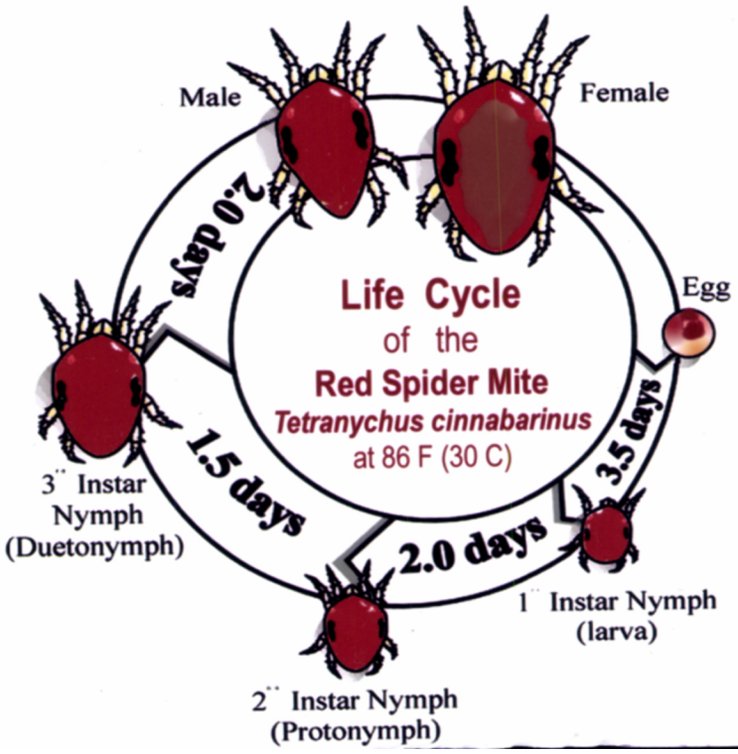
Initial Damage & Later Stage



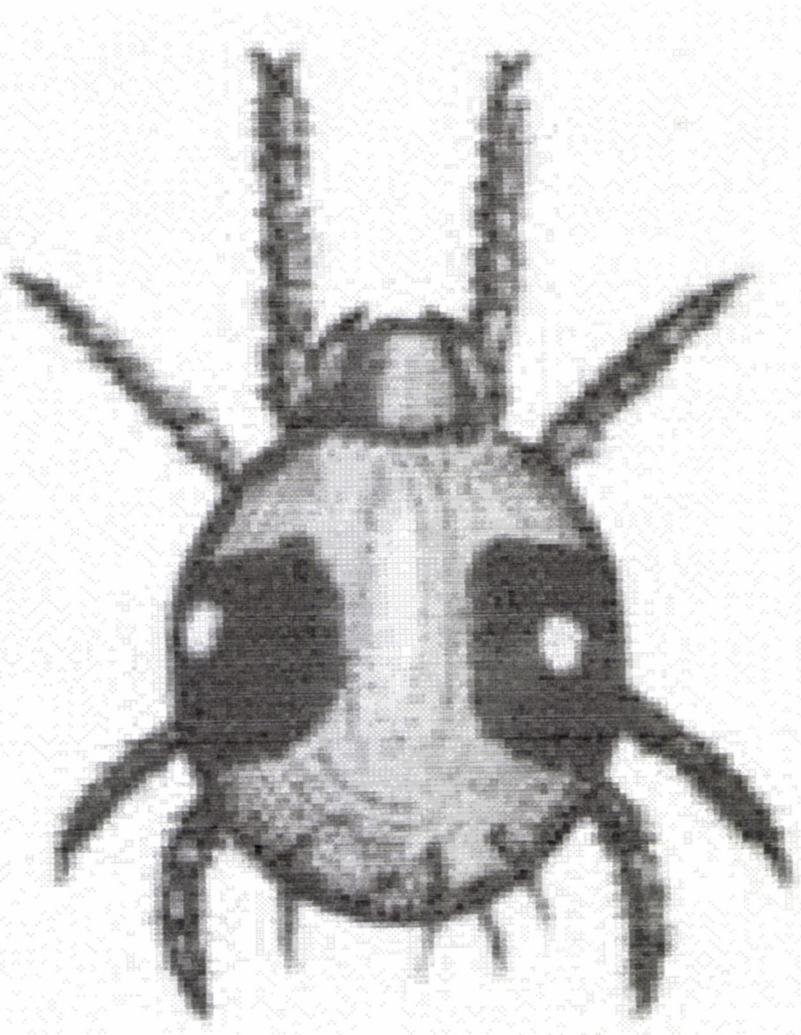


Microscopic view of the Colony





Chapter Two



REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The mite infesting brinjal belongs to Phylum:Arthropoda, sub-phylum : Chelicerata, Class : Arachnida, Sub-Class: Acari-Acariformes, Order : Prostigmata, Super Family : Tetranychoidea, Family : Tetranychidae, Genus : *Tetranychus* and Species : *cinnabarinus*. Earlier, it was known as *Acarus cinnabarinus* Boisd. (1867), lateron renamed as *Tetranychus biomaculatus* Harvey (1884) and then as *Tetranychus telarius* Linn. (1931). Presently, it is re-christened as *Tetranychus cinnabarinus* (Boisduval).

It is world widely distributed and in India, it mainly occurs in the States of Maharashtra, Gujrat, Haryana, Bihar, Punjab, Rajasthan, Orissa, Meghalaya, Kerala and Karnataka. It's host range includes brinjal, okra, tomato, bitter gourd, cucurbits, cabbage, beans, cotton, black gram, green gram, cowpea, soybean, watermelon, sunflower, sunhemp, castor, jute, rose, hollyhock etc. (Gupta, 1985). Very high temperature and relative humidity are detrimental for its development while moderate temperature and relative humidity are congenial. The population starts developing during March, prevails till July and declines thereafter during monsoon season. A number of natural enemies of this mite have been recorded and the prominent predators are coccinellids, staphylinids, anthocorids, thrips, lacewings and predacious mites like phytoseiids (*Amblyseius* spp./ *Phytoseilus* spp.) and *Stigmaeid*s.

Chemical control of phytophagous mites in India has been reviewed by earlier workers NageshChandra and Sannaveerappanavar (1984). The presence of phytophagous mite was reported as early as 1868 and its control with chemicals received more attention only in 1980s. Sulphur was essentially the only acaricide used until 1920 and is still being extensively applied. Lime sulphur, fish oil rosin soap and crude oil emulsion came into use in 1940s, to control mites infesting tea, grapes and

sorghum. Insecticides of plant origin like tobacco decoction and tobacco dust were also tested for their acaricidal properties. In late 1940s, chlorinated hydrocarbons appeared as potential acaricides but they did not prove satisfactory. In India, studies to evaluate the effectiveness of dicofol against mites began in early 1960s. Since then it has been extensively used for the control of various phytophagous mites. In between late 1960s and early 1970s, other acaricides like chlorobenzilate, binapacryl, tetradifon, aramite, oxythioquinox and chlorophenomidine were introduced and tested for their acaricidal property against the mite pest. From 1960 onwards, many contact and/or systemic organophosphates, cyclodiens and carbamates were tested and extensively used. The chemical control of mite, in fact, gained more importance around 1970s.

In India, earlier workers have recommended the use of lime sulphur (Rahman, 1939), powder of wood ash plus sulphur at 4:1 (Puttarudriah, 1947), aramite (Sen, 1958), parathion (Pawar and Rathore, 1959), diazinon (Singh and Guram, 1960) etc. for controlling the spider mites infesting vegetable crops. Earlier researchers have advocated following pesticides against the tetranychid mites infesting brinjal crop.

Pesticide	**Mite species**	**Researcher(s)**
Parathion/ diazinon (0.03%)	*T. telarius*	Lal *et al.* (1965)
Dicofol/ malathion (0.025%)	*T. telarius*	Bindra & Goyal (1966)
Carbophenothion (0.02%)/ chlorobenzilate (0.082%)/ lime sulphur (0.25%)/ dicofol (0.03%)	*T. urticiae*	Basu & Pramanik (1968)
Dimethoate (0.05%) / phosphamidon (0.025%)	*T. cucurbitae*	Atwal *et al.* (1969)
Dimethoate / diazinon (0.025%)	*T. telarius*	Bapu *et al.* (1970)

Pesticide	**Mite species**	**Researcher(s)**
Methyl demeton/ chlorobenzilate (0.025%)	*T. cucurbitae*	Sidhu & Singh (1971)
Chlordimeform/ dicofol (0.025%)	*T. cucurbitae*	Gupta *et al.* (1972)
Quinomethionate (0.1%)	*T. cucurbitae*	Chandra *et al.* (1973)
Dimethoate/ monocrotophos (0.025%)	*T. cucurbitae*	Singh *et al.* (1975)
Chlordimeform (0.02%) / traind (0.03%) / cyhexatin (0.1%)	*T. cucurbitae*	Krishnaiah & Tandon (1975)
Disulfoton at 5G (1.5 kg/ha)	*T. neocaledonicus*	Dhooria *et al.* (1976)
Dicofol (0.03%)	*T. neocaledonicus*	Pande & Sharma (1980)
Oxydemeton-methyl (0.025%)	*T. cinnabarinus*	Dhooria & Bindra (1980)
Dimethoate, ULV-formulation	*T. neocaledonicus*	Dhooria & Mann (1980)
Carbaryl (1 kg/ha)	*T. cucurbitae*	Dilbagh & Gill (1981)
Carbaryl (0.2%)	*T. telarius*	Patel *et al.* (1982)
Malathion (0.1%)	*T. telarius*	Goyal (1982)
Dimethoate/ phosphamidon (0.03%)	*T. neocaledonicus*	SubbaRao *et al.* (1984)
Dicofol (0.03%)/ ethion (0.1%) / sulphur (0.2%)	*T. telarius*	Shah *et al.* (1989)
Selvisulph (0.15%)	*T. macfarlanei*	Kumar *et al.* (1989)
Cyhexatin(0.03%) / sulphur(0.15%)	*T. cucurbitae*	Yadav *et al.* (1989)
Neem seed kernel extract (0.1%)	*T. urticae*	DevrajUrs (1990)
Dimethoate(0.03%) / sulphur (0.2%)	*T. cinnabarinus*	Kaneria & Bharodia (1991)
Dicofol (0.04%) followed by endosulfan (0.05%) phosphamidon (0.025%)	*T. cinnabarinus*	Verma (1992)
Neemark (0.5%)/ margocide (0.1%)	*T. cinnabarinus*	Patel *et al.* (1993)
Carbaryl(0.15%) plus dicofol (0.036%)	*T. neocaledonicus*	Sudhakar *et al.* (1998)

The perusal of the available literature revealed that there is a paucity of data, especially in India, on effectiveness of flufenzin and fenpyroximate against *T. cinnabarinus* infesting brinjal. Therefore, the literature pertaining to other species of the genus *Tetranychus*, but relevant to this study, have been presented below.

2.1 Bioefficacy

2.1.1 Dicofol

Dicofol 0.03% was found to be the most effective acaricide in comparison with other conventional ones, against *T. cinnabarinus* by using both leaf-disc bioassays and field experiments on brinjal. The LC_{50} value for adults was observed to be 0.0275 per cent (Kaneria and Bharodia, 1991) and 0.0244 per cent (Nassar *et al.*, 1984). Dicofol at 0.04 per cent had maximum ovicidal effect on eggs of *T. telarius* with 86.5 per cent kill (Palanisamy and Subramanian, 1977). Dicofol was found to be superior to ethion and sulphur for the management of *T. urticae* on okra (Singh and Singh, 1999).

2.1.2 Flufenzin

The studies carried out by Pap *et al.* (1994) revealed that flufenzin (SZI - 121) acts not only as a contact ovicide but also due to very good translaminar activity, it can enter in mite via ingestion. It possesses good transovarian activity. It also acts as sterilant agent on egg laying females. Higher inherent ovicidal activity was detected in both active ingredient and formulation. The compound had longer residual activity against the phytophagous mites. The chemical was found efficient against eggs and larvae but not on adultmites. Under field conditions, flufenzin at 60 g a.i./ ha showed higher efficacy than the label rates of clofentezine and hexythiazox in spring. In

comparison with amitraz and propargite , flufenzin showed similar or higher efficacy in summer.

Flufenzin (Flumite, 200 SC) gave satisfactory control of *T. urticae* (Roman *et al.*, 1997). In laboratory studies, flufenzin was found to be toxic to eggs and inhibited the development of eggs and premature stages of tetranychid mites. It was observed to be superior to all of the tested mite growth inhibitors and tebufenpyrad. The LC_{50} value for eggs, larvae and adults of the mite was 0.02, 0.6 and > 1000 ppm, respectively while for fenpyroximate, it was 1.1, 2.0 and 4.0 ppm, respectively. Under field conditions, flufenzin almost completely inhibited the hatching of grape mite, *T. urticae*. In brinjal it was found superior than ethion and dicofol against *T. cinnabarinus* (Pap *et al.*, 2002).

2.1.3 Fenpyroximate

Motoba *et al.*(1992) studied the mode of action of fenpyroximate in *T. urticae* with biochemical and morphological parameters. The results indicated that the inhibition of mitochondrial NADH-CoQ reductase by fenpyroximate seems to induce the morphological changes in mitochondria and decrease in ATP contents. This ultimately contributed to the acaricidal and knockdown activities against *T. urticae*.

Effective control of *Panonychus ulmi* on apple was obtained with fenpyroximate at low rates (Decraecke and Sterk, 1992). Excellent control of nymphs and adults of *T. urticae* was achieved by fenpyroximate in a glasshouse tomatoes and cucumber, without any phytotoxicity to crop plants. No ovicidal activity was detected; adults however, seemed to be more sensitive than nymphs (Veire *et al.*, 1992). On the contrast, the nymphs were observed to be more sensitive than adults (Korno *et al.*, 1990).

Diapausing *T. urticae* was found more susceptible to tebufenpyrad and fenobucarb, but less susceptible to fenpyroximate, pyridaben and propargite (Funayama and Takashi, 1993). Comparative toxicity of the selected acaricides were studied by Cho *et al.* (1993) against *T. urticae* wherein, ovicidal and adulticidal activities were examined. Fenpyroximate was found very active to all the life stages. The oviposition inhibition effect was greater than that of the standard, cyhexatin. At 100 ppm, fenpyroximate inhibited oviposition by at least 85 per cent for 25 days. At the same dose, it gave cent per cent knockdown within 3 h while the cyhexatin gave 91 per cent knockdown, 24 h after the treatment. The activity of fenpyroximate was observed to be unaffected with the increase in temperature.

Fenpyroximate, fenazaquin, abamectin and flufenoxuron were reported (Sterk, 1994) to be effective in controlling *Panonychus ulmi* on apple. In laboratory tests carried out by Cheng and Pan (1994) using glass slide-dip method, the LC_{50} value of fenpyroximate to adult *T. cinnabarinus* was estimated to be 237.93 ppm while the value for dicofol, it was 1791.43 ppm in respect of *T. urticae* .In studies conducted by Kimura and Kushita (1994), the LC_{50} value of fenpyroximate for adult female and eggs of *Panonychus ulmi* was estimated to be 0.18 ppm and 21.14 ppm, respectively while the values for *T. urticae* were 2.69 and 2.34 ppm, respectively.

Field efficacy of fenpyroximate and pyridaben was evaluated by Forti *et al.* (1994) against *Panonychus ulmi* and both the acaricides gave satisfactory control of the mite. Fenpyroximate, fenzaquin and tebufenpyrad were found most effective against *Panonychus ulmi*, which prevented the insurgence of new infestation for about 30 days after the treatment application. Ovicidal and adulticidal activity was exhibited by these acaricides (Laffi and Raboni, 1995). Fenpyroximate and pyridaben were characterized by a high level of biological activity against all life-stages of

Panonychus ulmi exerting a rapid initial effect and remained effective for about 30 days (Arnaudov, 1995). Adult females and eggs of *T. urticae* collected from apple orchards in Korea were found susceptible to fenpyroximate, abamectin and chlorfenson (Song *et al.*, 1995).

In Brazil, fenpyroximate induced significant reduction in the population of leprosies mite *Brevipalpus phoenics* (G) upto 27 days after its application on citrus. Hexythiazox and acrinathrin were however, found superior over fenpyroximate (Raga *et al.*,1996). In apple and pear orchards, fenpyroximate 0.025 per cent gave significant control of *Panonychus ulmi* under field conditions (Curkovic *et al.*, 1997). Fenpyroximate and clofentezine gave good results in summer season against *T. urticae* on strawberry (Antonin *et al.*, 1997). Fenpyroximate, azocyclotin, pyridaben, propargite and tebufenpyrad were found highly effective against the females of *T. viennensis* (z.) while clofentezien and hexythiazox gave very low (3.6 to 14.4 %) control. All these acaricides were observed to be highly effective against the eggs (Cho *et al.*, 1997). In China, Tang and Tang (1998) reported successful control of *T. urticae* on apple by the application of fenpyroximate. Hexythiazox and fenpyroximate when applied in mid-April, were found promising against *T. urticae* attacking apple trees in China (Ma *et al.*, 1998).

Efficacy of fenpyroximate was studied by Stamenkovic *et al.* (1999) in Yugoslavia against *Panonychus ulmi* infesting apple. The acaricide was applied at 0.005 and 0.0025 per cent to the motile mite population ranging between 6.2 to 28.2 per leaf and observations were recorded at 4, 7, 14, 21 and 28 days after the treatment. At both the concentrations, fenpyroximate was found effective and had slightly higher efficacy than the standard chemical, amitraz and considerably higher efficacy than another standard chemical, bromopropylate. The toxicity of some acaricides against

susceptible population of *T. urticae* was determined by Piao *et al.* (1999) using the glass slide and leaf blade residual toxicity method. The toxicity was determined to adult females as fenpyroximate > azocyclotin > chlorfenapyr > dicofol > propargite > pyridaben > amitraz and to eggs as hexythiazon > chlorfenapyr > flufenoxuron > pyridaben > amitraz.

Effectiveness of fenpyroximate was found to be decreased against *T. urticae* in majority of apple orchards in Japan, compared to that when it was introduced. Thus, the development of cross resistance was suggested. Fenpyroximate showed good ovicidal and adulticidal action (Kimura, 1999). Fenpyroximate and fenazaquin showed faster control of motile individuals of *Panonychus ulmi* under field conditions, controlling > 90 per cent population within 3 to 9 days after the application. The control of eggs in apple and pear orchards was > 77 per cent with 0.025 per cent fenpyroximate and 0.005 per cent fenazaquin (Curkovic *et al.*, 1999). Fenpyroximate 200 ml in 500 litres of water gave excellent (> 95 %) control of *T. urticae* infesting apple, pear and flowers in Shanxi, China (Chen, 2000). Fenpyroximate showed good to excellent effectiveness against *T. urticae* infesting greenhouse roses (Tjosvold *et al.*, 2001). The population of false spider mite, *Brevipalpus obovatus* (D.) was reduced by fenpyroximate faster than bromopropylate (Rez$^{k}_{\lambda}$ *et al.*, 2001).

Dispersal behaviour of *T. viennensis* was studied by Xu *et al.*, (1998) wherein, the mite was exposed to various sub-lethal concentrations of fenpyroximate on glass slides and peach branches in the laboratory. The mites were exposed directly to the chemical and its residues. A significant change in dispersal of the mites was observed as concentration of the acaricides increased from LC_5 to LC_{50}. Walk-off was the predominant mode of dispersal.

2.1.4 Resistance

Rotational use of dicofol induced the resistance in *T. urticae* (Rossi and Conti, 1997). A very high degree of resistance in *T. urticae* was noticed in Korea (Goka, 1998) and many fold increase (27.5 fold) in resistance was noticed in China (Kim *et al.*, 1994). Similarly, high resistance in *Panonychus cotri* was also observed in China (Huang *et al.*, 1993). Fenpyroximate resistance in *T. urticae* has been reported in Japan (Funayama & Takahashi, 1995 and Hori, 2001). Resistance in *Panonychus ulmi* has been pointed out in the studies carried out by Iroriatti *et al.* (2000) wherein, no cross resistance was evidenced to the acaricides belonging to the group of mitochondrial electron transport inhibitors.

2.1.5 Phytotoxicity

Dicofol did not show any phytotoxicity to french bean plants (Askari and Zare, 1976). No phytotoxicity symptoms due to fenpyroximate were observed on tomato and cucumber plants grown in glasshouse (Veire *et al.*, 1992). Similarly, fenpyroximate did not cause phytotoxicity to leaves of Japanese pear grown in greenhouse (Izwa, 2001).

2.2 Safety to beneficial arthropods

The studies carried out by Veire *et al.* (1992) indicated that fenpyroximate was found to be harmless to the predator, *Orius niger* without causing any adverse effects on mortality, fecundity and fertility. Exposure of parasitoid, *Encarsia formosa* to 80 ppm dose, did not have any effect on mortality, but the parasitization capacity of the wasp decreased considerably. However, when the wasps were exposed to 40 ppm dose, the parasitization capacity was slightly reduced. The residual contact toxicity of fenpyroximate to predatory mite, *Phytoseiulus persimilis* (AH) was rather less as evidenced by its presence for all the time during experimental period although,

in very limited numbers; as its host, *T. urticae* was significantly reduced by fenpyroximate. Good selectivity to a large number of beneficial arthropods like *Anthocoris nemoralis* and *Typhlodromus pyri* was exhibited by fenpyroximate on apple when sprayed against *Panonychus ulmi* (Decraeke and Sterk, 1992). Fenpyroximate was found to be slightly harmful to the predatory mite, *Typhlodromus pyri* feeding on *Panonychus ulmi* (Sterk, 1994). Pyridaben and fenpyroximate showed neutral side effects on predatory mite, *Amblyseius andersoni* feeding on *Panonychus ulmi*, both in the laboratory and field trials (Forti *et al.*, 1994). During two years of field tests carried out by Pap *et al.* (1994), flufenzin did not exhibit any adverse effect on bees, beneficial insects or predatory mites.

Effect of some acaricides on population of phytoseiid mites and other arthropods on citrus were investigated by Sato *et al.* (1995). Fenpyroximate at 5 g a.i. per 100 litres of water, was found harmful to the predatory mites, leading to a reduction over 80 per cent in the population, 8 days after the treatment. The studies carried out by Park *et al.* (1996) revealed that fenpyroximate was much less toxic to predatory mite, *Amblyseius womersleyi* (*Neoseilus longispinosus*) than to *T. urticae*. Fenpyroximate did not affect hatching of the eggs and development of immature predators. Treng and Kao (1997) evaluated the toxicity of 23 pesticides commonly used in strawberry cultivation, against the larvae of polyphagous predator, green lacewing, *Mallada basalis*. The tested pesticide dosages were equivalent to field dosages. Fenpyroximate was found to be harmless (mortality < 50%) to the larvae. In greenhouse, application of dicofol and fenpyroximate was found to be harmless to the hymenopterous parasitoid-complex of serpentine leaf miner, *Liriomyza trifolii* B. occurring on vegetables in Japan (Saito *et al.*, 1996).

Fenpyroximate and fenazaquin at 0.025 per cent were found toxic to the predatory mite, *Neoseiulus californicus* predating on *Panonychus ulmi* (Curkovic *et al.*, 1997). Similarly, fenpyroximate was observed to be very toxic to *Neoseiulus californicus* and the population density was reduced by 56 to 99 per cent over a period of 13 weeks (Muther, 1998). The side effects of 42 pesticides used in Brazilian citrus orchards on predacious mite, *Iphiseiodes zuluagai* (D & M) were investigated by Reis *et al.* (1998) using residual contact spray method in laboratory. The results revealed that 26 per cent pesticides (eg. clofentezine) were harmless, 14 per cent (eg. abamectin) were slightly harmful, 7 per cent (eg. sulphur) were moderately harmful and 52 per cent (eg. amitraz, dicofol, propargite, fenpyroximate etc.) were harmful. Reis *et al.*, (1999) also studied the side effects of 41 pesticides on phytoseiid mite, *Euseius alatus* D. in laboratory wherein mite mortality and fecundity were evaluated for 8 days. Approximately, 24.4 per cent test compounds (eg. clofentezine) were harmless, 14.6 per cent (eg. abamectin) were slightly harmful, 9.8 per cent (eg. benomyl) were moderately harmful and 51.2 per cent (eg. amitraz, dicofol, fenpyroximate etc.) were harmful.

The population of mite, *Neoseiulus chilenensis* predacious on *Panonychus ulmi* was found to be fairly low in fenpyroximate and other acaricidal treatments (Curkovic *et al.*, 1999). The investigations conducted by Laffi and Brevilacqua (1999) for studying the effects of some acaricides on the predacious phytoseiid mite, *Amblyseius andersoni* (C.) revealed that fenpyroximate and clofentezine were moderately toxic while dicofol and amitraz were highly toxic to the mites. El-Aldewy *et al.* (2000) reported that fenpyroximate was safest in comparison with dicofol for the coccinelid predator, *Stethorus gilvifrons* (M.) while least effective against its prey, *T. urticae*. The acute toxicity studies carried out in Brazil by Sato *et al.* (2002) using

the residual contact method, revealed that the predacious mite, *Neoseiulus californicus* was 2.9 times more tolerant to fenpyroximate than its prey mite, *T. urticae* and was found harmless to the predacious mites.

2.3 Safety to soil microbes

The studies on decay dynamics and mobility property of flufenzin molecules in soil conducted by Ferenczi *et al.* (1998) indicated that flufenzin, by its proper use, did not pose any danger to the soil environment. Even by remaining for too long period, it does not endanger the life of soil-organism. The degradation of fenpyroximate was studied by Izawa *et al.* (1993) in diluvial and volcanic-ash soils under upland laboratory conditions. Fenpyroximate degradation and CO_2 evolution were negligible in sterilized soils during the incubation. It was assumed that fenpyroximate degraded through hydrolysis of tert-butyl ester, isomerization, or cleavage of the oxime ether structure, N-demethylation, oxidation of methyl group at the 3-position on the pyrazol ring and hydroxylation of the phenoxy ring and finally mineralized to CO_2 and/ or bound to soil organic matter. The growth of the bacteria, *Brevibacillus brevis*, used for controlling grey-moulds on tomato and lettuce in liquid culture was not affected by fenpyroximate (White *et al.*, 2001).

2.4 Residues

The residues of flufenzin (SZI-121) were determined by Pap *et al.* (1994) in grape and apple samples by HPLC after second (summer) treatment with flufenzin at a dose of 0.6 L/ha (60 g a. i./ha). The average recovery and the limit of determination were 91.9 per cent and 0.02 mg/kg, respectively. The residues in apple was recorded 0.17 ppm at zero day while 0.04 and 0.03 ppm at 27 and 61 days thereafter, respectively. In grape, 0.35 ppm was recorded at zero day, whereas after 27 and 61 days, it was recorded as 0.12 and 0.06 ppm, respectively.

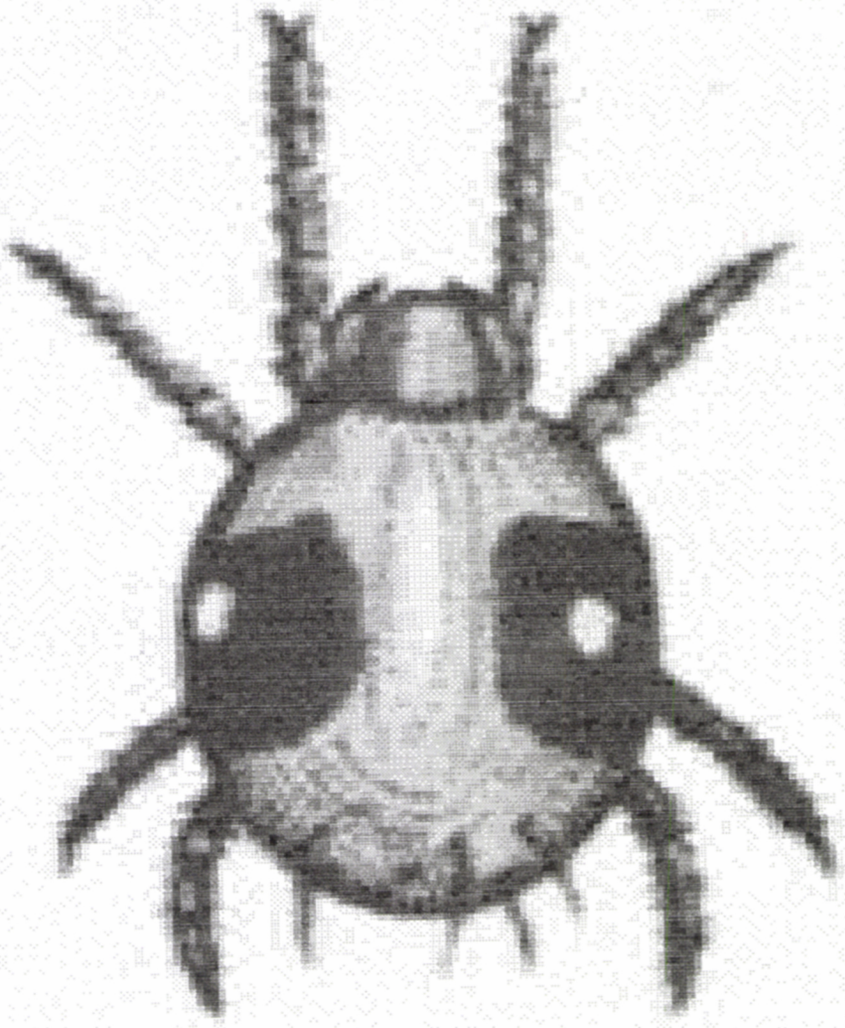
Exposed to light from xenon lamp of spectral intensity and wavelength distribution comparable to that of sunlight, fenpyroximate degraded in neutral aqueous solution with a half-life of 5 h , forming primarily its cis geometric isomer. The degradation of these isomers was also measured and yielded a half-life of 10.5 h. The quantum yield (7.5%) of the photo-transformation, was calculated directly from the absorption spectrum of fenpyroximate, the wavelength distribution of light source and the rate at which degradation occurred. This approach was selected rather than actinometry because it measured all parameters directly, did not depend on the additional assumption inherent in actinometery and required only the parameters already prescribed in the USA's Environmental Protection Agency (EPA) guidelines. The rapid degradation of fenpyroximate and its geometric isomer indicated that, when exposed to sunlight they could not accumulate in an aqueous environment (Swanson *et al.*, 1995).

FAO panel of experts on pesticide residues in food and environment has advocated the use of fenpyroximate along with certain other acaricides against the phytophagous mites, after evaluating the residues in food (Anonymous, 1996). A method, using off-line supercritical fluid extraction (SFE) and micro liquid chromatography (μLC) with UV-detection at 260 nm, was developed by Halvorsen *et al.* (2000) for selective determination of fenpyroximate in apple samples. The packed capillary liquid chromatography method utilizes 20 μL injection volumes with on-column focusing. A 350 x 0.32 mm capillary column packed with romasil 100-CIB was used with a mobile phase acetonitrile and 10 mM ammonium acetate (85 : 15, v/v) at a flow rate of 5 μl/minute. A two-step SFE procedure was used to extract fenpyroximate selectively in 2g apple samples, with Hydromatrix (HMX) added as a water absorbent at 1 : 1 (w : w) ratio.

The volume of the acetonitrile extract was reduced by evaporation and water was added to make a final composition of acetonitrile-water (40 : 60 v/v). The resulting 2.0 ml solution was filtered using a 0.45 µm poly (vinylidene difluoride) syringe filter before µLC analysis. Validation of the method was accomplished with apple samples spiked with fenpyroximate, covering the range of 0.1 to 1.0 µg/kg. Within-day and between-day repeatabilities were in the range of 4-18 per cent relative standard deviation. Accuracy, measured as recovery, was approximately 60 per cent. Apple samples contain fenpyroximate above the quantification level.

Fenpyroximate residues were estimated by Pentareddy (2003) in chilli fruits at the detectability of 0.05 ppm by HPLC equipped with UV-VIS detector. Initial residues of 0.053 ppm due to spray treatment at 12.5g a.i./ha reached below detectable limit of 0.05 ppm at one day after the treatment. Initial residues of 0.081 and 0.121 ppm resulted due to fenpyroximate at 18.75 and 25g a.i./ha, respectively, dissipated to below detectable limit in 1.04 and 3.06 days, respectively. At double the recommended rate i.e. 50g a.i./ha, the initial residues were 0.237 ppm which dissipated to below detectable limit within 5.92 days after the application.

Chapter Three



MATERIAL AND METHODS

3. MATERIAL AND METHODS

The red spider mite heavily attacks the brinjal crop, especially in dry hot months. Present investigations comprised of field and laboratory experiments conducted during 2003-04. The studies were undertaken to evaluate two new selective miticides viz., flufenzin and fenpyroximate for their bioefficacy against the mite, safety for the beneficials and dissipation of residues on brinjal fruits. In bioassay studies, the toxicity of the test acaricides on different life stages of the mite and the relative toxicity (LC_{50} value determination) studies were conducted for the larval and adult stages. The field studies were undertaken on the cultivator fields located in endemic pockets wherein the bioefficacy, the adverse effects of the acaricides on plant growth and the yield were assessed. In safety studies, the impact of the acaricides on the abundance of predatory mites was evaluated under field conditions. Studies on bioassays were under taken for estimating their influence on certain beneficials. The dissipation pattern and the residue status of the test compounds on processed and unprocessed brinjal fruits were also studied. The bioassays were conducted in the Departmental Laboratory while residue analysis was conducted in the Pesticide Residue Research Laboratory.

3.1 Test acaricides

3.1.1 Flufenzin

It is a highly selective miticide discovered initially by Nihon Nohyaku Co. Ltd. which was launched in 1996 as Flumite ® 200 in Hungary (Belgium), by Agro-Chemie Company as a potent acaricide against a broad range of phytophagous mites. It is a new tetrazine analogue having both contact and translaminar mode of action. It is a sort of mite growth regulator (MGR) which inhibits the development of eggs and

premature stages and also acts as a sterilant in egg laying females. Besides its ovicidal action, it exerts a distinct influence on all consecutive life stages and is rather more effective against the varying age-structure population of mites. It does not exert adverse effects on beneficials such as specialized predatory mites (*Phytoseilus* spp., *Amblyseius* spp., *Typhlodromus* spp, etc.) and other phytophagous predators like *Encarsia formosa*; *Cocinella* spp; *Chrysoperla* spp. etc.

Common name : Flufenzin

Chemical name and structure : Given in Fig. 1 (A)

Trade name : Flumite (SZI-121), 200 SC (20%)

Manufacturer : M/s Rotam India Ltd., Mumbai

3.1.2 Fenpyroximate

It is a selective acaricide belonging to pyrazole group. It is contact poison and acts as mitochondrial electron transport inhibitor (METI compound). It gives fast knockdown within a day after the application. Prior to knockdown, the treated mites spin down from leaves and thus, stop feeding and ovipositing. It is active against all developmental stages mainly larvae, nymphs and adults. A good acaricidal performance is seen in between 4 to 7 days after the treatment. It gives a residual control upto 21 to 28 days, when applied at recommended rates. Being non-systemic and translaminar miticide, effective control is achieved when the crop plants are treated with high volume sprayer with thorough foliage coverage. Application of this acaricide, when the mites are in immature or at a susceptible stage and at low population build up gives good control. According to WHO hazard standards, it is slightly hazardous (Class - III). It is relatively gentle to natural enemies and beneficial insects. It has little effect on bees, predatory mites (eg. *Amblyseius longispinosus*),

lacewing, parasitic wasps, ladybug, predatory spiders, predacious thrips (eg. *Scolothrips* spp.), minute pirate bug (eg. *Orius* spp.) etc. at 2 to 4 times of the labeled rate. However, depending on rate, the levels of these mite predators may be suppressed for 1 to 3 weeks, after the application. Application only once in a season is advisible.

Common name : Fenpyroximate

Chemical name and structure : Given in Fig. 1 (B)

Trade name : Fenpyroximate (NNI-850), 5% EC

Manufacturer : M/s Excel Industries Ltd., Mumbai

3.2 Bioefficacy studies

3.2.1 Laboratory bioassays

Culture of the test mite was maintained on potted brinjal plants in the glass house. The test individuals roughly having similar age and size were used for the bioassays. Two separate sets of bioassays were conducted. In first set, laboratory bioefficacy was evaluated on life stages of the test mite viz., egg, larva, nymph and adult while in second set, the relative toxicity was evaluated against larvae and adults. In both the bioassay studies, residual leaf disc dip method was used on more or less similar lines adopted by EI - Banhaway and Reda (1989) and Sannaveerappanvar and ChannaBasavanna (1989).

Initially, brinjal leaf discs of 4 x 4 cm were excised which were later on dipped into respective concentrations of the test acaricide (s) for a period of five seconds. The treated leaf discs were then shed dried for half an hour under ceiling fan at room temperature. Each excised leaf disc was then placed on wet cotton in a petridish wherein, the upper surface of the disc was in contact with the moist cotton. Each of the concentrations was replicated thrice @ ten test-individuals per replicate.

The leaf discs dipped in distilled water were kept as the untreated check. All the excised petridishes were kept at room temperature. Respective observations were recorded under the microscope, per cent mortality was then computed, subjected to arcsine transformation and finally to the statistical analysis. Following bioassays were conducted .

3.2.1.1 Egg stage

Thirty gravid females were placed on each excised untreated leaf disc and they were left for 12 h to oviposit and removed thereafter. Then the eggs were counted from each of the leaf discs. The leaf discs containing eggs were dipped in the respective concentration of the test acaricide for five seconds and were allowed to dry. The observations were recorded on the number of eggs that failed to hatch, seven days after the treatment.

3.2.1.2 Larval stage

The eggs were obtained on separate untreated leaf discs, in a similar manner as mentioned in para 3.2.1.1 and were allowed to hatch into larvae. Ten freshly emerged larvae were placed on each of the excised treated leaf discs with the help of a fine camel's hair brush. Observations on number of alive and dead larvae were recorded 72 h after the treatment application.

3.2.1.3 Nymphal stage

Two separate sets of experiments were undertaken for the two distinct nymphal instars wherein, freshly emerged protonymphs and duetonymphs @ ten individuals per replicate were placed on each of the excised treated leaf discs with the help of the fine hair brush. Observations on number of alive and dead nymphs were recorded 72 h after the treatment.

3.2.1.4 Adult stage

Ten adult individuals of mixed sexes were placed on each of the excised treated leaf discs with the help of fine hair-brush. Observations on alive and dead adults were recorded 72 h after the treatment application.

3.2.1.5 Relative toxicity

Before finalizing the desired concentrations to be tested for the present studies, pilot concentrations for each of the test acaricide were prepared in geometric range in accordance with the recommended concentration. The series of concentrations were evaluated against the test individuals to observe the mortality tending towards lower and higher sides. Based upon the mortality parameter in respect of these pilot concentrations, seven concentrations were ascertained for each test acaricide. Stock solution of 100 ml for each test acaricide was prepared in distilled water and a test series of 50 ml for each concentration was prepared from each of the stock solutions.

Two separate sets of experiments were undertaken for larval and adult stage. Freshly emerged test individuals were released on each of the excised treated leaf discs, @ ten per replicate. Observations on alive and dead individuals were recorded 72 h after the treatment. The per cent mortality was calculated, corrected by using the formula advocated by Abbott (1925) and the data were subjected to probit analysis described by Finney (1971). The toxicity ratio was worked out for each of the test acaricide, after computing the LC_{50} value.

3.2.2 Field experiment

Two experiments were conducted one in *kharif*, 2003 and another in summer, 2004 to evaluate the field bioefficacy of the test acaricides on cultivator's field located in endemic pockets at village Nandur and Warwandi belonging to Rahuri Tahsil, respectively.

Table 1: Treatment details

Sr. No.	Treatments	Dose (g a.i./ha)	Conc. (a. i.)		Product (ml/L)
			(%)	(ppm)	
1	Flufenzin, 200 SC (20%)	60	0.012	120	0.6
2	Flufenzin, 200 SC (20%)	80	0.016	160	0.8
3	Flufenzin, 200 SC (20%)	100	0.020	200	1.0
4	Flufenzin, 200 SC (20%)	200	0.040	400	2.0
5	Fenpyroximate, 5% EC	15	0.003	30	0.6
6	Fenpyroximate, 5% EC	20	0.004	40	0.8
7	Fenpyroximate, 5% EC	25	0.005	50	1.0
8	Fenpyroximate, 5% EC	50	0.010	100	2.0
9	Dicofol, 18.5% EC	250	0.050	500	2.7
10	Untreated control	-	-	-	-

Fig. 1 (A) Flufenzin

Chemical name : 3-(2- chlorophenyl)-6-(2,6-difluorophenyl)– 1,2,4,5 – tetrazine

Molecular formula : $C_{14}H_7ClF_2N_4$

Structural formula :

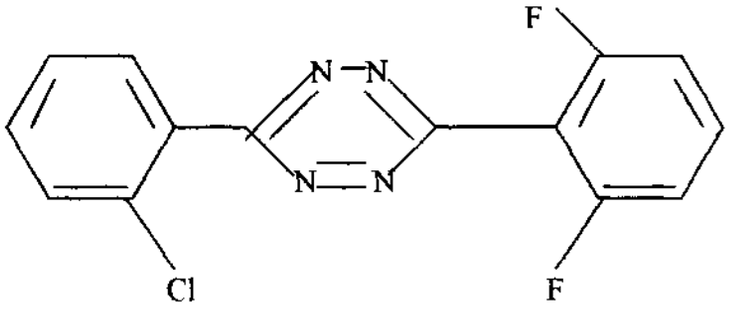


Fig. 1 (B) Fenpyroximate

Chemical name: tert-butyl (*E*)-E- (1,3-dimethyl-5-phenoxypyrazol-4-ylmethylneamino-oxy)-p-toluate

Molecular formula : $C_{24}H_{27}N_3O_4$

Structural formula :

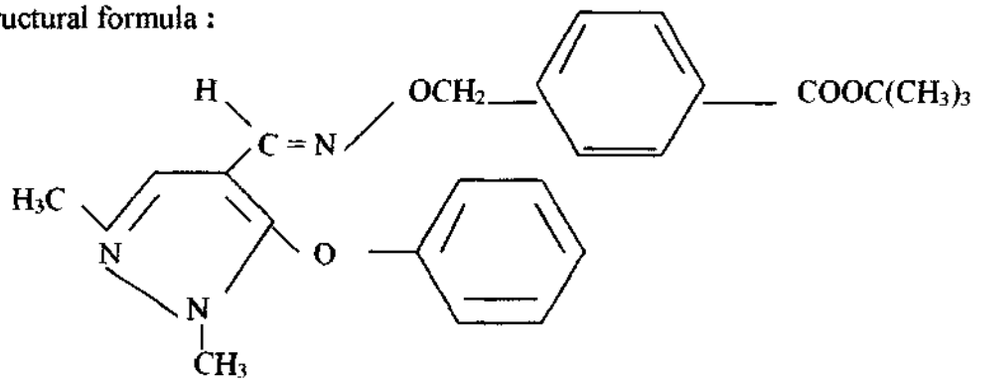
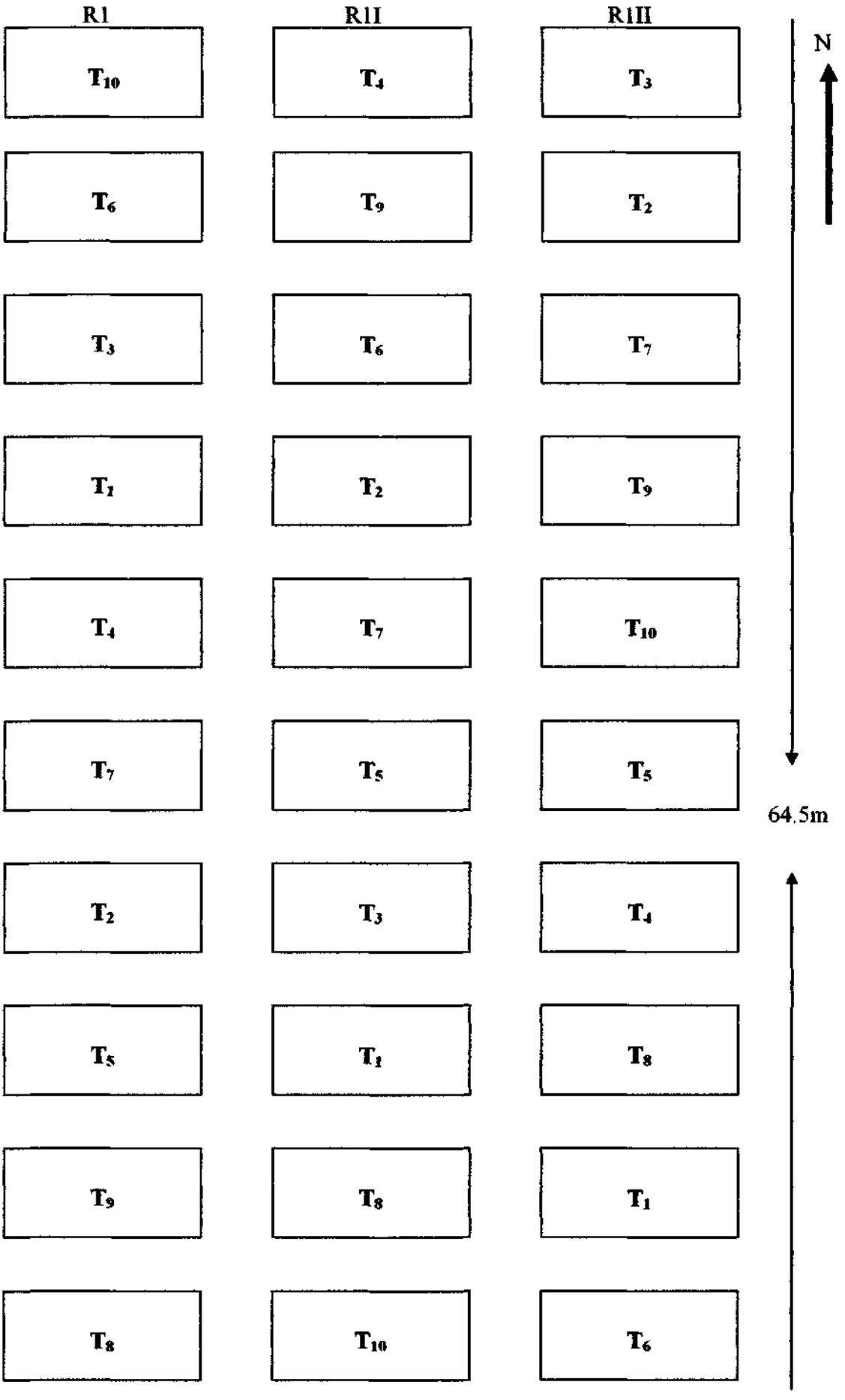


Fig. 1 Chemical and structural formulae of the acaricides

T-6009



Gross Plot Size : 7.2 m x 6.0 m Plant spacing : 0.75 m x 0.60 m

Fig. 2 Plan of layout

The experiments were conducted in randomized block design (RBD), each consisting of ten treatments with three replications (Fig.2). Out of ten treatments, the treatments with the highest dosages of flufenzin at 200 g a. i./ha and fenpyroximate at 50g a.i./ha were not considered for the bioefficacy and impact studies which, however were incorporated only for the residues studies. One-month-old seedlings of brinjal, variety *Krishna* were transplanted on 20-04-2003 (*kharif*) and 15-11-2003 (summer), each having the net plot size of 6.0 x 4.5 M with 0.75 x 0.60 M spacing. Each plot had about sixty plants. Except the pesticides, all other crop management practices were followed as per the local recommendations and no acaricide was applied so that there was natural mite infestation. The treatment details are given in Table 1. The treatments were applied as foliar sprays at the middle of the fruiting phase of the crop, synchronizing with the evenly distributed moderate to high infestation of mite in the field alongwith fair build-up of natural population of predatory phytoseiid mites. During the entire course of the investigations, two rounds of foliar spray applications were given at an interval of 21 days. Manually operated high volume knapsack sprayer at fluid discharge rate of 500 L/ha was used for spraying. The observations pertaining to different aspects were recorded.

3.2.2.1 Effectiveness against mite

Five plants were randomly selected and tagged from each of the experimental net plots, excluding the border rows. On every pre-selected plant, three fairly uniform leaves one each from top, middle and bottom canopy were selected and tagged. The motile mite population was counted on both upper and lower surfaces of the leaves, by using magnifying lense (10x). A pretreatment count was recorded just before the spray application. The post treatment counts were recorded at 1,3,5,7,9,11,13,15 and 21 days after the treatment (DAT), during the early hours of the day, when fairly low

mite activity was observed. The data on surviving population of the mite were transformed to square root value $(n + 1)^{1/2}$ to stabilize the heterogeneous variances. The transformed data for respective dates were analysed as a randomized block design. The means of three replicates were compared by using the least significant difference (LSD) test at possibility of 5 per cent to decide the significance of individual treatment effect.

3.2.2.2 Phytotoxic effect

The observations were recoded in each of the experimental plots in respect of phytotoxicity symptoms, if any on brinjal plants. After the spray application, effect on crop health was evaluated by recording observations on leaf tips and surface, wilting, vein clearing, necrosis and epinasty and hyponasty. The observations were recorded at 0, 1, 2, 3, 5, 7, 9, 11, 13, 15 and 21 days after the treatment application by using zero to ten scale.

3.2.2.3 Effect on fruit yield

The yield data of marketable fruits from each picking were summed up from each of the experimental net plot and the data were subjected to statistical analysis. The merit of the test acaricides was evaluated on the basis of the prevailing mite infestation, the cumulative mean yield and the per cent increase yield over untreated check.

3.3 Safety studies

Conservation of beneficial fauna and flora prevailing within the brinjal ecosystem is of immense importance. The impact of the test acaricides on safety of beneficial arthropods was evaluated by selecting certain representative organisms. Two distinct sets of experiments (*viz.*, laboratory and field) were carried out for observing their adverse effects.

3.3.1 Impact on abundance of predatory mites

The number of motile predatory mites (phytoseiid spp. complex) was counted on the same tagged leaves from the pre-selected plants within the experimental field during *kharif*, 2003. The counts were taken prior to the treatment application and also on 3,7,14 and 21 days thereafter. The data on counts in respect of each of the evaluation dates were transformed to square root $(n + 1)^{1/2}$ value to correct the heterogeneous variances. The transformed data were analysed statistically and the mean of three replicates was compared by using LSD at the probability of 5 per cent to decide the significance of individual treatment effect.

3.3.2 Impact on beneficials under laboratory condition

The influence of the test acaricides on the representative beneficials *viz.*, the predatory mite, green lacewing, forager honeybee, earthworm and the soil microbial activity was studied. The test concentrations of acaricides were similar to those in field experiments..

3.3.2.1 Predatory mite

The culture of a predatory phytoseiid mite, *Amblyseius* spp. was maintained on its prey mite, *T. cinnabarinus* on potted brinjal plants within the glasshouse. The bioassays were carried out on adults of the predatory mite, using the residue leaf disc dip method described in para 3.2.1. Ten adults of mixed sexes having nearly similar size were used as the test individuals per replicate. There were eight treatments, which were replicated thrice. Observations on alive and dead individuals were recorded under the microscope 72 h after the treatment application. The per cent mortality was computed, subjected to arcsine transformation and then to statistical analysis. The means of three replicates were compared by using the LSD at the probability of 5 per cent to decide the significance of individual treatment effect.

3.3.2.2 Lacewing

The eggs of the green lacewing, *Chrysoperla carnea* Stephens were procured, allowed to hatch and the first instar grubs of similar age and size were used as the test individuals. Initially, the *Corcyra* eggs for feeding to lacewing grubs, were sprayed with the test concentrations separately and were shed dried within the laboratory. A test tube of 20 x 5.5 cm size was taken and one hundred treated eggs alongwith ten test individuals were introduced in it. After one day feeding, the grubs were fed with the untreated *Corcyra* eggs.

The experiment was consisting of eight treatments. Each of the concentrations / treatments alongwith the untreated check was replicated thrice. All the experimental test tubes were kept at room temperature for 72 h in the laboratory. On the basis of dead and alive grubs, the per cent mortality was worked out, subjected to arcsine transformation and analysed statistically. To decide the significance of individual treatment effect, the means of three replicates were compared by using the LSD at the probability of 5 per cent.

3.3.2.3 Forager honeybee

The forager worker honeybees, *Apis cerana indica* Fabricius were obtained from the Central Bee Research and Training Institute, Pune. The relative toxicity of the test acaricides was tested by using the contact filter paper technique, as carried out by Muranjan (2000). The Whatman No. 1 filter paper was dipped in the solution of the test concentration and fully soaked paper was taken out. Then it was further allowed to dry for about one hour under ceiling fan at room temperature. The filter paper circle was then placed in 90 mm petridish and ten forager worker honeybees were released in dish and immediately, the dish was covered by placing the lid. Prior to release, the bees were immobilized by keeping in plastic bag, which was chilled in

a refrigerator at 3^0 C for about two minutes. The bees were allowed to recover from the effect of chilling and then the treated filter paper circle was taken out very carefully, without disturbing the bees. The bees were fed with forty per cent sugar solution in water on cotton swab. Each of the test concentrations / acaricides was replicated thrice @ ten test individuals per replicate. Similarly for comparison, ten bees were exposed to the filter paper dipped in distilled water, which was kept in petridish. This untreated check was replicated thrice. All the petridishes were kept at room temperature for 24 h for recording the post treatment observations. The numbers of dead and alive bees were counted. Moribund bees were considered as dead. The per cent mortality was computed subjected to arcsine transformation and then analysed statistically. The means of three replicates were compared by using the LSD at the probability of 5 per cent to decide the significance of individual treatment effects.

3.3.2.4 Earthworm

Adults of the earthworm *Eisenia foetida* (Sav.) having similar age, size and weight were procured and the relative toxicity was tested by using the contact filter paper test, advocated by the United States Environmental Protection Agency (EPA) and on the similar lines carried out by Naik (2001). The piece of Whatman No. 1 filter paper of 7 x 8 cm size was dipped in the solution of the test concentrations. The wet paper was taken out and then it was allowed to dry for about one hour, under the breeze of ceiling fan air at room temperature. The excised filter paper was placed in 8 x 3 cm size glass vial and the paper was then rewetted with 2 ml deionised water with the help of a syringe. Before exposing the earthworms to the excised filter paper, the worms were washed and placed in between sheets of moistened paper towel for one hour. A single worm was placed in each of the vials and then the vials were

closed with muslin cloth entwined by rubber band. The procedure followed was similar to all the test concentrations/ acaricides. There were eight treatments, replicated thrice and each replicate was consisting of ten such vials @ one worm per vial. All the experimental vials were kept in dark chamber at room temperature for 48 hr exposure period. The mortality of the worms was recorded in each of the replicate. The worms were considered dead when they did not respond even to gentle mechanical stimulus at front end. The per cent mortality was computed, subjected to arcsine transformation and then to statistical analysis. To decide the significance of individual treatment effect, the mean of three replicates was compared by using the LSD at the probability of 5 per cent.

3.3.3 Effect on soil-microbial activity

Microbial biomass carbon in soil is an indicator of soil microorganism activity. Soil microorganisms play a key role in the release and retention of nutrients in soil. The depletion in the levels of biomass carbon (and other nutrients contained therein) may result from the reduced activity of soil microorganisms affected by harmful chemicals. A simple fumigation- extraction procedure for direct measurement of carbon in microbial biomass supplied by the Project Co-ordinator, AICRP on Pesticide Residues was employed for the present investigations to assess whether foliar sprays on crop influenced the activity of soil microbial biomass. Procedure for microbial biomass carbon (MB-C) estimation was as below.

The reagent used were distilled chloroform; concentrated H_2SO_4; 0.5 M K_2SO_4 (dissolved 43.563 g K_2SO_4 to 500 ml distilled water); 0.2 M $K_2Cr_2O_7$ (dissolved 0.9808 g $K_2Cr_2O_7$ to 100 ml distilled water); orthophosphoric acid; 0.005 M ferrous ammonium sulphate (dissolved 3.92 g FAS and 0.15 ml H_2SO_4 to 2 litres of distilled water) and ferroin indicator.

Three cores of moist soil were collected 28 days after the last treatment application from each plot and pooled to make one representative 500 g soil sample per plot. The samples were taken to laboratory in plastic bags. The individual soil sample was pulverized, mixed and passed through No. 10 (2 mm mesh) sieve. Five sets per sample, each containing 10 g of soil were prepared on the day of its collection for further assays. One set was oven dried at 100^0C for 24 h for determining the moisture content. Two sets were stored in refrigerator at 15^0C for next day extraction. The remaining two sets were taken in 50 ml beakers. The beakers containing acid washed (ethanol-free) chloroform @ 20 ml/10 g soil and the soil sample were placed in desiccator of which inner side was lined with moistened filter paper. The desiccator was made oxygen free by applying vacuum sealed properly to prevent air passage and was kept in the dark for 24 h fumigation.

Next day, fumigated and unfumigated soil samples were removed from the desiccator and refrigerator, respectively. The soils were thawed and transferred to 250 ml GG-stoppered conical flask. Twenty-five ml of 0.5 M K_2SO_4 was added to each flask and the flasks were shaken for 30 min on mechanical shaker. After shaking, contents were filtered through Whatman No. 1 filter paper and 10 ml filtrate per sample was poured into 500 ml boiling flask. The reagents *viz.*, 2 ml of 0.2 M $K_2Cr_2O_7$, 10 ml concentrated H_2SO_4 and 5 ml orthophosphoric acid were added to each filtrate. Two blanks were processed in a similar manner.

The contents of flask were refluxed at 100^0C for half an hour on hot plates. Flasks were removed and 250 ml water was added immediately in each flask. After cooling to room temperature, 2 to 3 drops of ferroin indicator were added and the contents were titrated against 0.005 M FAS to brick- red end point. Determinations

of extractable microbial biomass carbon (MB-C) in soil were calculated using specified formulae and were expressed as µg/g soil.

3.4 Residue analysis

The test acaricides *viz.*, fenpyroximate (@ 25 and 50 g a.i./ha) and flufenzin (@ 100 and 200ga.i/ha) were evaluated in the present investigation for studying their dissipation pattern and the residual status on brinjal fruits under both processed and unprocessed conditions. The samples of the fruits from the field experiment conducted during *kharif*, 2003 were collected from both treated and untreated check. Pesticide residues were analysed in edible quality fruits collected periodically after the last spray to decide the safety of treatments to consumers. Fruit samples from each plot were collected at an interval of 0 (1h), 1, 3, 5, 7 and 10 days after the last treatment application and subjected to analysis by extraction, cleanup and estimation as described under each compound.

3.4.1 Fenpyroximate

3.4.1.1 Extraction

Fenpyroximate residues were extracted as per the protocol supplied by M/S Excel Industries Ltd, Mumbai.The sample fruits were chopped into pieces and mixed thoroughly, from which a representative 50 g sample was taken. It was homogenized in a tissue homogenizer with acetone as extraction solvent. Initially, the sample was extracted with 100 ml solvent and vacuum- filtered through Buchner funnel, using Celite filter aid. The filter cake was then re-extracted with 50 ml acetone rinsing the blender jar and filter bed with 50 ml additional acetone for complete extraction. The combined extract was concentrated to about 20 ml on rotary vacuum evaporator at 40^0C with chilled water circulation.

3.4.1.2 Cleanup

After transferring to 500ml separatory funnel, the extract was diluted with 200 ml of 10 per cent acqueous sodium chloride solution. The solution was partitioned with 100 ml of dichloromethane by vigorous shaking for two minutes. After separation of the phases, the lower organic phase (dichloromethane) was collected. The dichloromethane containing the residue was filtered and dried through a funnel overlaid with anhydrous sodium sulphate on cotton wool to make it free from traces of water. The process was repeated twice with additional 50ml of dichloromethane. The combined dichloromethane was concentrated to near dryness. The concentrated dichloromethane extract (approximately 3 ml) was subjected to cleanup by column chromatography using Florisil as adsorbent. The extract was loaded on the top of the column and allowed to percolate down. Soon after, the analyte was eluted with 100 ml acetonitrile into 500 ml round- bottomed flask and reduced to dryness on rotary vacuum evaporator at 40^0C. The residue was dissolved in 5 ml of HPLC- grade acetonitrile for injecting into HPLC system. Prior to injection, the sample extract was filtered through hydrophilic membrane of 0.45 µm pore size fitted in 10ml syringe with Luer-Loktip.

3.4.1.3 Estimation

Residue were determined by using Shimadzu High Performance Liquid Chromatograph (HPLC) equipped with LCD-10 AT pump and SPD-10A UV-VIS detector (sensitivity-0.01A.U.F.S.) connected to Shimadzu C-R6A integrator. The column was RP-18 CLS-ODS-m (25 cm length x 4.6mm i.d.). The mobile phase used was 20 per cent water in acetonitrile, isocratic at a flow rate of 1.2 ml per minute. The UV detector was operated at 235 nm. The volume injected was 20 µl, using fixed loop Rheodyne injector. The retention time was 11.65 ± 0.15 minutes. Signals from detector were recorded on integrator and responses are reported as relative response

(peak height for test compound versus peak height for standard) per microgram of compound. The residue levels are expressed as mg/kg (ppm) and the limit of detection (LOD) was considered as 0.05 ppm.

The data on dissipation of residues on fruits were subjected to statistical method suggested by Hoskins (1961) to work out the RL_{50} (residue half-life in days: time required for a residue to decrease by half) and T_{BDL} (days required for the residue to reach below detectable limit of 0.05 ppm).

3.4.2 Flufenzin

3.4.2.1 Extraction

Flufenzin residues were extracted as per the protocol supplied by M/S Rotam India, Mumbai. The sample fruits were chopped into pieces and mixed thoroughly. The fruit sample weighing 50 g was blended with 10-12 ml water in tissue homogenizer. Ten gram homogenate was made into free flowing powder in mortar by adding enough Celite 545 filter aid and by grinding with pestle.

3.4.2.2 Cleanup

The free flowing powder was transferred into glass column (300 x 18 mm i. d.). The column was tapped gently, each time the powder added for uniform loading. The mortar and pestle was rinsed with 20 ml extracting solvent (hexane plus dichloromethane @ 7 : 3 ratio) and the solvent mixture was poured onto the column. The flow rate was adjusted to 5 ml per minute. The extraction was completed with another 100 ml extracting solvent. The solvent was collected in round-bottomed flask and the extract was concentrated to 0.5 ml on rotary vacuum evaporator. Three ml of hexane was added to round bottom flask and the extract was taken in 15ml graduated test tube. The extract in test tube was concentrated after

adding 1 ml methanol. The final extract after adjusting to 1.0 ml was sonicated and filtered through 0.45 µm membrane filter for injection on HPLC.

3.4.2.3 Estimation

Residues were determined on Shimadzu High Performance Liquid Chromatograph (HPCL) with SPD-10A UV-VIS detector at 270 nm wave length. The chromatograms were plotted on Shimadzu C-R6A data integrator. The column was RP-18 CLS-ODS (250 X 4.6 mm i.d.). The mobile phase was methanol plus water at 75:25 ratio at a flow rate of 1.0 ml per minute. The volume injected was 20 µl, using fixed loop Rheodyne injector. The retention time was 11.65 ± 0.15 minutes. Signals from detector were recorded on integrator and responses are reported as relative response (peak height for test compound versus peak height for standard) per microgram of compound. The residue levels are expressed as mg/kg (ppm) and the limit of detection (LOD) was considered as 0.05 ppm. The data on dissipation of residues on fruits were subjected to statistical method suggested by Hoskins (1961) to work out the RL_{50} and T_{BDL}

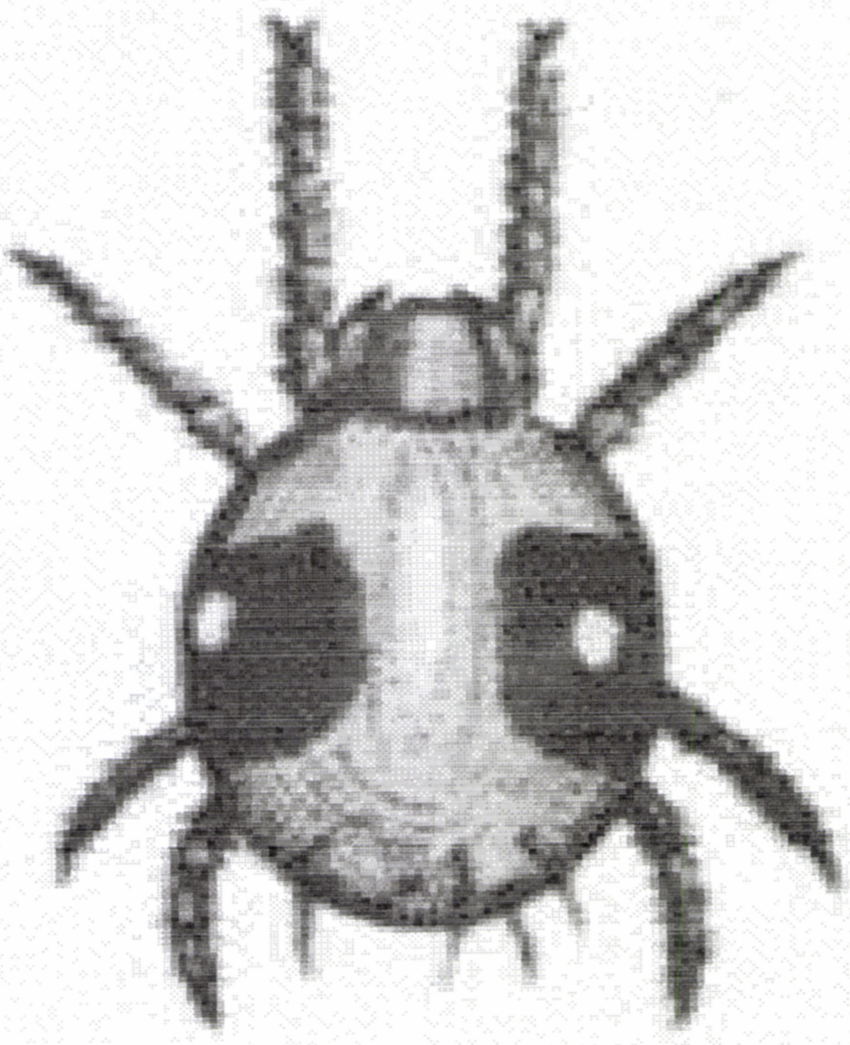
3.4.3 Recovery studies

The recovery percentage for flufenzin from brinjal fruits was determined by fortifying 20 and 50µg of flufenzin standard of 500 ppm concentration to 50g chopped fruits. Similarly, fenpyroximate recovery percentage was studied by fortifying 100 and 200 µg of active ingredient by applying 2-4 ml of 50 ppm standard to 50 g chopped fruits. Another 50 g sample portion was taken as blank. After few minutes, the samples were analysed following the analytical procedure prescribed earlier. Per cent recoveries were calculated as the difference between the amount of fenpyroximate / flufenzin found in the fortified sample and in the control sample.

3.4. 4 Effect of processing on reduction of residues

Fruit samples harvested at O (1 h) day after the last spray application were subjected to distinct home processes. One was only washing of fruits with tap water and another was washing followed by cooking. The samples were analysed following the procedure mentioned earlier.

Chapter Four



EXPERIMENTAL FINDINGS

4. EXPERIMENTAL FINDINGS

The present investigations comprising of field experiments and bioassasys were designed to evaluate the test acaricides (*viz.*, flufenzin and fenpyroximate) against the phytophagous mite *T. chinnabarinus* for bioefficacy and also to study the impact of acaricides on beneficial arthropods. Residue analyses were carried out to study the dissipation pattern of the residues and to study the effect of household processes for reduction of rešidues. The data generated from all these experiments were processed statistically and the findings based on the same are presented in this chapter.

4.1 Bioefficacy studies

Both laboratory bioassays and field experiments were conducted to evaluate the bioefficacy of the test acaricides, the results are presented below.

4.1.1 Laboratory bioassays

The bioassays were carried out for each of life-stages of the test mite, using residual leaf-disc-dip method. The results are given as under.

4.1.1.1 Toxicity to eggs

The data on mean reduction in hatching are presented in Table 2. The data indicated that all the acaricides resulted in significant reduction in egg-hatching, conforming an ovicidal action of the test compounds. Flufenzin 100 and 80 g a.i./ha was found significantly superior over rest of the acaricides. The lower dose of flufenzin i.e. 60 g a.i./ha was found on par with dicofol at 250 g a.i./ha, the standard check. The lowest dose of fenpyroximate at 15 g a.i./ha comparatively had less effect on hatching (45.90% decrease), whereas, its high doses were observed to be significantly superior (62.80 to 74.90 % reduction). The relative toxicity to egg in the descending order was observed as flufenzin > dicofol> fenpyroximate. Thus, flufenzin

Table 2 : Bioassay studies on the acaricides against mite, *Tetranychus cinnabarinus* on brinjal

Sr. No.	Acaricide	Dose g a.i./ha	Effect of acaricide treatments on mite-life stage (s)												
			Egg			Larva			Nymph					Adult		
			Eggs tested (No.)	Decline in hatching (%)		Larvae tested (No.)	Larval mortality (%)		Each instar nymphs tested (No.)	Protonymph mortality (%)		Duetonymph mortality (%)		Adults tested (No.)	Adult mortality (%)	
				A	T		A	T		A	T	A	T		A	T
1	Flufenzin	60	40.00	83.70	66.27	30	73.30	58.94	30	76.70	61.15	81.10	64.25	30	31.30	33.25
2	Flufenzin	80	38.00	93.10	74.88	30	84. 15	66.29	30	80.00	63.47	84.40	66.79	30	36.70	37.25
3	Flufenzin	100	41.70	99.30	85.95	30	93.30	75.37	30	83.30	65.97	87.80	69.60	30	38.90	38.58
4	Fenpyroximate	15	38.30	45.90	42.65	30	88.90	71.22	30	90.00	71.73	83.30	65.97	30	91.10	72.71
5	Fenpyroximate	20	37.00	62.80	52.44	30	95.60	77.52	30	93.70	75.37	90.00	71.73	30	95.60	78.02
6	Fenpyroximate	25	38.70	74.90	59.94	30	100.0	88.19	30	97.80	82.45	93.30	75.37	30	98.90	85.30
7	Dicofol	250	39.30	85.60	67.86	30	86.70	68.93	30	94.40	75.44	90.00	71.73	30	94.40	76.51
8	Untreated control	-	40.70	8.30	17.01	30	2.20	7.58	30	3.30	9.09	2.20	7.47	30	2.20	7.58
F	:				Sig.			Sig.			Sig.		Sig.			Sig.
LSD (5%)	:				4.18			5.14			6.96		5.50			5.41

A : Observed count T : Arcsine transformed value

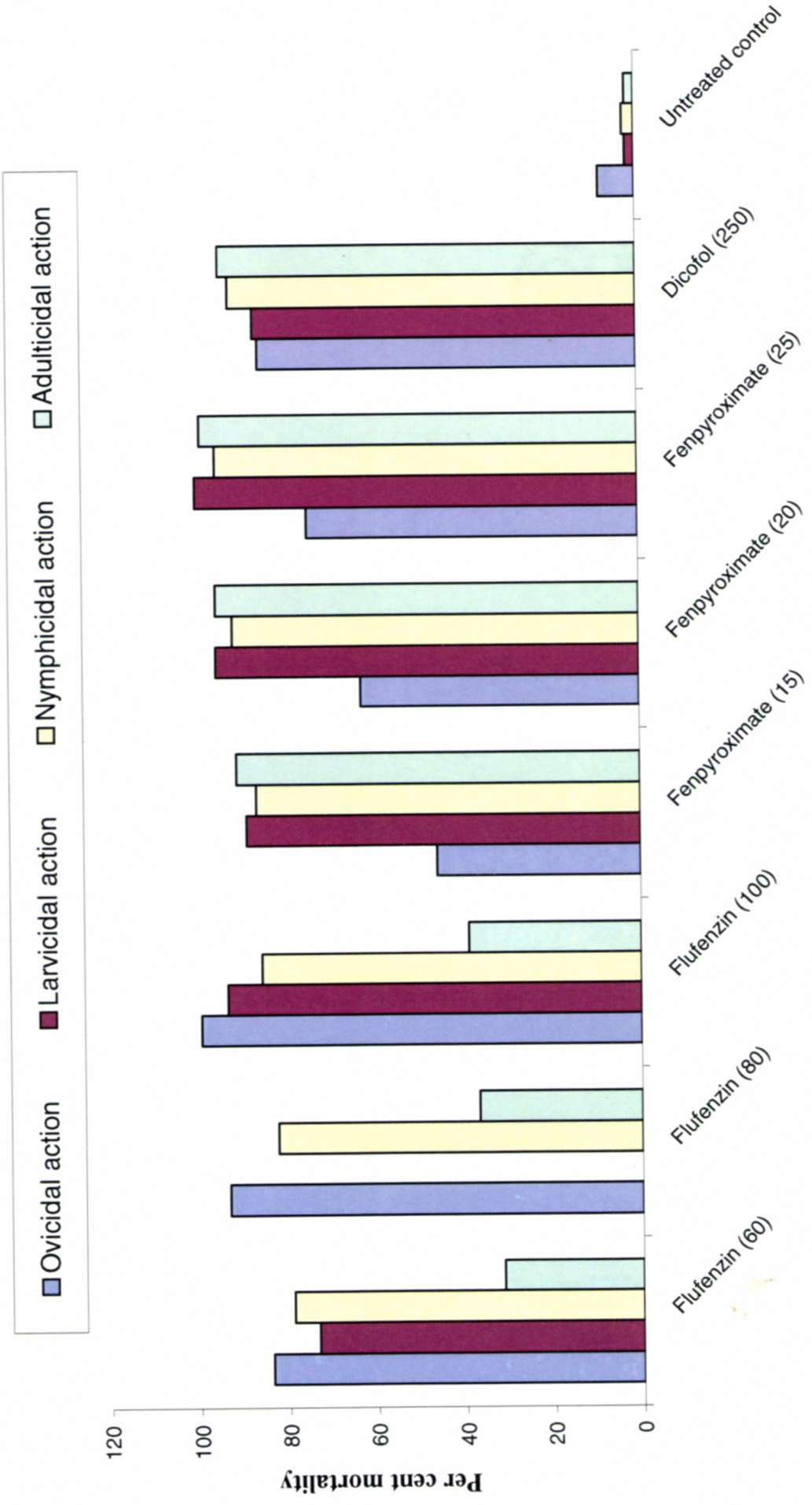


Fig. 3 Effect of acaricides on life-stages of mite

was found to be an excellent contact ovicide giving 83.70 to 99.30 per cent mortality. The standard check, dicofol also showed good ovicidal effect (85.60%) while moderate effect was noticed in fenpyroximate (45.90 to 74.90%). Further, the data on mean number of eggs laid in different acaricides were in the range of 37.0 to 41.70 egg while for the untreated check, it was 40.70 eggs. This indicated that, none of the acaricides exhibited any oviposition inhibition effects on the egg-laying female.

4.1.1.2 Toxicity to larvae

The data on mean larval mortality obtained in different treatments are presented in Table 2. All the acaricides significantly showed good larval mortality which was in the range of 73.30 to 100 per cent. The highest dose (25 g a.i./ha) of fenpyroximate was found significantly superior amongst all, exhibiting cent per cent mortality. The dose of fenpyroximate, 20 g a.i./ha was observed to be on par with the highest dose i.e. 100g a.i./ha of flufenzin. The lower dose of fenpyroximate (15 g a.i./ha), intermediate dose of flufenzin (80 g a.i./ha) and the standard check, dicofol (250 g a.i./ha) were found statistically on par, recording the larval mortality between 84.15 to 88.90 per cent. The lowest dose (60 g a.i./ha) of flufenzin, although relatively less effective exhibited 73.30 per cent larval mortality. the relative toxicity to larvae was in the order of fenpyroximate > flufenzin > dicofol.

4.1.1.3 Toxicity to nymphs

Two distinct bioassays were conducted separately to study the bioefficacy on both protonymphs and duetonymphs of the test mite.

4.1.1.3.1 Efficacy of protonymphs

The data on mean nymphal mortality are presented in Table 2. All the acaricides were found significantly superior in causing nymphal mortality. The treatment of fenpyroximate at 25 g a.i./ha was observed to be most superior giving

97.80 per cent mortality. Its remaining two doses and the standard check, dicofol were observed statistically in similar range (90.0 to 94.4% mortality). The nymphal mortality in flufenzin treatment ranged between 76.70 and 83.30 per cent and were on par with each other.

4.1.1.3.2 Efficacy on duetonymphs

All the acaricides were observed significantly efficient in causing the nymphal mortality (Table 2). The highest (25 g a.i./ha) dose of fenpyroximate recorded 93.3 per cent mortality and was found to be significantly superior followed by its intermediate dose (20 g a.i./ha) and dicofol (250 g a.i./ha). The mortality in the lowest dose of fenpyroximate (15 g a.i./ha) and all the three dosages of flufenzin ranged from 81.10 to 87.80 per cent and were observed to be statistically on par. In comparison with fenpyroximate and dicofol, flufenzin showed relatively low nymphicidal action.

Thus, the results in respect of bioefficacy against protonymphs and duetonymphs indicated that fenpyroximate and dicofol were equally effective and gave excellent mortality while flufenzin was moderately effective.

4.1.1.4 Toxicity to adults

The data on adult mortality are presented in Table 2. The data revealed that all the acaricides were significantly superior over untreated control in causing adult mortality. The highest dose of fenpyroximate (25 g a.i./ha) was found to be significantly most effective in killing the adults (98.90 % mortality). Its intermediate dose (20 g a.i./ha) and dicofol (250 g a.i./ha) were at par, followed by the lowest dose of fenpyroximate (15 g a.i./ha). On the other hand, all the dosages of flufenzin which were on par with each other exhibited the kill in the range of 31.30 to 38.90 per cent. The highest dose of flufenzin (100 g a.i./ha) recorded moderate kill of adults (38.90%) indicating its poor performance against the adults. The relative toxicity to adults was

fenpyroximate > dicofol> flufenzin. Thus, fenpyroximate and dicofol were found to be promising adulticides.

4.1.2 Dose-mortality response assays

Two separate bioassays were conducted for estimating the LC_{50} values of the acaricides for larval and adult stages of the test mite. There were significant differences in LC_{50} values for both the stages in respect of the acaricides. The non-significant Chi-square (χ^2) values of the data indicated homogeneity and good fit to probit model. The data are presented in Table 3 & 4 and Fig. 4 to 6.

The LC_{50} values for larvae in respect of fenpyroximate, flufenzin and dicofol were 2.1591, 0.5704 and 166.2499 ppm whereas for adults, the LC_{50} values were 4.3686, 1153.5680 and 309.1889 ppm, respectively. The order of toxicity to larvae was flufenzin > fenpyroximate > dicofol while to adults it was fenpyroximate > dicofol > flufenzin. Thus, fenpyroximate showed excellent larval and adult mortality while dicofol exhibited moderate action against larvae and adults. Flufenzin showed excellent larvicidal action, on the contrary, it was relatively ineffective to adults, as also evidenced under filed experiments.

4.1.3 Field bioefficacy

Field studies were conducted during two different seasons *viz., kharif*, 2003 and summer, 2004 to assess bioefficacy of the acaricides against the mite on brinjal. There were two treatment applications given at an interval of 21 days. Simultaneously, the phytotoxic effect, if any and the yield was also recorded. The observations on surviving motile mite populations were recorded at every alternate day starting from one day after the treatment application (DAT) till 15 days and lastly at 21 DAT. The mean pre-treatment population of motile mite per leaf was found in the range of 237.9 to 257.57 in *kharif* season while it ranged between 179.10 and 186.90 in the summer season.

Table 3 : Relative toxicity of the acaricides to larval stage of mite, *Tetranychus cinnabarinus*

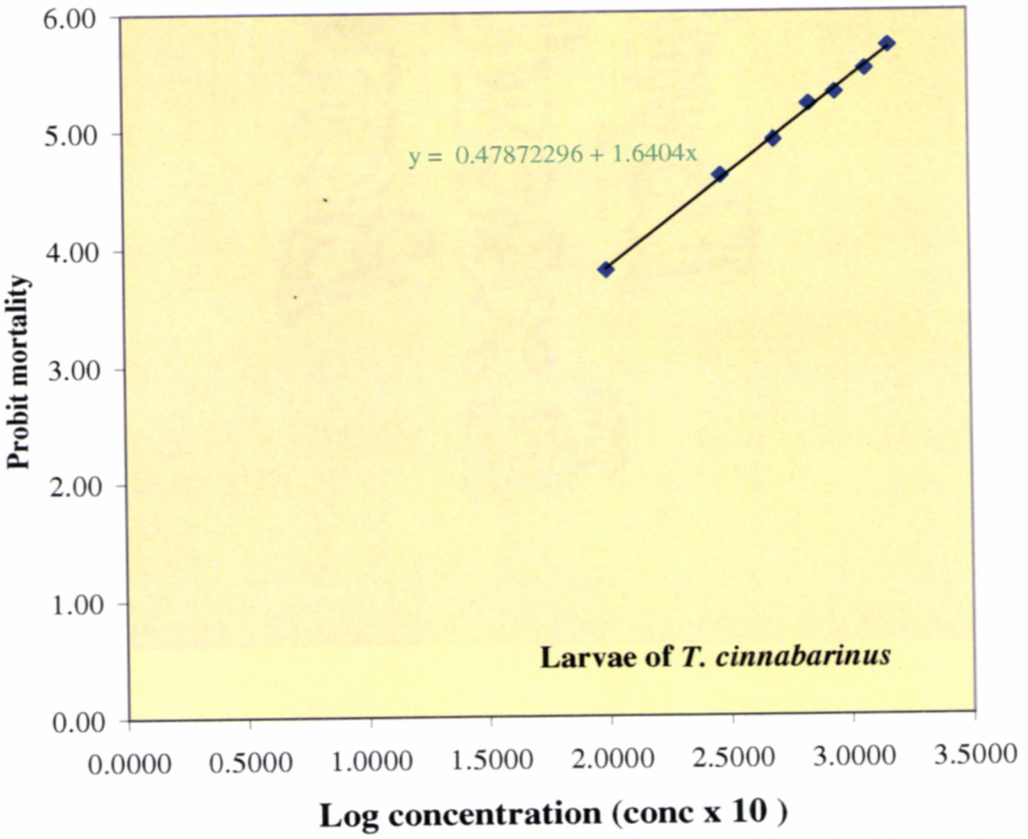
Sr. No.	Acaricide	Heterogeneity χ^2= (5)	Regression Equation	LC_{50} (ppm)	95 % Fiducial Limits		Relative Toxicity
					Upper (ppm)	Lower (ppm)	
1.	Flufenzin 200 SC	3.10154	Y= 0.478723 + 1.6404 ϰ	0.5704	0.7342	0.4432	291.4620
2.	Fenpyroximate 5 EC	- 0.30933	Y= - 19.264481 + 7.2773 ϰ	2.1591	2.2891	2.0364	76.9996
3.	Dicofol 18.5 EC	3.82551	Y= 8.391775 + 2.5651 ϰ	166.2499	196.1948	140.8754	01.0000

Y= Probit kill, ϰ = log (Concentration x 10^3) LC_{50} = Concentration computed to give 50 % mortality

Table 4 : Relative toxicity of the acaricides to adult stage of mite, *Tetranychus cinnabarinus*

Sr. No.	Acaricide	Heterogeneity $\aleph^2 = (5)$	Regression Equation	LC_{50} (ppm)	95 % Fiducial Limits		Relative Toxicity
					Upper (ppm)	Lower (ppm)	
1.	Flufenzin 200 SC	- 4.314689	$Y = - 57.783370 + 10.3568\ \aleph$	1153.5680	1202.9386	1106.2236	00.2680
2.	Fenpyroximate 5 EC	- 0.331809	$Y = - 21.212636 + 7.2006\ \aleph$	4.3686	4.6606	4.0949	70.7753
3.	Dicofol 18.5 EC	1.394619	$Y = - 23.182417 + 5.1332\ \aleph$	309.1889	336.0824	284.4474	01.0000

Y= Probit kill, $\aleph$ = log (Concentration x 10^3) LC_{50} = Concentration computed to give 50 % mortality



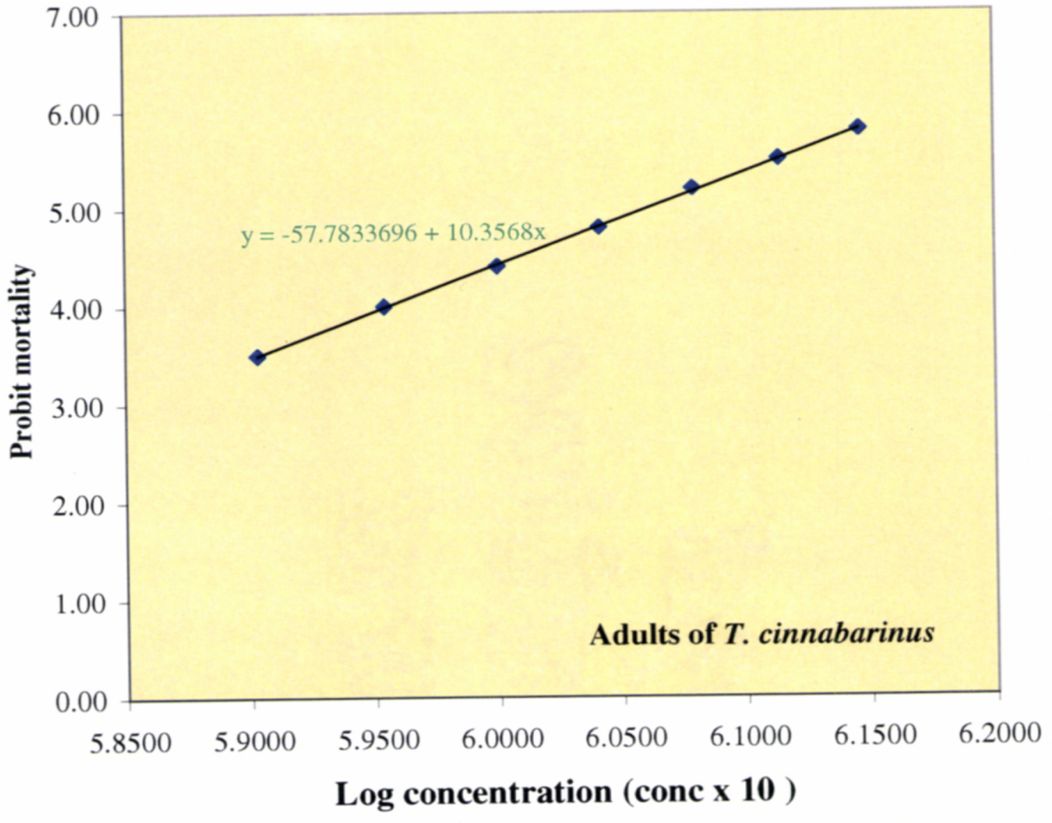
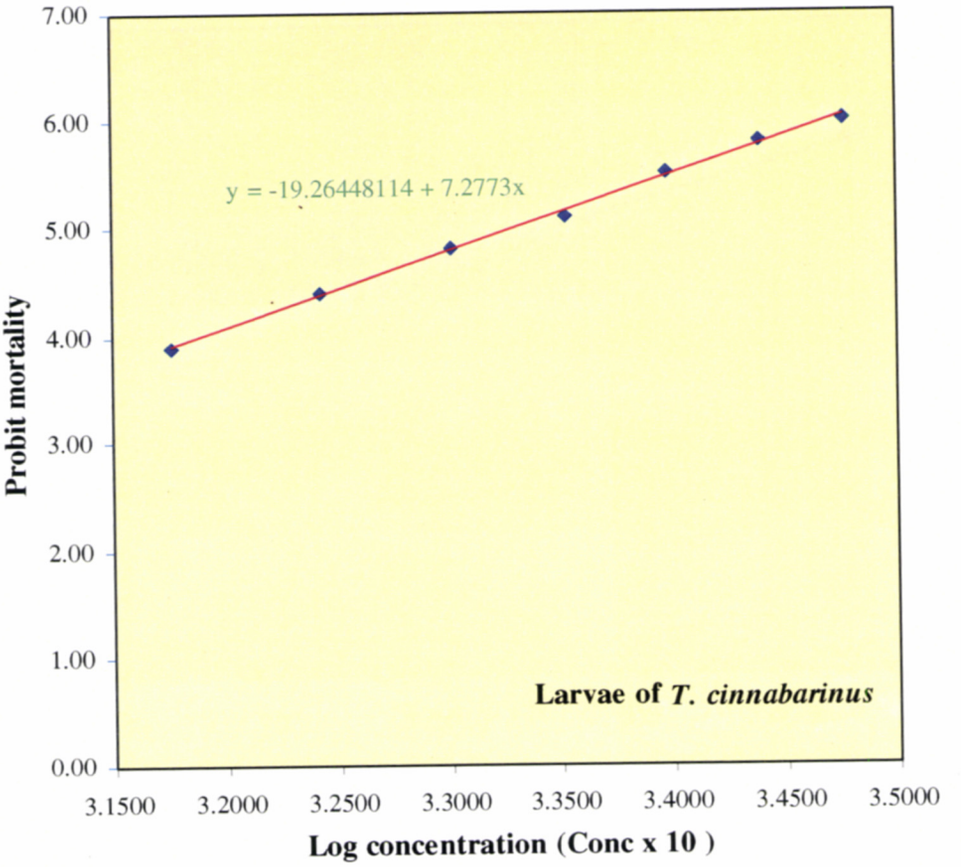


Fig. 4 Probit regression lines for flufenzin



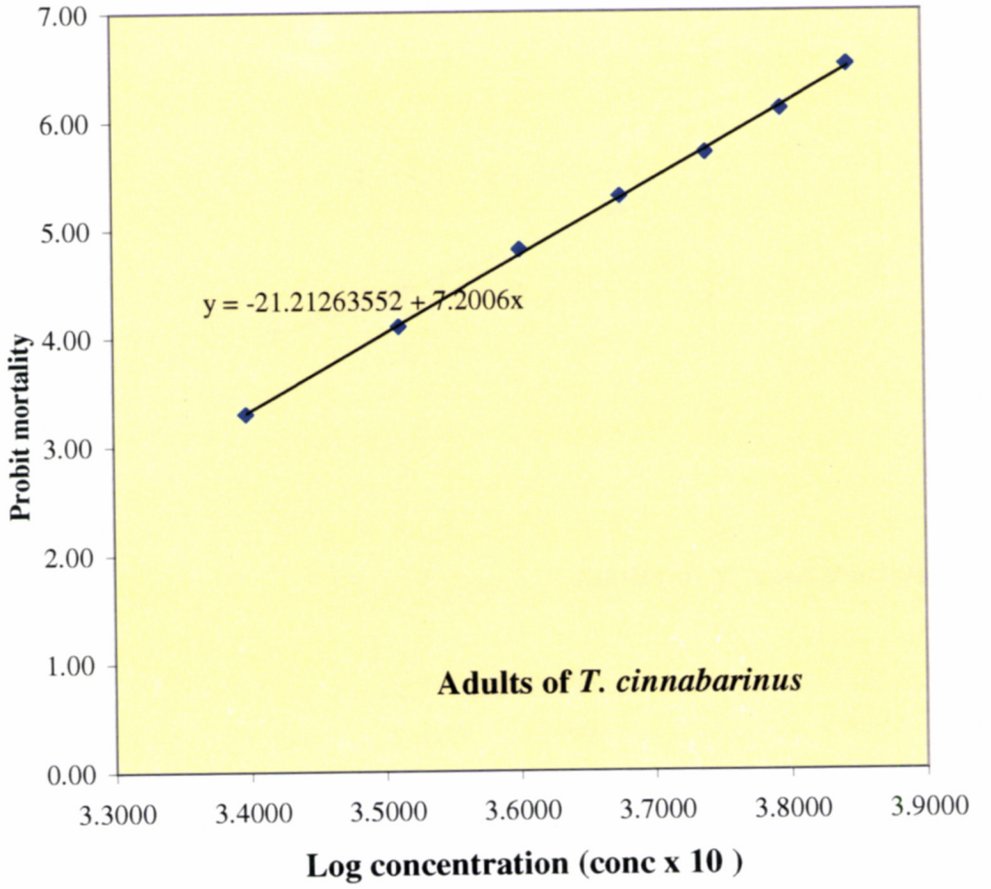
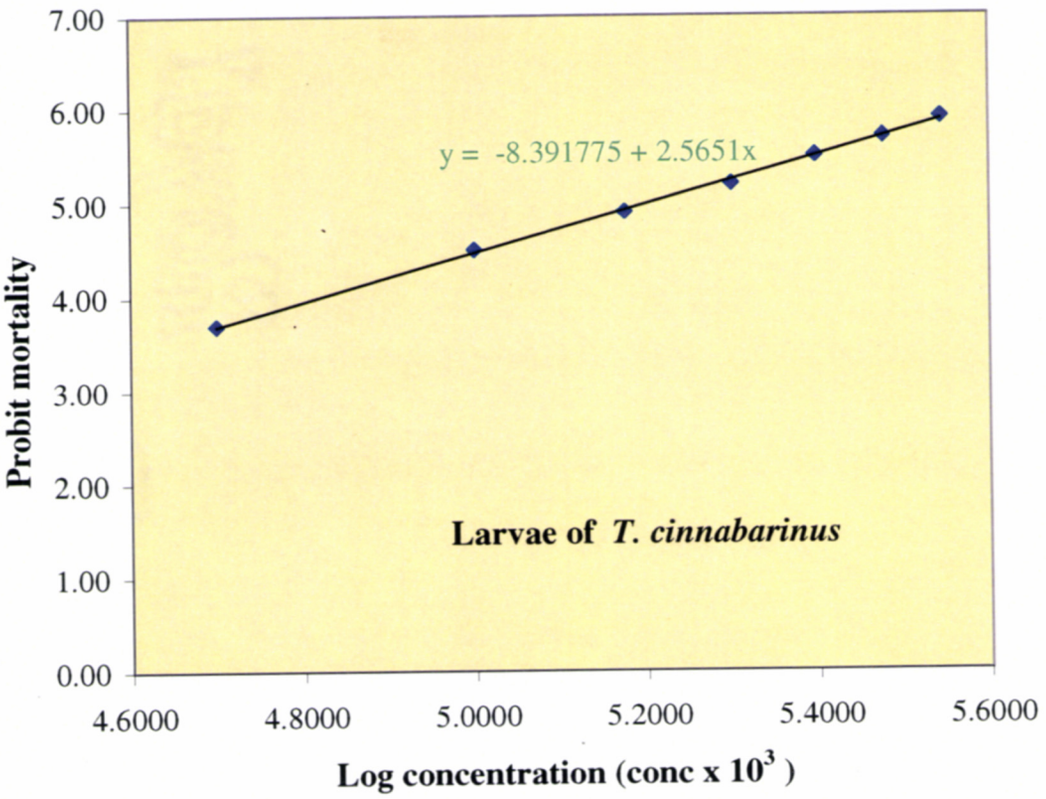


Fig. 5 Probit regression lines for fenpyroximate



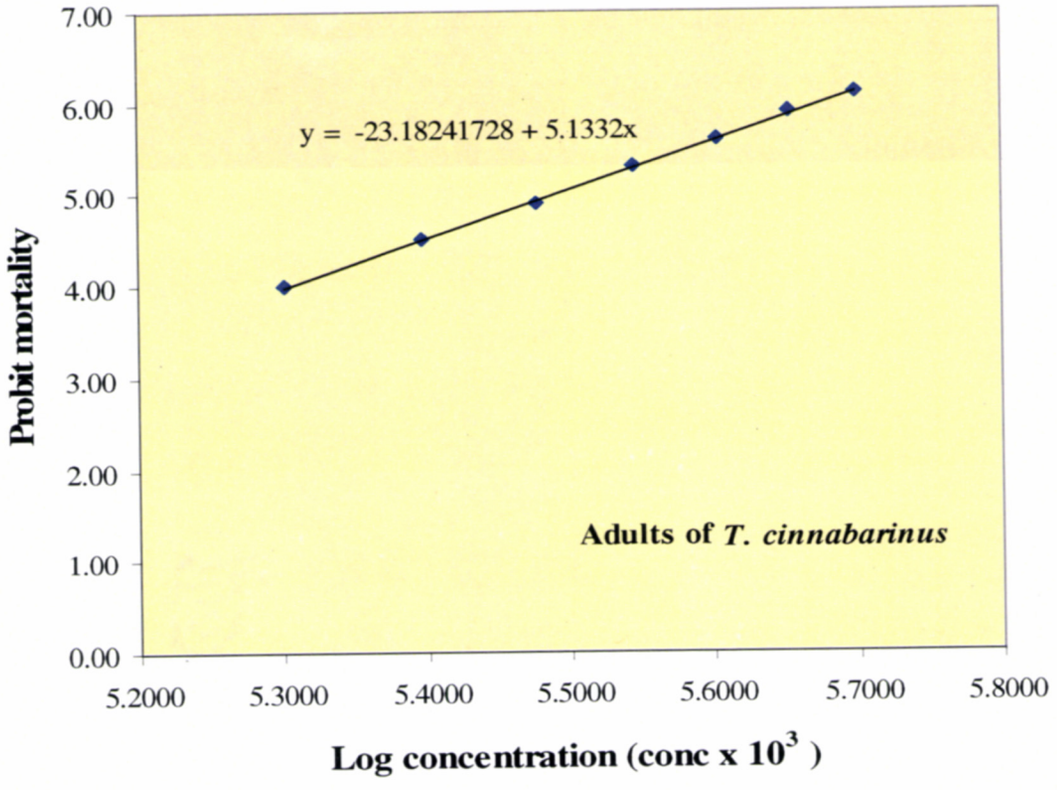


Fig. 6 Probit regression lines for dicofol

4.1.3.1 Field efficacy for *kharif*, 2003

4.1.3.1.1 First spray

The data on mean surviving mite population recorded per leaf are presented in Table 5.

1) Dicofol : Initial pre-treatment population level of 252.90 mites per leaf declined sharply at 3 DAT recording the average of 53.67 mites per leaf, which reduced further to 30.90 mites per leaf at 7 DAT. The population, thereafter started increasing steadily and reached to 65.80 at 15 DAT and 107.57 at 21 DAT.

2) **Fenpyroximate :** The mite counts recorded at various observation dates indicated that all the three dosages exhibited a sharp decline in mite population at 1 DAT itself. In both the higher dosages (25 and 20 g a.i. /ha), significantly low count was recorded till 15 DAT, which gradually increased to around 17 mites per leaf at 21 DAT. The lower dose of 15 g a.i./ha also exhibited more or less similar trend, recording the population level of 9.77 and 49.43 mites at 15 and 21 DAT, respectively.

3) Flufenzin :All three dosages showed decline in the population however, the population declined remarkably in between 5 and 15 DAT. The sharp decline in the population was noticed at 5 and 9 DAT in 80 and 100 g a.i./ha doses, respectively. The population level was further reduced (24.53 and 8.63 mites per leaf) till 15 DAT and regained (143.0 and 119.97 mites per leaf) at 21 DAT. In the third dose (60 g a.i. /ha), a similar trend of gradual decline was observed and the lowest level in this treatment reached to 29.23 mites at 15 DAT. The population build-up was noticed at 21 DAT.

4.1.3.1.2 Second spray

The data on mean motile mite population recorded per leaf are presented in Table 6.

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Table 5 : Field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, after first spray, *kharif*, 2003

Sr. No.	Acaricide	Dose/ g a i./ha	Mean number of motile mites /leaf																			
			Pre-spray		1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	245.33	15.69	188.77	13.77	169.90	13.07	140.33	11.89	116.53	10.84	86.80	9.37	75.30	8.73	48.90	7.06	29.23	5.50	172.57	13.17
2	Flufenzin	80	237.90	15.45	163.47	12.82	137.67	11.77	116.33	10.83	90.47	9.56	71.37	8.51	47.20	6.94	34.43	5.93	24.53	5.05	143.00	12.00
3	Flufenzin	100	243.00	15.61	127.10	11.31	115.00	10.76	65.33	8.14	43.10	6.64	35.33	6.02	25.23	5.12	20.10	4.58	8.63	3.08	119.97	10.99
4	Fenpyro-ximate	15	248.20	15.78	48.33	7.02	9.43	3.23	0.00	1.00	0.00	1.00	1.77	1.66	1.77	1.66	3.47	2.11	9.77	3.28	49.43	7.10
5	Fenpyro-ximate	20	257.57	16.08	22.33	4.81	0.00	1.00	0.00	1.00	0.00	1.00	0.77	1.32	0.77	1.32	1.43	1.56	4.13	2.27	17.00	4.24
6	Fenpyro-ximate	25	253.67	15.96	10.67	3.41	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.57	1.25	2.13	1.76	16.00	4.10
7	Dicofol	250	252.90	15.93	53.67	7.38	31.67	5.71	32.00	5.74	30.90	5.64	34.57	5.96	41.90	6.55	57.77	7.67	65.80	8.17	107.57	10.42
8	Untreated control	-	244.80	15.67	243.70	15.63	241.63	15.57	241.33	15.55	242.90	15.60	249.10	15.80	255.10	15.98	261.23	16.17	265.90	16.32	292.33	17.12
	F:			NS		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%)			-		0.80		0.61		0.54		0.56		0.66		0.73		0.78		0.78		0.66

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

1) Dicofol: The gradual decline in the population level was noticed till 7 DAT with a sharp decline (10.53 mites per leaf) at 3 DAT. Thereafter, the population increased gradually and reached upto 49.03 mites at 21 DAT.

2) Fenpyroximate : All three doses showed remarkable decrease in the population level at 1 DAT wherein, population ranged between 1.10 and 10.47 mites per leaf. The population level was suppressed to the great extent even upto 21 DAT, which was in the range of 0.8 to 11.03. The susceptibility of the mites in all the three dosages was observed to be almost in the similar range.

3) Flufenzin: Although, the reduction in the population (95.67 and 61.67 mites per leaf) was observed at 1 DAT in two higher dosages of 80 and 100 g a.i./ha, an excellent control was achieved between 11 and 15 DAT. The number of mites at 15 DAT was 14.33 in 80 g a.i./ha and 4.43 in 100 g a.i./ha. Thereafter, the mite population regained till 21 DAT. Similarly, the gradual decline in population was maintained by the lower dose (60 g a.i./ha), recording the minimum population (22.80 mites per leaf) at 15 DAT which, regained to 114.77 at 21 DAT.

4.1.3.1.3 Overall efficacy for *kharif* season

The data on combined effect of two sprays of acaricidal treatments on mite population infesting brinjal are presented in Table 7. The statistical analysis indicated significant differences in mite counts from treated and untreated plots.

1) Dicofol : Gradual reduction in the population was observed in 7 DAT wherein, the sharp decline (21.11 mites per leaf) was noticed at 3 DAT. The mite count then increased steadily, recording a mean of 49.03 mites at 21 DAT.

2) Fenpyroximate: All the three dosages exhibited a sharp decline immediately at 1 DAT. The count on surviving mite population indicated that dosages *viz.*, 25 and 20 g a.i./ha showed excellent performance in suppressing the mites upto 21 DAT and also

Table 6 : Field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, after second spray, *kharif*, 2003

Sr. No.	Acaricide	Dose/ g a.i./ha	Mean number of motile mites /leaf																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	135.67	11.69	120.67	11.03	100.33	10.06	77.90	8.88	63.67	8.04	50.43	7.17	37.80	6.23	22.80	4.88	114.77	10.76
2	Flufenzin	80	95.67	9.83	85.67	9.31	75.37	8.73	57.53	7.65	44.23	6.73	31.43	5.70	22.70	4.87	14.33	3.91	83.37	9.18
3	Flufenzin	100	61.67	7.91	59.10	7.75	39.77	6.38	20.23	4.60	15.67	4.08	10.77	3.43	7.87	2.98	4.43	2.32	58.00	7.68
4	Fenpyroxi-mate	15	10.47	3.38	3.00	2.00	5.57	2.56	1.53	1.59	2.57	1.89	3.10	2.02	2.43	1.85	1.30	1.52	11.03	3.46
5	Fenpyroxi-mate	20	1.90	1.70	0.77	1.32	1.00	1.41	0.57	1.25	1.33	1.52	1.67	1.63	1.00	1.40	0.70	1.30	1.57	1.60
6	Fenpyroxi-mate	25	1.10	1.45	0.00	1.00	0.00	1.00	0.00	1.00	0.30	1.14	0.00	1.00	0.20	1.09	0.20	1.09	0.80	1.34
7	Dicofol	250	24.63	5.06	10.53	3.40	11.67	3.56	12.00	3.61	17.10	4.25	20.57	4.64	26.77	5.27	31.13	5.67	49.03	7.07
8	Untreated control	-	282.67	16.83	272.70	16.53	269.90	16.45	267.67	16.38	262.87	16.23	247.87	15.77	252.43	15.91	246.67	15.72	253.33	15.36
	F:			Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%):			0.55		0.56		0.62		0.53		0.56		0.27		0.56		0.53		0.58

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

Table 7 : Overall field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, during *kharif*, 2003

Sr. No.	Acaricide	Dose g a.i /ha	Mean number of motile mites / leaf																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	162.22	12.77	144.61	12.06	120.33	11.01	97.22	9.91	75.22	8.73	62.89	7.99	43.33	6.66	26.00	5.20	143.67	12.03
2	Flufenzin	80	129.72	11.43	111.67	10.61	95.67	9.83	74.00	8.66	57.78	7.67	39.33	6.35	28.56	5.44	19.45	4.52	113.06	10.68
3	Flufenzin	100	94.39	9.76	92.05	9.64	52.56	7.32	31.78	5.72	25.50	5.14	18.00	4.35	14.00	3.86	6.72	2.76	89.00	9.48
4	Fenpyro-ximate	15	29.22	5.50	6.22	2.69	2.78	1.94	0.78	1.33	2.17	1.78	2.43	1.85	2.94	1.98	5.55	2.56	30.22	5.58
5	Fenpyro-ximate	20	12.11	3.61	0.39	1.18	0.50	1.22	0.28	1.13	1.05	1.43	1.22	1.49	1.28	1.51	2.33	1.82	9.28	3.21
6	Fenpyro-ximate	25	5.89	2.62	0.00	1.00	0.00	1.00	0.00	1.00	0.17	1.08	0.00	1.00	0.33	1.15	1.22	1.49	8.39	3.06
7	Dicofol	250	39.17	6.33	21.11	4.70	21.83	4.78	21.44	4.74	25.83	5.18	31.22	5.68	45.22	6.57	48.44	7.03	78.28	8.90
8	Untreated control	-	263.17	16.24	257.17	16.06	255.61	16.01	255.28	15.99	256.00	16.02	256.50	16.03	256.83	16.04	256.28	16.02	263.83	16.26
	F:			Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%):			0.67		0.56		0.55		0.53		0.59		0.61		0.66		0.66		0.61

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

beyond the observation date. The lower dose (15g a.i./ha) also kept the mite population significantly low (22.80 mites per leaf) upto 21 DAT. This in turn indicated that fenpyroximate at 15 g a.i./ha dose gave promising control upto 21 DAT while, the efficacy in its higher two dosages lasted for even more period.

3) Flufenzin: In all the dosage of the treatment, the mite count slowly reduced with the laps of time and an increase in the population was apparent at 21 DAT. It seems that in 100, 80 and 60 g a.i./ha doses, better efficacy of the compound was noticed at 9, 13 and 15 DAT, respectively.

4.1.3.2 Field efficacy for summer, 2004

4.1.3.2.1 First spray

The data on mean motile population per leaf are presented in Table 8 which indicated significant reduction in mite counts in all treatment plots as compared to untreated plots.

1) Dicofol : It is observed from the data that the pre-spray population of 182.80 mites per leaf was suppressed to 44.20 at 1 DAT which was further decreased to 20.13 on 5 DAT. Then the mite count started increasing gradually recording 51.20 and 92.13 mites at 15 and 21 DAT, respectively.

2) Fenpyroximate: The pre-treatment population of motile mites in all the three dosages as in the range of 179.80 to 183.0, however at 1 DAT, there was a sharp decline in the population level, which was ranging from 31.13 to 46.0. Very few mites survived in higher dose (25 g a.i./ha) between 3 to 5 DAT which gradually increased upto 67.67 mites per leaf at 21 DAT. In the plots treated with intermediate dose (20 g a.i./ha), the mite count of 12.23 mites per leaf recorded at 3 DAT was further reduced to 5.33 at 15 DAT and again developed to 73.77 at 21 DAT. On 3rd day after the treatment, the population was 46.0 mites in the plots treated with the compound

Table 8 : Field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, after first spray, summer, 2004

Sr. No.	Acaricide	Dose/ g a.i./ha	Mean number of motile mites / leaf																			
			Pre-spray		1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	182.23	13.54	142.50	11.96	130.53	11.47	104.00	10.25	85.30	9.29	67.33	8.27	55.10	7.49	38.20	6.26	23.67	4.97	119.77	10.99
2	Flufenzin	80	179.10	13.42	121.77	11.08	122.33	11.10	89.97	9.54	70.43	8.45	54.00	7.42	37.47	6.20	28.57	5.44	18.77	4.44	107.57	10.42
3	Flufenzin	100	179.97	13.45	95.53	9.82	93.33	9.71	53.57	7.39	30.43	5.61	25.77	5.18	18.10	4.37	14.33	3.91	7.10	2.85	93.77	9.74
4	Fenpyro-ximate	15	183.00	13.57	46.00	6.86	37.23	6.18	22.00	4.80	10.90	3.45	11.00	3.46	13.80	3.84	11.00	3.46	8.00	3.00	86.10	9.33
5	Fenpyro-ximate	20	179.80	13.44	35.87	6.07	12.23	3.64	10.77	3.43	6.23	2.69	2.43	1.85	7.13	2.85	5.20	2.49	5.33	2.52	73.77	8.64
6	Fenpyro-ximate	25	183.00	13.57	31.13	5.67	1.00	1.41	3.43	2.10	2.10	1.76	0.20	1.09	0.00	1.00	1.67	1.63	2.57	1.89	67.67	8.29
7	Dicofol	250	182.80	13.56	44.10	6.72	20.80	4.67	20.13	4.60	22.00	4.79	23.90	4.99	34.53	5.96	44.00	6.71	51.20	7.22	92.13	9.65
8	Untreated control	-	186.90	13.71	188.33	13.76	191.57	13.88	195.33	13.99	197.77	14.10	203.43	14.30	208.37	14.47	213.43	14.65	222.33	14.95	232.43	15.28
	F:			NS		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%)			-		0.21		0.02		0.16		0.18		0.13		0.13		0.14		0.17		0.29

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

@ 15 g a.i./ha which decreased further to 8 at 15 DAT and thereafter slowly increased to 86.10 at 21 DAT.

3) Flufenzin : On the evaluation dates covering 1 to 15 DAT, decreasing trend in the mite population was noticed for all the three dosages. However, the low population build-up was noticed in all treatment plots at 21 DAT. The plots treated with 100 g a.i./ha dose, the pre-treatment count of 179.97 decreased to 95.33 and 7.10 mites per leaf at 1 and 15 DAT, respectively with a great reduction at 11 DAT. The plots receiving 80 g a.i./ha dose also exhibited similar trend wherein, the sharp decline in population was noticed at 15 DAT. In lower dose (60 g a.i./ha), there was a steady decline in the population level as evidenced by the count of 142.50 and 23.67 mites per leaf at 1 and 15 DAT, respectively.

4.1.3.2.2 Second spray

The data recorded after the second spray on mean motile population per leaf are presented in Table 9. The mite population in all the treatment plots was significantly lower than the untreated plots.

1) Dicofol : The population in this treatment was observed to be decreasing gradually upto 7 DAT with a sudden decline at 3 DAT. The population level thereafter increased on the evaluation dates from 9 to 21 DAT.

2) Fenpyroximate: All the dosages showed a remarkable population decline immediately at 1 DAT, with a further reduction in population till 15 DAT. The population in all treatment plots then slowly increased upto 21 DAT. In the plots treated with 25 g a.i./ha dose, very less surviving mites were noticed from 3 to 15 DAT. Almost the same trend was observed in the intermediate dose (20 g a.i./ha) wherein, the population of 7.57 mites per leaf on third day after treatment was

Table 9 : Field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, after second spray, summer, 2004

Sr. No.	Acaricide	Dose/ g a.i./ha	Mean number of motile mites /leaf																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	91.57	9.62	87.80	9.42	71.77	8.53	58.90	7.74	43.33	6.66	36.00	6.08	24.13	5.01	16.77	4.22	81.77	9.10
2	Flufenzin	80	70.90	8.48	68.90	8.36	59.33	7.77	44.00	6.71	31.20	5.67	22.43	4.84	16.23	4.15	10.80	3.43	64.57	8.10
3	Flufenzin	100	51.67	7.26	47.77	6.98	30.37	5.60	17.00	4.24	13.33	3.78	9.20	3.19	6.43	2.72	3.70	2.17	47.77	6.98
4	Fenpyro-ximate	15	21.80	4.78	18.87	4.45	12.00	3.61	6.00	2.65	4.30	2.30	6.00	2.65	4.30	2.30	2.43	1.85	42.53	6.60
5	Fenpyro-ximate	20	16.47	4.18	7.57	2.93	5.33	2.52	3.20	2.05	1.57	1.60	2.10	1.76	2.80	1.95	1.43	1.56	31.00	5.65
6	Fenpyro-ximate	25	10.20	3.35	4.57	2.36	2.70	1.92	1.30	1.52	0.80	1.34	0.57	1.25	0.57	2.25	0.43	1.19	26.33	5.23
7	Dicofol	250	21.20	4.71	11.80	3.57	11.10	3.48	9.10	3.18	12.80	3.71	6.43	2.72	21.10	4.70	26.63	5.25	50.00	7.14
8	Untreated control	-	230.80	15.22	228.10	15.14	225.20	15.04	220.13	14.87	215.57	14.72	209.77	14.51	204.47	14.33	197.33	14.08	188.57	13.76
	F:			Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%):			0.24		0.27		0.22		0.21		0.24		0.25		0.25		0.22		0.29

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

declined to 1.56 mites at 15 DAT. Similarly, in lower dose (15 g a.i./ha), the mite count of 18.84 recorded at 1 DAT steadily reduced to 1.85 at 21 DAT.

3) Flufenzin : The perusal of the data given in Table 9 indicated that in all the three dosage treatments, decline in the population was noticed from 1 to 15 DAT and thereafter, number of mites gradually increased at 21 DAT. The sudden decline in the number of mites was detected at 7, 13 and 15 DAT in respect of 100, 80 and 60 g a.i./ha dosages, respectively.

4.1.3.2.3 Overall efficacy for summer season

The overall efficacy of the acaricides against the brinjal mite was calculated by combining the data obtained in first and second sprays. The statistical analysis showed significant differences in the efficacy between three acaricides and the untreated control (Table 10).

1) Dicofol: Gradual reduction in the number of surviving mites was noticed till 5 DAT (15.61 mites per leaf) which however, progressively increased to a level of 71.22 at 21 DAT.

2) Fenpyroximate: All the dosages resulted in significant reduction in mite population till 15 DAT, then the number of mites increased at 21 DAT. The number of mites remained at very low levels in the plots treated with 25 g a.i./ha dose between 3 and 5 DAT. Similar pattern albeit with slight variations in the population decline was noticed in the intermediate dose (20 g a.i./ha); wherein the population fluctuated between 9.89 and 3.33 mites per leaf from 3 to 5 DAT. The mite population level of 28.06 recorded on 3 DAT in respect of the dose at 15 g a.i./ha was further declined to 5.22 mites at 15 DAT.

3) Flufenzin : There was decrease in mite population corresponding to an increase in the dosage. The population gradually reduced in all the dosages till 15 DAT and

Table 10 : Overall field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal, during summer, 2004

Sr. No.	Acaricide	Dose ga i./ha	Mean number of motile mites / leaf																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	116.89	10.86	109.17	10.50	87.83	9.42	72.11	8.55	55.33	7.51	45.55	6.82	31.17	5.67	20.22	4.61	100.78	10.09
2	Flufenzin	80	96.50	9.87	95.61	9.83	74.67	8.70	57.22	7.63	42.61	6.60	29.94	5.56	22.39	4.84	14.78	3.97	86.06	9.33
3	Flufenzin	100	73.61	8.64	70.56	8.46	41.93	6.55	23.72	4.97	15.67	4.02	13.11	3.75	10.39	3.37	5.39	2.53	70.78	8.47
4	Fenpyro-ximate	15	33.89	5.91	28.06	5.39	17.00	4.24	8.43	3.07	7.67	2.94	9.89	3.30	7.67	2.94	5.22	2.49	64.33	8.08
5	Fenpyro-ximate	20	25.05	5.10	9.89	3.30	8.05	3.01	4.72	2.39	2.00	1.73	4.66	2.38	4.00	2.24	3.33	2.08	52.39	7.31
6	Fenpyro-ximate	25	20.67	4.65	2.78	1.94	3.06	2.01	1.73	1.65	0.50	1.22	0.28	1.13	1.11	1.45	1.50	1.58	47.00	6.93
7	Dicofol	250	32.67	5.80	16.27	4.15	15.61	4.08	18.56	4.40	18.33	4.40	20.50	4.64	32.56	5.79	38.94	6.32	71.22	8.50
8	Untreated control	-	209.55	14.51	209.83	14.52	210.28	14.53	208.94	14.49	209.06	14.49	209.05	14.69	208.94	14.49	209.83	14.52	210.50	14.54
F:				Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
LSD(5%):				0.19		0.19		0.15		0.40		0.53		0.18		0.18		0.18		0.28

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

then a slight increase at 21 DAT was observed. The per leaf count of 70.56 mites recorded at 3 DAT in higher dose (100 g a.i./ha) slowly declined to 5.39 mites at 15 DAT. In the intermediate dose (80 g a.i./ha), the mite count of 95.61 recorded at 1 DAT slowly reduced to 14.78. However, in the plots treated with 60 g a.i./ha dose, although reduction in population was observed, the rate of mortality was low in comparison with the remaining two dosages. The sharp decline in the population of mite was noticed on 7, 13 and 15 DAT in respect of 100, 80 and 60 g a.i./ha dosages, respectively.

4.1.3.3 Cumulative efficacy for both seasons

The efficacy was judged on the basis of two seasons pooled data pertaining to the surviving mite population as well as the per cent decline in the population of mite.

4.1.3.3.1 Efficacy based on population

The data on mean number of mites per leaf were analysed statistically to compare the means of treatments for the significance test. The data presented in Table 11 indicated that the untreated control plots had significantly higher mite counts than all the three acaricides treated plots.

1) Dicofol : The noticeable decline in mite population was observed at 3 DAT and the population remained at low levels upto 7 DAT (18.50 mites per leaf). Thereafter, a slow growth in the mite population was observed on next observation dates.

2) Fenpyroximate : The striking effect of the acaricide on mite infestation was noticed at 1 DAT in all the three dosages. The population level decreased further till 15 DAT and thereafter, it was raised at 21 DAT. The mite population fluctuated marginally from 3 to 15 DAT (1.39 to 1.33 mites per leaf) in the higher dose (25 g a.i./ha). Similarly, the population remained at very low levels in the plots receiving 20 g a.i./ha dose (5.14 to 2.90 mites) from 3 to 15 DAT. In the lower dose

Table 11 : Cumulative field bioefficacy of the acaricides against mite, *Tetranychus cinnabarinus* on brinjal

Sr. No.	Acaricide	Dose ga i /ha	Mean number of motile mites / leaf																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	139.63	11.77	127.23	11.25	104.11	10.18	84.66	9.19	65.28	8.08	54.21	7.37	37.26	6.14	23.14	4.89	122.22	11.01
2	Flufenzin	80	112.95	10.55	103.64	10.14	85.25	9.22	65.61	8.09	50.20	7.08	34.63	5.92	25.48	5.10	17.10	4.21	99.63	9.93
3	Flufenzin	100	83.94	9.08	78.80	8.80	47.26	6.88	27.69	5.27	22.53	4.77	15.83	4.03	12.18	3.55	5.97	2.61	79.88	8.85
4	Fenpyro-ximate	15	31.65	5.51	17.13	3.97	9.89	2.99	4.61	2.17	4.91	2.33	6.17	2.55	5.30	2.43	5.38	2.41	47.27	6.63
5	Fenpyro-ximate	20	19.14	4.20	5.14	2.22	4.26	2.09	2.50	1.75	1.53	1.58	2.92	1.89	2.61	1.85	2.90	1.91	30.84	5.04
6	Fenpyro-ximate	25	13.28	3.47	1.39	1.44	1.53	1.51	0.85	1.32	0.33	1.14	0.14	1.06	0.75	1.31	1.33	1.49	27.70	4.74
7	Dicofol	250	35.90	5.97	18.70	4.34	18.73	4.34	18.50	4.31	22.09	4.73	25.86	4.97	37.41	6.09	43.69	6.58	74.68	8.57
8	Untreated control	-	236.38	15.37	233.50	15.28	232.94	15.27	232.12	15.24	232.74	15.27	230.28	15.19	232.89	15.27	233.06	15.28	241.67	15.53
	F:			Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	LSD (5%):			1.84		1.9		1.7		1.41		1.11		1.22		0.95		0.68		2.33

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

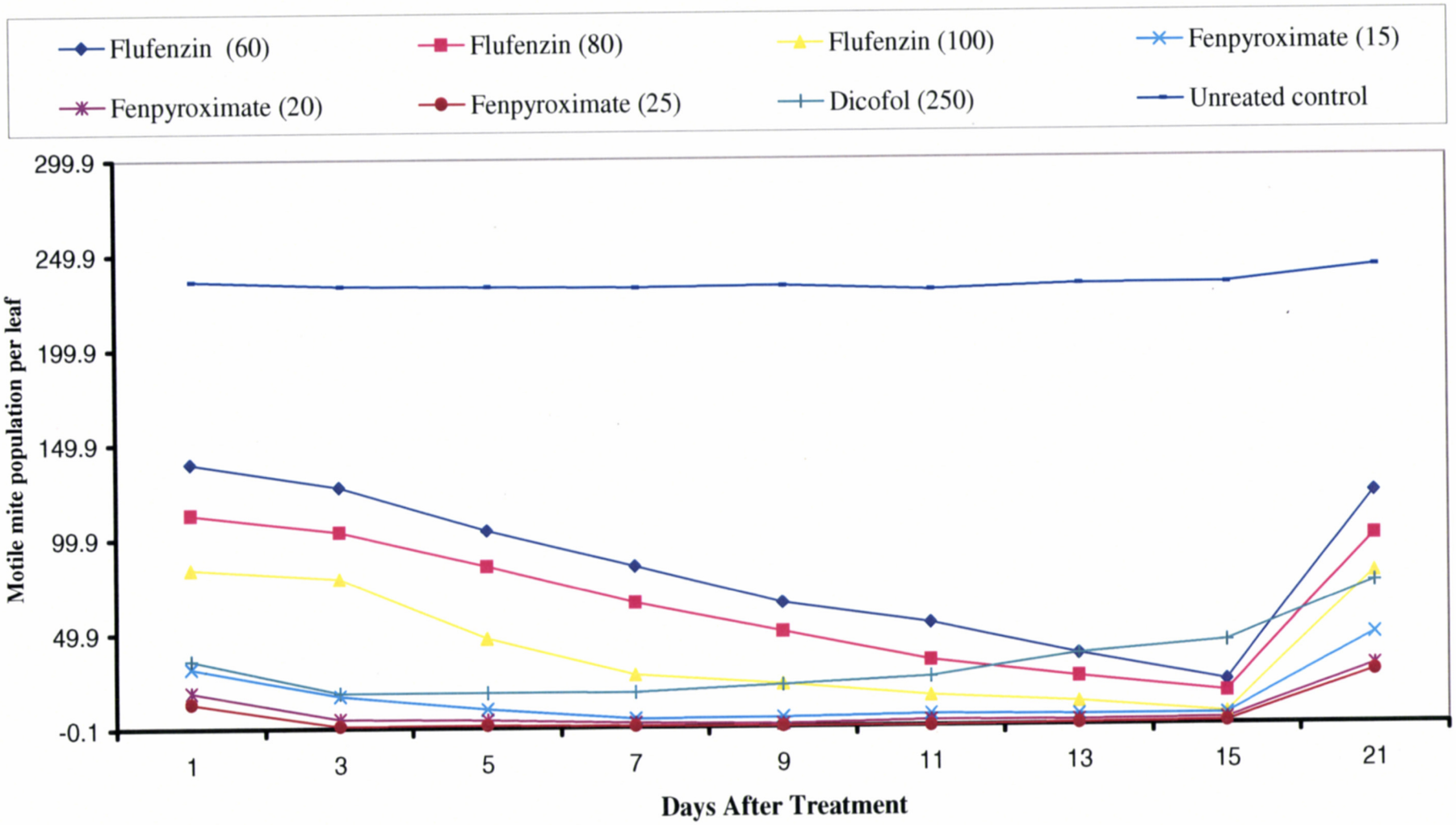


Fig. 7 Cumulative field bioefficacy of acaricides against mite on brinjal

(15 g a.i./ha), the mite population of 17.6 recorded at 3 DAT further decreased to 5.38 at 15 DAT.

3) Flufenzin : Slower decline in the population level was noticed in all the three dosages. However, the population re-established at 21 DAT. The sharp decline in population at 9, 13 and 15 DAT noticed in 100, 80 and 60 g a.i./ha dosages, respectively indicated the dose-dependence efficacy of the compound.

4.1.3.3.2 Efficacy based on per cent population decline

The per cent population decline due to acaricide treatments was calculated on the basis of the initial population and mean survival of mite in treatment plots. The pooled data on mean decline in population of mite are presented in Table 12 and the extent of protection offered by the acaricides is depicted in Fig. 8.

1) Dicofol : Maximum efficacy offered by the compound was recorded at 3 DAT, which extended till 7 DAT. The efficacy slowly decreased till 21 DAT with progressive increase in the mite numbers.

2) Fenpyroximate In all the dosages, the sharp fall in the population was noticed between 1 and 3 DAT. The efficacy efficiently prevailed till 15 DAT and thereafter, low rise in number of mites was seen at 21 DAT.

3) Flufenzin : The efficacy in all the three dosages progressively increased with the laps of the days. Maximum efficacy was noticed in all the three doses on 15th day after spray (86.98 to 96.23%). However, all the dosages did not offer promising protection at 21 DAT, as evidenced by rise in mite counts.

4.1.3.4 Salient features of results obtained in field bioefficacy studies

1) Dicofol : Very good control of mite was noticed between 3 and 5 days after the treatment application, which was extended till 7 DAT. The maximum decline in mite population observed in this treatment was 88 per cent.

Table 12 : Cumulative mean per cent decline in motile mite population on brinjal due to acaricide applications

Sr. No.	Acaricide	Dose ga.i /ha	Mean per cent decline in motile mite population																	
			1 DAT		3 DAT		5 DAT		7 DAT		9 DAT		11 DAT		13 DAT		15 DAT		21 DAT	
			A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	Flufenzin	60	22.45	28.28	28.95	32.54	41.95	40.37	52.85	46.63	63.68	52.94	69.95	56.76	79.28	62.93	86.98	68.85	32.25	34.60
2	Flufenzin	80	32.63	34.83	37.48	37.72	48.35	43.91	60.38	50.99	70.00	56.79	79.13	62.82	84.63	66.92	89.80	71.38	40.50	39.52
3	Flufenzin	100	47.03	43.15	50.18	45.10	69.50	56.37	82.63	65.37	85.98	68.01	90.18	71.74	92.60	74.23	96.23	78.80	49.55	44.74
4	Fenpyro-ximate	15	77.30	61.58	83.95	67.21	90.70	74.10	95.95	79.59	95.75	78.70	94.63	77.36	95.70	78.36	96.58	79.40	65.30	54.32
5	Fenpyro-ximate	20	84.48	67.16	94.55	77.96	95.23	78.60	97.18	81.17	97.15	81.45	95.73	79.32	96.75	80.26	97.35	80.79	75.25	61.76
6	Fenpyro-ximate	25	89.20	71.43	98.15	84.21	98.05	82.70	99.25	85.61	99.68	87.07	99.78	87.28	99.20	85.07	99.00	84.34	78.38	64.34
7	Dicofol	250	77.20	61.50	88.35	70.07	88.45	70.14	88.68	70.35	85.85	67.92	84.60	67.32	76.30	60.87	72.00	58.06	51.83	46.05
8	Untreated control	-	1.13	5.66	2.48	7.77	3.05	8.72	3.63	9.28	4.33	9.43	5.38	10.47	6.43	11.40	7.65	12.42	9.58	13.88
F:				Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
LSD (5%):				4.18		5.98		6.37		5.47		6.35		7.48		6.69		6.54		11.95

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

2) Fenpyroximate : All the test-dosages exhibited dose-dependent efficacy trend in suppressing the mite population. Excellent control in the range of 96 to 99 per cent was noticed till 15 DAT, indicating the extent of protection offered could be even more days, but less than 21 days after the spray application. Moreover, the sudden decline in population was found between 1 and 3 DAT.

3) Flufenzin : The protection offered by the test-dosages of this compound indicated the relationship between the dose and time. As the dose was lowered, the time in days to occur the mite mortality was increased and vice-versa. Maximum efficiency in extending the protection was observed to be 96, 89 and 87 per cent in 100, 80 and 60 g a.i./ha doses, respectively which was noticed on 13 and 15 DAT.

4.1.4 Effect on general health of plants

The observations on the studies on phytotoxicity of the acaricides to brinjal plants are presented in Table 13. The phytotoxic-influence of the acaricides on brinjal plants was evaluated by recording various observations in 0 to 10 scale. None of the three acaricides showed any type of injury to the crop plants thus, the acaricides exhibited 0 scale rating. At all the dosages the plants were found to be healthy.

4.1.5 Effect on yield

The data pertaining to mean yield of marketable fruits and the profit margins contributed by the applications of the acaricides are presented in Table 14. The data revealed that the yield was in the range of 19.63 to 20.59 and 15.30 to 16.78 t/ha, during *kharif*, 2003 and summer, 2004 seasons, respectively. In both the seasons, maximum yield (20.59 and 16.78 t/ha) was contributed by higher dose of fenpyroximate (25 g a. i./ ha) while minimum (19.63 and 15.30 t/ha) by the untreated control. In *kharif* season, higher and intermediate dosages of both the candidate acaricides were observed at par with their lower doses and dicofol were observed on

Table 13 : Phytotoxic effect of the acaricides on brinjal plants

Sr. No.	Acaricide	Dose g a.i./ha	Score : Days After Treatment (DAT)										
			0	1	2	3	5	7	9	11	13	15	21
I) Observation on injury on leaf tips and leaf surface													
1	Flufenzin	100	0	0	0	0	0	0	0	0	0	0	0
2	Fenpyroximate	25	0	0	0	0	0	0	0	0	0	0	0
3	Dicofol	250	0	0	0	0	0	0	0	0	0	0	0
II) Observation on wilting													
1	Flufenzin	100	0	0	0	0	0	0	0	0	0	0	0
2	Fenpyroximate	25	0	0	0	0	0	0	0	0	0	0	0
3	Dicofol	250	0	0	0	0	0	0	0	0	0	0	0
III) Observation on vein clearing													
1	Flufenzin	100	0	0	0	0	0	0	0	0	0	0	0
2	Fenpyroximate	25	0	0	0	0	0	0	0	0	0	0	0
3	Dicofol	250	0	0	0	0	0	0	0	0	0	0	0
IV) Observation on necrosis													
1	Flufenzin	100	0	0	0	0	0	0	0	0	0	0	0
2	Fenpyroximate	25	0	0	0	0	0	0	0	0	0	0	0
3	Dicofol	250	0	0	0	0	0	0	0	0	0	0	0
V) Observation on epinasty and hyponasty													
1	Flufenzin	100	0	0	0	0	0	0	0	0	0	0	0
2	Fenpyroximate	25	0	0	0	0	0	0	0	0	0	0	0
3	Dicofol	250	0	0	0	0	0	0	0	0	0	0	0

par with untreated control giving the yield in the range of 19.63 to 20.37 t/ha. In summer season, all the three dosages of fenpyroximate, and flufenzin at 100 and 80 g a.i./ha dosages were at par. The yield recorded in these plots ranged between 16.15 and 16.78 t/ha. Flufenzin at 60 g a.i./ha and dicofol at 250 g a.i./ha again found on par with the untreated control.

The pooled yield data indicated that fenpyroximate at 25 and 20 g a.i./ha doses and flufenzin at 100 g a.i./ha dose were statistically in similar range. Fenpyroximate at 15 g a.i./ha and flufenzin at 80 g a.i./ha were on par with each other. Flufenzin at 60 g a.i./ha and dicofol at 250 g a.i./ha were found at par with untreated control.

The computation of profit-margins contributed by the acaricides under the studies indicated that higher margins were exhibited by fenpyroximate at 25 and 20 g a.i./ha. The treatment with fenpyroximate at 25 g a.i./ha yielded the highest profit margin by Rs. 7,340/- over untreated control whereas, the treatment with dicofol resulted in the lowest profit of Rs. 1,139/- over untreated plots. The comparison of the margins with that of maximum extent of protection offered by them suggested that all the three dosages of fenpyroximate and the higher dose of flufenzin (100 g a.i./ha) prominently controlled the mite and offered better returns. The low differences in the yield might be attributed to the fact that prior to initiation of the present experiments, the complete experimental fields including the untreated control were sprayed with insecticide by the concerned cultivators for controlling the fruit borer damage. Similarly, after completion of the observations, the fields were protected from the pest by the cultivators.

4.2 Studies on safety of beneficials

The impact of the acaricides on beneficial arthropods like predatory mite, green lacewing, honeybee and earthworm was studied.

Table 14 : Mean yield of brinjal fruits and profit margins due to acaricide applications

Sr. No.	Acaricide	Dose (g a.i./ha)	Mean fruit yield (t/ha)			Additional yield over control (t/ha)	Additional income over control (Rs./ha)	Treatment cost (Rs.)	Profit margin (Rs./ha)	Maximum protection offered (%)
			Kharif-03	Summer-04	Cumulative					
1.	Flufenzin	60	20.00	15.78	17.89	0.43	3,010	500	2,510	86.98
2.	Flufenzin	80	20.30	16.15	18.04	0.58	4,060	600	3,460	89.80
3	Flufenzin	100	20.37	16.59	18.48	1.02	7,140	700	6,440	96.23
4	Fenpyroximate	15	19.93	16.22	18.07	0.61	4,270	800	3,470	96.58
5	Fenpyroximate	20	20.44	16.67	18.56	1.10	7,700	1,000	6,700	97.35
6	Fenpyroximate	25	20.59	16.78	18.68	1.22	8,540	1,200	7,340	99.78
7	Dicofol	250	19.93	15.56	17.74	0.28	1,960	821	1,139	88.68
8	Untreated control	-	19.63	15.30	17.46	-	-	-	-	-
	F :		Sig.	Sig.	Sig.					
	LSD (5%) :		0.47	0.70	0.52					

Price of average yield of brinjal @ Rs. 7000/ t
Treatment cost (Include cost of acaricide plus cost of applications @ Rs. 100 x 2 = 200
Cost of acaricide per litre : Flufenzin, 200 SC (20%) : Rs. 500 /-, Fenpyroximate 5% EC : Rs. 1000/-, Dicofol 18.5% EC : Rs. 230/-

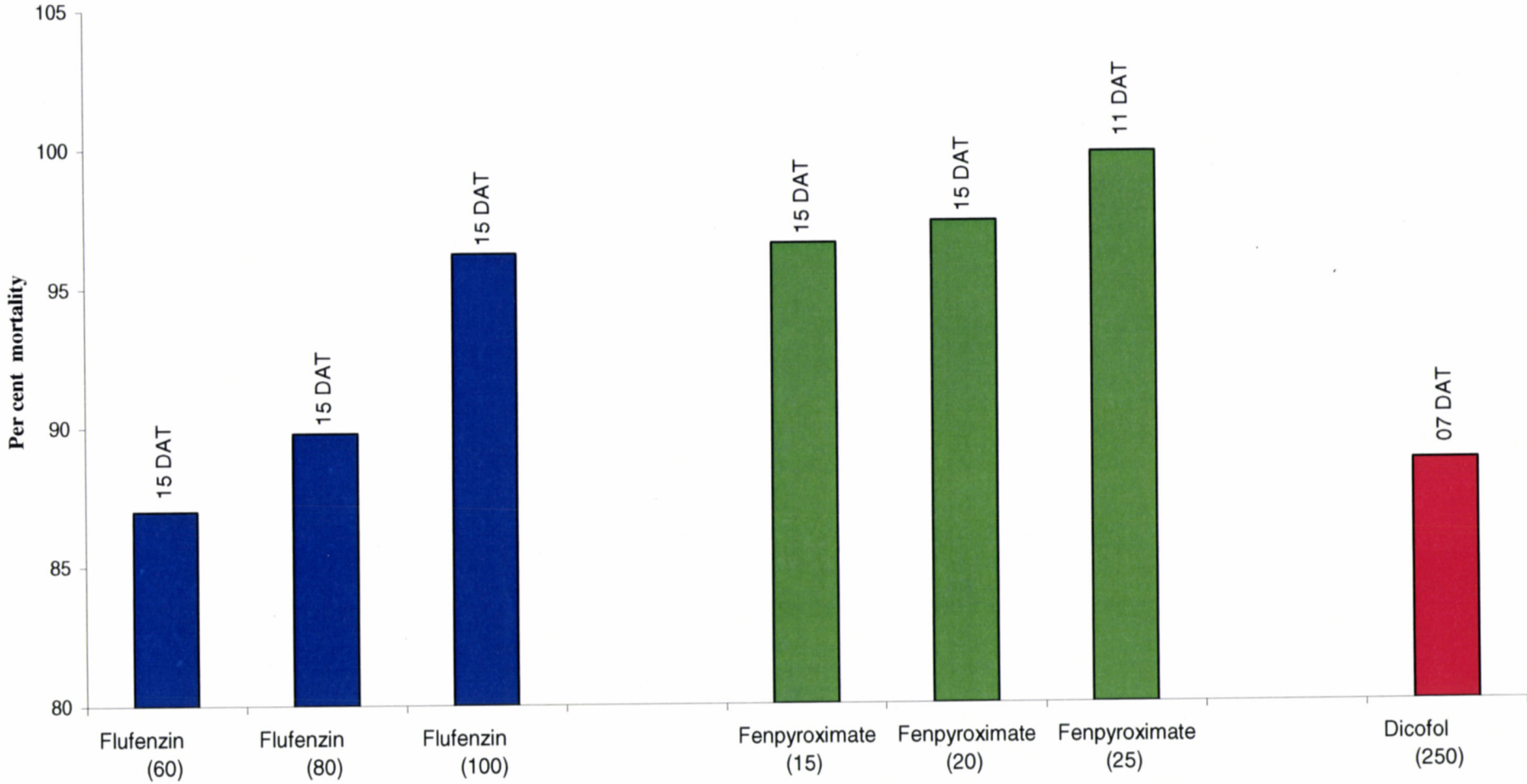


Fig. 8 Maximum protection offered by acaricides under Field conditions

4.2.1 Impact on predatory mite

The influence of the acaricides on predatory phytoseiid mite (s) was studied under both laboratory and field conditions.

4.2.1.1 Under field conditions

The data on the abundance of predatory (phytoseiid spp. complex) mites are presented in Table 15. The pre-spray mean population of the predatory mites was noticed in the range of 7.33 to 10.00 per leaf. The post-spray count recorded at 21 days after the treatment was in the range of 3.67 to 12.00 per leaf. During the entire course of observations, slight increase in the predatory mite population was observed, especially in untreated control.

In the plots treated with dicofol, the treated check, the most adverse effect on the population of predatory mites was noticed. The initial mean population of 9.33 was reduced to 0.33 mites per leaf and then fluctuated in between 0.67 and 1.67, till 14 DAT. The population was slightly grown upto 3.67 mites per leaf at 21 DAT.

In fenpyroximate treated plots, both higher (25 g a.i./ha) and intermediate (20 g a.i./ha) dosages also showed a sharp decline in the population of the predatory mites, particularly in between 3 and 14 DAT. Thereafter, a gradual increase in the population took place, ranging to around 50 per cent at 21 DAT. Its lower dose (15 g a.i./ha) also exhibited the same trend, recording the population of 3.33 and 6.33 mites per leaf at 14 and 21 days after the treatment, respectively.

In case of flufenzin treatments, the population level of the mites was almost unaffected till 3 DAT. However, a sharp reduction in predatory mites was recorded on 7^{th} day. Higher population reduction was noticed in highest dose of 100 g a.i./ha wherein the population ranged from 1.00 to 1.91 in between 7 and 17 DAT, which gradually regained to 7.67 mites per leaf. More or less similar trend was exhibited by

Table 15 : Impact of the acaricides on the abundance of predatory phytoseiid-mites on brinjal

Sr. No.	Acaricide	Dose g a.i./ha	Mean number of motile mite predators /leaf										
			Pre-spray		3 DAT		7 DAT		14 DAT		21 DAT		Mean (± S.D.)
			A	T	A	T	A	T	A	T	A	T	
1.	Flufenzin	60	9.00	3.16	9.33	3.21	10.67	3.41	8.67	3.11	11.67	3.56	3.29 (0.19)
2.	Flufenzin	80	8.00	2.98	8.33	3.04	7.67	2.93	5.67	2.56	9.00	3.16	2.93 (0.23)
3	Flufenzin	100	8.67	3.11	9.33	3.21	1.00	1.41	2.67	1.91	7.67	2.94	2.52 (0.81)
4	Fenpyroximate	15	8.33	3.03	1.00	1.41	1.67	1.63	3.33	2.06	6.33	2.69	2.16 (0.69)
5	Fenpyroximate	20	7.33	2.84	0.33	1.14	1.33	1.52	2.67	1.90	5.00	2.43	1.97 (0.68)
6	Fenpyroximate	25	9.33	3.20	0.33	1.14	0.67	1.28	2.33	1.82	4.00	2.23	1.93 (0.83)
7	Dicofol	250	10.00	3.31	0.33	1.14	0.67	1.28	1.67	1.63	3.67	2.16	1.90 (0.88)
8	Untreated control	-	9.67	3.26	10.00	3.30	10.33	3.35	11.00	3.46	12.00	3.60	3.39 (0.14)
	F :			N.S.		Sig.		Sig.		Sig.		Sig.	
	LSD (5%)			0.50		0.47		0.34		0.35		0.37	

A : Observed count T : Square root of (n+1) transformed value DAT : Days After Treatment

its intermediate dose (80 g a.i./ha). The range of predatory mite population in the lower dose of 60 g a.i./ha however, was almost in the similar range found in the untreated control. Thus, the predatory mite species were less affected by the spray application of flufenzin at 60 g a.i./ha.

The mean values computed for each of the treatments indicated that the lowest population of predatory mites was recorded in dicofol. In case of fenpyroximate, the population ranged from 1.93 to 2.16 mites per leaf while it ranged from 2.52 to 3.29 mites per leaf in flufenzin. Thus, the overall results revealed that for the predatory mites dicofol was found to be the most harmful while flufenzin was safe. With regards to fenpyroximate, it appeared to be moderately harmful. The order of toxicity was dicofol > fenpyroximate > flufenzin.

4.2.1.2 Laboratory conditions

The data on adult predatory mite mortality (*Amblyseius* spp.) observed in different treatments are presented in Table 16 and Fig. 9. The data revealed that dicofol was found to be the most toxic to adults of the predatory mites. Three dosages of fenpyroximate caused the adult mortality in between 36.67 and 56.67 per cent exhibiting moderate toxicity to the predatory mite. The predatory mite was found to be comparatively less susceptible to flufenzin wherein, the adult mortality recorded in all the three dosages ranged from 6.27 to 16.67 per cent. Thus, dicofol, fenpyroximate and flufenzin were observed to be very harmful, moderately harmful and safe to the predatory mite, respectively. The order of toxicity was found similar to that observed under field conditions.

4.2.2 Impact on beneficial arthropods

Laboratory bioassays were conducted on three representative organisms *viz.*, green lacewing, honeybee and earthworm.

Table 16 : Impact of the acaricides on beneficial arthropods under laboratory conditions

Sr. No.	Acaricide	Dose g a.i./ha	Mean per cent mortality							
			Predatory phytoseiid mite (Adult)		Green lacewing (Larva)		Honeybee (Forager worker)		Earthworm (Adult)	
			A	T	A	T	A	T	A	T
1.	Flufenzin	60	6.67	12.29	6.67	12.29	23.33	28.78	0.00	0.00
2.	Flufenzin	80	10.00	15.00	13.33	17.71	26.67	30.79	3.33	6.14
3	Flufenzin	100	16.67	23.36	16.67	23.36	33.33	34.93	13.33	21.14
4	Fenpyroximate	15	36.67	37.14	13.33	21.14	23.33	28.78	6.67	12.29
5	Fenpyroximate	20	46.67	42.99	20.00	26.07	26.67	30.79	10.0	18.43
6	Fenpyroximate	25	56.67	48.93	26.57	30.29	36.67	36.93	16.67	23.36
7	Dicofol	250	90.00	71.57	86.67	68.86	96.67	82.65	93.33	77.11
8	Untreated control	-	3.33	6.14	3.33	6.14	6.67	12.29	0.00	0.00
F :				Sig.		Sig.		Sig.		Sig.
LSD (5%)				9.53		11.14		7.72		9.70

A : Observed count T : Arcsine transformed value

4.2.2.1 Green lacewing

The data on mean per cent mortality of larvae of green lacewing are presented in Table 16 and Fig. 9. The results revealed that dicofol was found to be more toxic to the lacewing larvae in comparison with other two test acaricides. All the three dosages of fenpyroximate and the higher dose of flufenzin (100 g a.i./ha) were observed to be less toxic and were on par with each other, the larval mortality ranged between 13.33 and 26.57 per cent. The lower dose of flufenzin (60 g a.i./ha) was found to be relatively safe while its highest (100 g a.i./ha) and intermediate (80 g a.i./ha) dosages exhibited 16.67 and 13.33 per cent larval mortality, respectively. Thus, flufenzin appeared to be more safer than fenpyroximate. The toxicity to the larvae of green lacewing was in the descending order as dicofol > fenpyroximate > flufenzin.

4.2.2.2 Honeybee

The data in respect of bee mortality observed in different acaricide treatments are presented in Table 16 and Fig. 9. The data indicated that dicofol was found to be extremely toxic (96.67% mortality) while the test acaricides were slightly toxic (23.33 to 36.67% mortality). The higher (25 g a.i./ha) and intermediate (20 g a.i./ha) dosages of fenpyroximate caused 36.67 and 26.67 per cent bee mortality respectively. The toxicity of flufenzin at higher (100 g a.i./ha) and intermediate (80 g a.i./ha) dosages were observed in almost similar range. The lower doses of both the candidate acaricides resulted in equal (23.33%) mortality of honeybee. The order of toxicity could be stated as dicofol > fenpyroximate > flufenzin.

4.2.2.3 Earthworm

It could be seen from the data in respect of the mortality of earthworms presented in Table 16 and Fig. 9, that dicofol being an organochlorine compound proved very harmful to the earthworms, recording 93.33 per cent mortality. On the

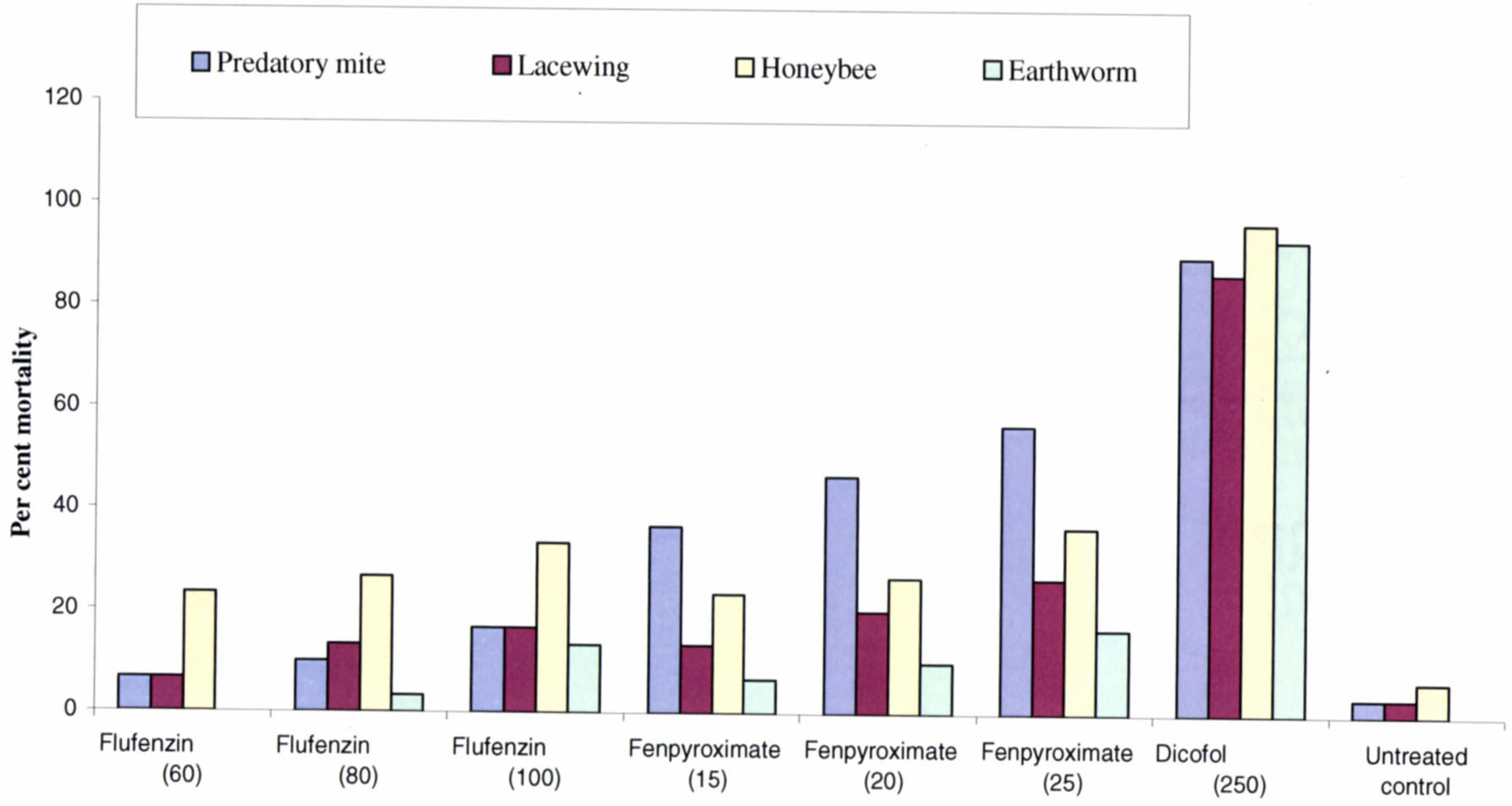


Fig. 9 Impact of acricides on beneficial arthropods under laboratory conditons

contrary, the three dosages of both the test acaricides resulted in less than 17 per cent mortality of the worms. The higher dosages of both the test acaricides and the intermediate dose of fenpyroximate (20 g a.i./ha) were found on par with each other, recording 10.00 to 16.67 per cent mortality. The intermediate dose of flufenzin (80 g a.i./ha) and lower dose of fenpyroximate (15 g a.i./ha) were comparatively more safe. Moreover, flufenzin at 60 g a.i./ha was found at par with untreated control (no mortality). Amongst the three acaricides, flufenzin was found to be relatively safe, fenpyroximate to be slightly harmful and dicofol to be very harmful to the earthworms.

4.2.3 Impact on soil microbial biomass

Soil samples collected four weeks after final spray in *kharif* season were brought to the laboratory for assessment of biological action of the acaricides on microbial population. The impact on soil microbes was measured as microbial biomass carbon by fumigation – extraction method. This method considers microbial biomass carbon (MB-C) as a good indicator of microbial activity in soil. The data on MB-C in µg /g soil obtained in plots treated with different acaricides are given in Table 17.

The MB-C in different treatments ranged from 180.3 to 230.3 µg /g soil, the minimum MB-C recorded in dicofol treated plots while maximum MB-C was found in untreated control plots. The MB-C was observed to be slightly higher in flufenzin in comparison with fenpyroximate, another test acaricide. In both the candidate acaricide treatment plots, decreased in microbial biomass carbon with corresponding increased levels of the dosage was found. However, all the acaricide treatments were found to be statistically at par with untreated control. Numerically, dicofol and fenpyroximate had slightly more harmful influence on soil biomass while flufenzin had less influence.

Table 17 :Estimation of microbial biomass carbon (MB-C) in soil collected from experimental field

Sr. No.	Acaricide	Dose (g a.i./ha)	Soil wet wt. (g)	Oven-dry wt. (g)	Soil H_2O content (%)	MB-C (µg/g soil)
1.	Flufenzin	60	10.4	7.5	25	225.7
2.	Flufenzin	80	11.0	8.2	21	223.3
3	Flufenzin	100	11.5	8.4	23	219.3
4	Fenpyroximate	15	10.5	7.8	19	210.7
5	Fenpyroximate	20	12.0	8.9	23	200.3
6	Fenpyroximate	25	10.4	7.6	20	190.3
7	Dicofol	250	11.0	8.1	24	180.3
8	Untreated control	-	10.5	7.7	22	230.3
	F :					N.S.
	LSD (5%) :					30.61

4.3 Estimation of pesticide residues

The test acaricides *viz.*, flufenzin at 100 and 200 g a.i./ha and fenpyroximate at 25 and 50 g a.i./ha were taken in the present investigations for studying their dissipation pattern and the residual status in / on brinjal fruits. The reference standards of parent compounds were obtained from the concern manufacturers and the residues in their formulations were determined. The methods employed for residue analysis were provided by the manufacturer. Reversed-phase high performance liquid chromatography (HPLC) with ultraviolet detection at specified wavelength was used for determining the residues of both the test acaricides. The suitability of the chromatography system was validated by performing recovery experiments. The linearity of the detector was determined using calibration standards. Peak identification was established by comparing the characteristic retention times of peaks in the standard chromatograms and sample chromatograms. Standards were injected at the beginning and at the end of the analysis of a set of samples to evaluate stability of chromatography system and the standards. All the analyses were carried out in duplicate and the data were analysed statistically to interpret the results.

4.3.1 Recovery studies

An untreated samples (control) and untreated sample fortified with known amount of pesticide standard were included in each set of samples analysed to establish percentage recovery. The average percentage recovery of each acaricide was determined by applying two fortification levels. Test of spiked samples showed that the overall extraction efficiencies for residue analyses were 90.0 per cent for flufenzin and 87.70 per cent for fenpyroximate (Table 18 and 19). These recoveries were within the commonly acceptable range of 80 to 110 per cent, which suggested

Table 18: Recovery of flufenzin added to brinjal fruits

Added (µg/g sample)	Recovered (µg/g sample)	Recovery (%)
0.50	0.44	88
0.50	0.43	86
0.50	0.46	92
1.00	0.92	92
1.00	0.89	89
1.00	0.93	93
Mean recovery (± S.D.)		90.0 (± 2.76)
LOD (Limit of detection)		0.05 ppm

Table 19: Recovery of fenpyroximate added to brinjal fruits

Added (µg/g sample)	Recovered (µg/g sample)	Recovery (%)
2.0	1.74	87.00
2.0	1.76	88.00
2.0	1.80	90.00
4.0	3.50	87.50
4.0	3.50	87.42
4.0	3.45	86.25
Mean recovery (± S.D.)		87.7 (± 1.27)
LOD (Limit of detection)		0.05 ppm

the quite acceptable precision for analyses. The limit of detection (LOD) was considered as 0.05 ppm for both the analyses.

4.3.2 Initial deposits and dissipation

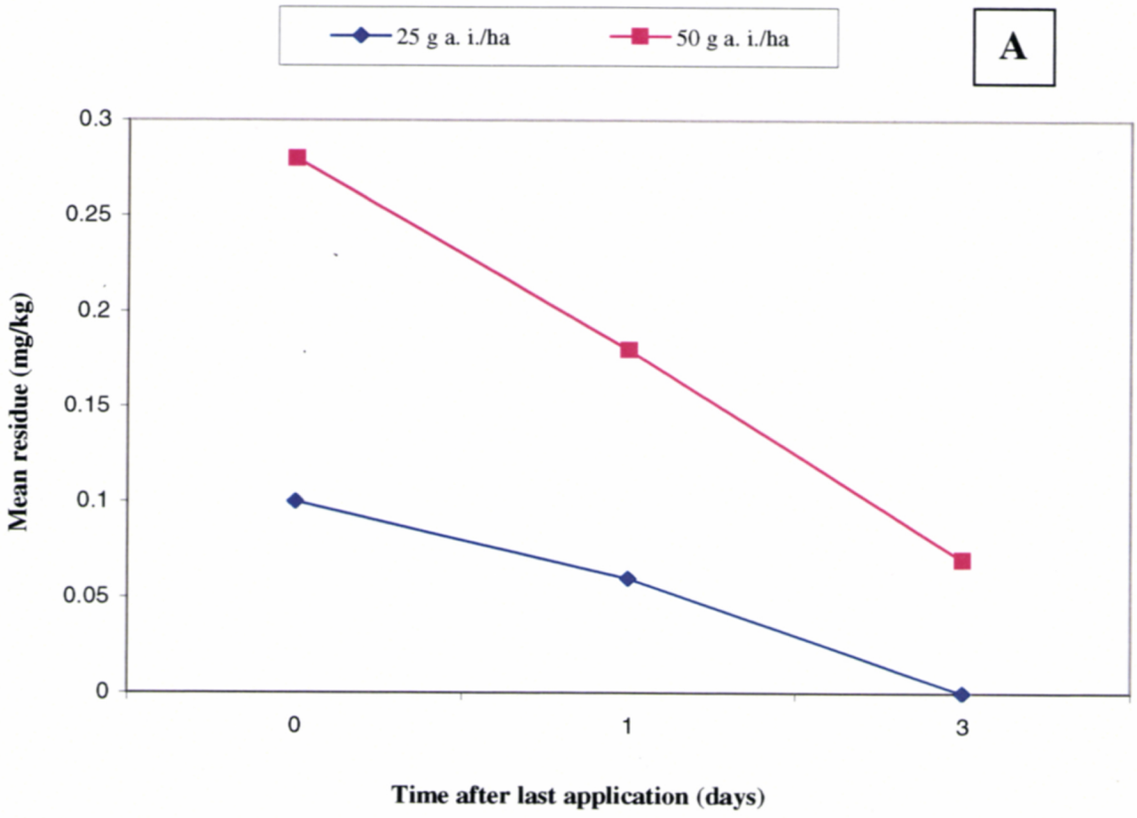
To obtain preliminary data on the rate of dissipation and residue levels resulting from a field treatment, the untreated check and acaricide treatments at higher two dosages were evaluated for the residues on 0, 1, 3, 5, 7 and 10 days after the second spray in *kharif*, 2003. The mean residues of acaricides at different sampling times are given in Table 20 and the residue dissipation is depicted in Fig. 10.

1) Flufenzin: The retention time for the parent compound was 4.80 minutes. In control samples, no peaks were detected in the chromatograms. Flufenzin in treated sample was quantified by reading the samples against a chromatogram of flufenzin standard. In highest application rate of 200 g a.i./ha, the concentration of parent compound at zero time (≈ 1h) was 0.37 ppm. A decrease in the level of total residue was observed with elapsed time. Residue level of 0.06 ppm detected at 7^{th} day was dissipated to below detectable level of 0.05 ppm within 8 days of post-application. Detectable residue was not noticed in the fruit samples colleted on 10^{th} day. The initial residue of 0.20 ppm resulted from the lowest dose (100 g a.i./ha) was further dissipated with the time to a level of 0.05 ppm on 5^{th} day of post-treatment and below the detectable level within 6 days. Detectable residue was not found in the fruit samples collected on 7^{th} day. Under field conditions, the half-life (RL_{50}) was estimated to be 2.52 and 2.72 days for the recommended and double the recommended dose , respectively. The days required for the residue to reach below the detectable limit (T_{BDL}) for the lowest and highest dose was 5.20 and 8.28 days, respectively.

Table 20 : Dissipation of the acaricide residues on brinjal fruits after second spray of *kharif*, 2003

Days After Spray	Mean Residues in mg/kg (± SD)			
	Dose of flufenzin		Dose of fenpyroximate	
	100 g a.i./ha	200 g a.i./ha	25 g a.i./ha	50 g a.i./ha
0	0.20 (0.01)	0.37 (0.02)	0.10 (0.03)	0.18 (0.04)
1	0.16 (0.02)	0.32 (0.01)	0.06 (0.01)	0.12 (0.03)
3	0.10 (0.02)	0.22 (0.03)	BDL	0.07 (0.01)
5	0.05 (0.01)	0.13 (0.02)	BDL	BDL
7	BDL	0.06 (0.01)	BDL	BDL
10	BDL	BDL	BDL	BDL
RL_{50} (days)	2.52	2.72	1.36	2.25
T_{BDL} (days)	5.20	8.28	1.36	4.03
Regression equation	Y = 2.3196 – 0.1193 x	Y = 2.6163 – 0.1109 x	Y = 2.0 – 0.2219 x	Y = 2.2384 – 0.1339 x

BDL : Below Detectable Limits of 0.05 mg/kg (ppm)



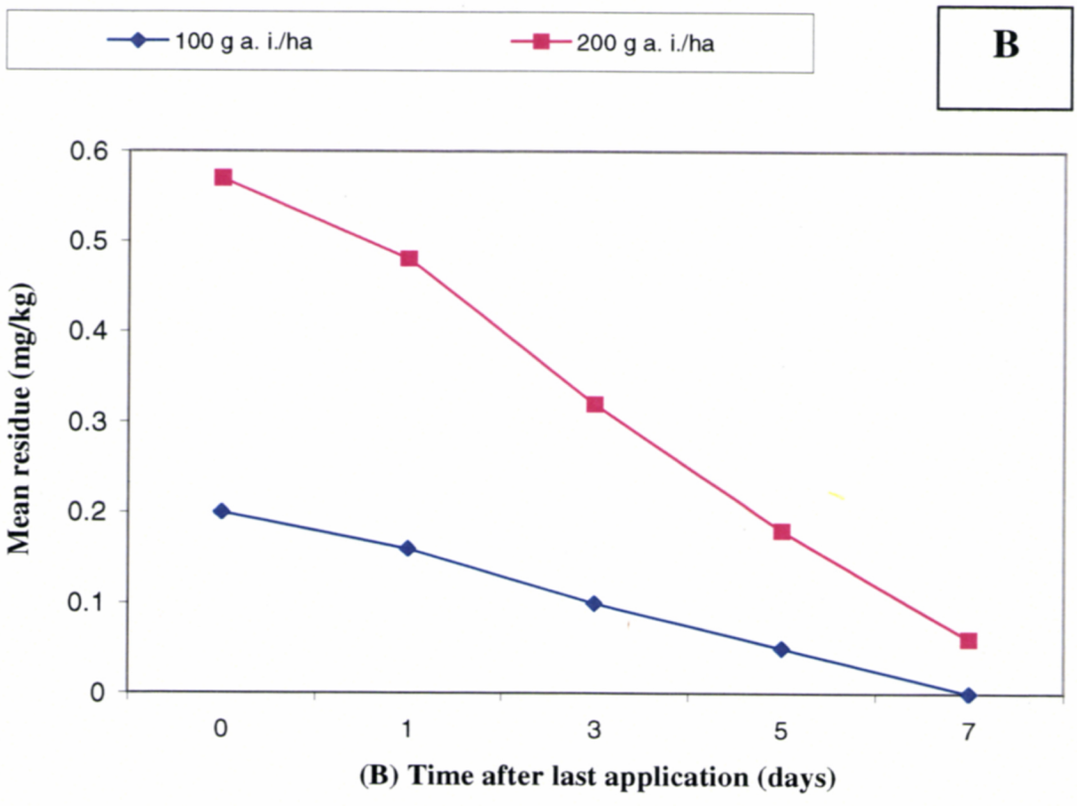


Fig. 10 Dissipation of residues in brinjal fruits in *kharif*, 2003
(A) flufenzin (B) fenpyroximate

2. Fenpyroximate: Retention time for the parent compound was 8.55 minutes. The immediate post-application (zero time) residue level on fruits was 0.18 ppm for double the dose of 50 g a.i./ha. The level of residue was decreased with time, to a level of 0.07 ppm within 3 days, which was further decreased below the detectable limit of 0.05 ppm within 4 days. Initial residue level of 0.10 ppm resulted from the lowest rate of application (25 g a.i./ha) was detected to be 0.06 ppm at 1 day while on 3rd day, the residue was not detected in the samples. Under filed conditions, half-life (RL_{50}) was estimated to be 1.36 and 2.25 days for the lowest and the highest dose, respectively. The days required for the residue to reach below the detectable limit (T_{BDL}) for the recommended and double the recommended dose were 1.36 and 4.03 days, respectively.

4.3.3 Fixation of maximum residue limit

Maximum residue limit (MRL) is the maximum concentration for a pesticide residue on crop or food commodity resulting from good agricultural practice. The concentration is expressed in milligrams of pesticide residue per kilogram of the commodity (mg/kg). Acceptable daily intake (ADI) of a pesticide is the daily intake which, during the entire life time appears to be without appreciable risk to the health of the consumer on the basis of all facts known at the time of evaluation of the pesticide. It is expressed as milligrams per kilogram of body weight (mg/kg b.w.). The ADI is derived with the formula, ADI = No observed effect level (NOEL) / safety factors. The NOEL is the highest dose of a substance in experimental animal studies that does not cause any detectable toxic effects. It is expressed as mg/kg b.w. The maximum permissible intake (MPI) is derived with the formula, MPI = ADI x average body weight of human being. It is expressed as mg per person per day. Theoretical maximum residue contribution (TMRC) or total dietary exposure is calculated by

using the formula, TMRC = Σ (F_I x T_I), wherein F_I represents the food consumption estimate of each commodity for which the pesticide is registered/recommended (in terms of kg of food per person per day). T_I represents the established or proposed maximum residue limit i.e. the highest level of residues found on the commodity when it is served for the first time for consumption. TMRC is usually expressed as mg of pesticide per person per day.

Assuming a total intake of 1.5 kg per 60 kg man from a diet containing various items (wheat, pulses, vegetables, milk etc.), the intake of brinjal is 75 g (1500 g diet contains 75g of brinjal, thus 1000 g contains 50g i.e. 0.05 kg). It is further assumed that all commodities in the diet contain residues of a pesticide. Therefore, the TMRC for each commodity is estimated and summed upto calculate total dietary exposure. For fixation of MRL of the pesticide, the value of MPI is compared with the total dietary exposure (TMRC). If the value of TMRC is lower than the value of MPI, then the residues remaining on the crop under good agricultural practice are proposed as MRL on that crop. At international level, MRLs are fixed jointly by FAO/WHO and in India, these are being fixed by Ministry of Health, Government of India, New Delhi (Handa *et al.*, 1999).

4.3.3.1 Fixation of proposed MRL for flufenzin

As per the technical information supplied by the manufacturer, the ADI of flufenzin is 0.00918 mg/kg b.w./day. Assuming an average body weight of Indian male of 60 kg, the MPI and TMRC are calculated as under;

MPI = ADI x Average body weight

MPI = 0.0918 x 60 ; MPI = 5.508 mg per person per day

TMRC = Daily consumption of food commodity x Residue remaining on crop

TMRC = 0.05 x 0.4 ; TMRC = 0.02 mg per person per day

Herein, the value of TMRC (0.02) is much smaller than the value of MPI (5.508), assuming that the summation of total dietary intake of flufenzin resulting from the residues found on all commodities in a day's diet would be less than MPI (5.508). Hence, the maximum residues found on brinjal i.e. 0.37 ppm could be proposed as the maximum residues limit, rounded upto 0.4 ppm of flufenzin on brinjal. The mean residues concentration determined on brinjal is 0.37 ppm, which is within the level of 0.4 ppm MRL proposed in this study. Therefore, the estimated dissipation pre-harvest interval arrives to zero days. Besides, the consumer risk at ADI of 0.0918 and TMRC of 0.02 would be 0.36 per cent of MPI of 5.508 mg per person per day.

4.3.3.2 Fixation of proposed MRL for fenpyroximate

As per the technical information supplied by the manufacturer the ADI of fenpyroximate is 0.01 mg/kg b.w./day. The MPI and ADI are calculated as follows:

MPI = 0.01 x 60 ; MPI = 0.60 mg per person per day

TMRC = 0.05 x 0.2 ; TMRC = 0.01 mg per person per day

Herein, the value of TMRC (0.01) is much smaller than the value of MPI (0.60). Hence, the maximum residues found on brinjal i.e. 0.18 ppm could be proposed as the maximum residues limit, rounded upto 0.2 ppm of fenpyroximate on brinjal. The mean residue concentration determined on brinjal is 0.18 ppm, for which dissipation pre-harvest interval arrives to zero day. Besides, the consumer risk at ADI of 0.01 and TMRC of 0.01 would be 1.67 per cent of MPI of 0.60 mg/person/day.

4.3.4 Effect of home processes on decline of residues on fruits

In this study, the brinjal fruit samples harvested immediately (zero time, 1hr) after the second spray were subjected to two home-processes *viz.*, 1. Thorough washing of fruits with tap water and 2. Washing followed by cooking. The data on residue levels prior to and after the processing are given in Table 21.

Table 21 : Effect of processing of brinjal fruits on decline of acaricide residues

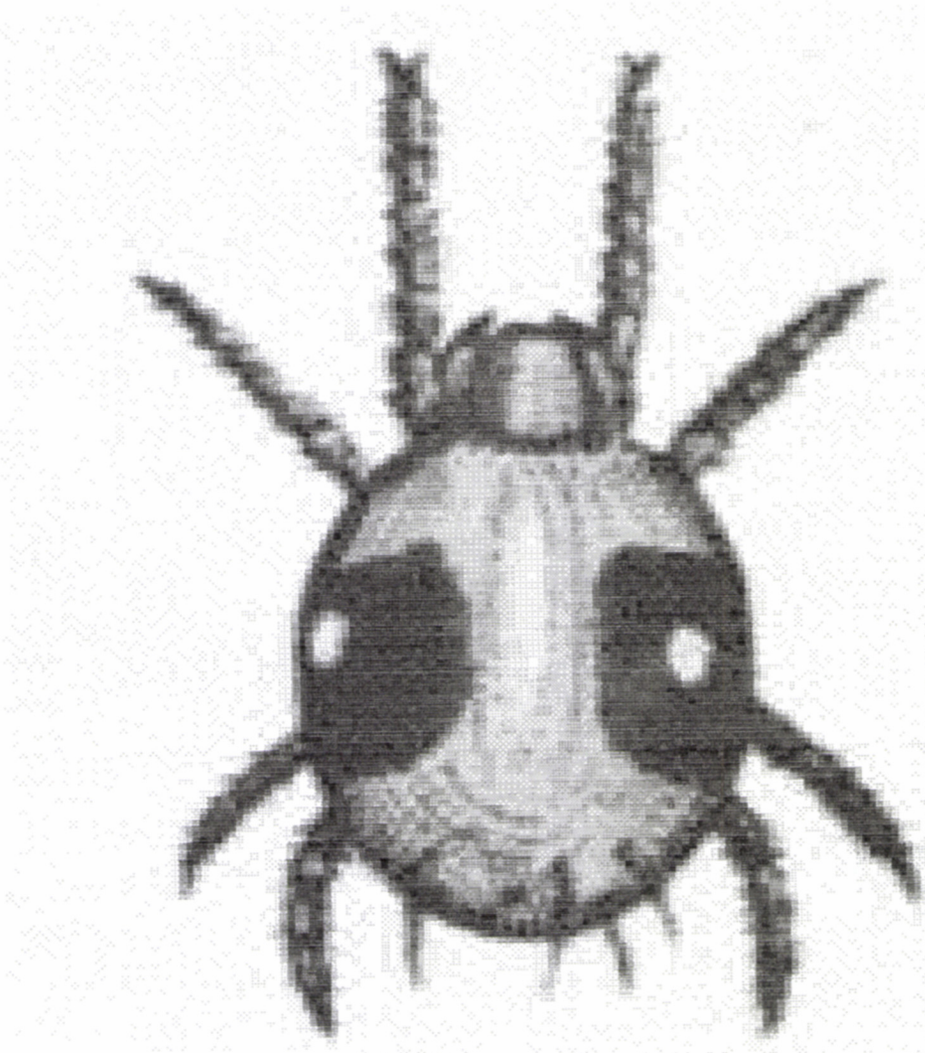
Sr. No.	Particulars	Dose of flufenzin (g a.i./ha)		Dose of fenpyroximate (g a.i./ha)	
		100	200	25	50
1	Residues in mg/kg : 0-DAS (Pre-washing)	0.200	0.370	0.100	0.180
2.	Residues in mg/kg : 0 -DAS (Post-washing)	0.104	0.210	0.054	0.080
3.	Decline of residues After washing (%)	48.00	43.24	46.00	55.56
4.	Residues in mg/kg after washing and cooking : 0-DAS	0.060	0.120	0.030	0.045
5.	Decline of residues after washing and cooking (%)	70.00	67.57	70.00	75.00

DAS : Days After (second) Spray

1) Flufezin: Initial residue level was 0.37 ppm in the highest dose of 200 g a. i./ ha and 0.20 ppm in the lowest dose of 100 g a. i./ ha. The post-washing residues were estimated to be 0.21 ppm in the highest dose while 0.104 ppm in the lowest dose, indicating 43.24 and 48.0 per cent reduction. The residue level due to both washing and cooking processes was 0.12 ppm in the highest dose and 0.06 ppm in the lowest dose, which resulted in 67.57 and 70.0 per cent reduction in residues, respectively.

2) Fenpyroximate: Pre-washing fenpyroximate residue level was 0.18 ppm in highest dose of 50 g a. i./ ha while 0.10 ppm in the lowest dose of 25 g a.i./ha,. The residues level after washing was 0.08 ppm in the highest dose and 0.054 ppm in the lowest dose, which showed 55.56 and 46.0 per cent removal of residues by washing alone, respectively. Due to both washing and cooking processes, the decline in residues was 70 per cent (0.03 ppm) and 75 per cent (0.045 ppm) in the recommended and double the dose of fenpyroximate, respectively.

Chapter Five



DISCUSSION

5. DISCUSSION

The results obtained in the present investigations are discussed in this chapter

5.1 Bioefficacy studies

The acaricidal effects of the candidate acaricides were evaluated by conducting both laboratory bioassays and field bioefficacy trials.

5.1.1 Laboratory bioefficacy

It was evaluated by using residual leaf-disc-dip method on life-stages *viz.*, egg, larva, nymph and adult. The relative toxicity ratio (LC_{50}) was also evaluated for larvae and adults.

5.1.1.1 Efficacy on egg-stage

The results indicated that flufenzin, dicofol and fenpyroximate were relatively found to be excellent, good and moderate contact ovicides, respectively. None of the test acaricide exhibited sterilization effect / oviposition inhibition effect on the egg-laying females.

The results obtained in the present studies in respect of ovicidal action of flufenzin are in agreement to those reported by Pap *et al.* (1994 and 2002). Moreover, they found that the compound also acts as sterilant agent on egg-laying females, which was not apparent under present studies.

Cho *et al.* (1993), Cheng and Pan (1994), Laffi and Raboni (1995), Song *et al.* (1995), Cho *et al.* (1997), Kimura (1999) and Curkovic *et al.* (1999) reported moderate to excellent ovicidal action by fenpyroximate in different species of tetranychid mites. However, Veire *et al.* (1992) and Piao *et al.* (1999) found that fenpyroximate did not exhibit any ovicidal action. Under the present studies, the compound exhibited relatively moderate action against the test species. In the present investigations, dicofol showed 85.6 per cent decline in hatching. Similar observations

(86.5% decline) were recorded by Singh and Singh (1999). Under these studies, no oviposition inhibition effect on the egg-laying females was noticed however, oviposition inhibition has been reported for fenpyroximate (Cho *et al.*, 1993) and for flufenzin (Pap *et al.*, 1994).

5.1.1.2 Efficacy on larval-stage

The results indicated that all the acaricides under the studies contributed 73.30 to 100 per cent larval mortality. Fenpyroximate, flufenzin and dicofol were found to be excellent, fairly good and moderate larvicides, respectively.

The results obtained in respect of flufenzin are in agreement with that of Pap *et al.* (1994) wherein they advocated this compound to be efficient larvicide. Cho *et al.* (1993) found that fenpyroximate was very effective against all the life-stages, including the larvae. In the present studies it was found to be excellent larvicide.

5.1.1.3 Efficacy on nymphal-stage

The result indicated that fenpyroximate and dicofol were found to be good nymphicides while flufenzin to be moderately active nymphicide. The susceptibility of nymphs to fenpyroximate has been documented by Korno *et al.* (1990), Veire *et al.* (1992) and Cho *et al.* (1993), thus the findings in respect of fenpyroximate are in confirmation with earlier findings.

5.1.1.4 Efficacy on adult-stage

The results revealed that fenpyroximate and dicofol were found to be excellent adulticides while the adults were less susceptible to flufenzin. Veire *et al.* (1992), Cho *et al.* (1993) Laffi and Raboni (1995), Cho *et al.* (1997) and Piao *et al.* (1999) observed fenpyroximate to be very efficient against the tetranychid adults. The results obtained in respect of fenpyroximate are in conformity with these workers. The results indicated for flufenzin were also in agreement with the findings reported by

Pap *et al.* (1994 and 2002) wherein, flufenzin found to be less susceptible to tetranychid mites. Further, adults were found to be more sensitive to fenpyroximate than nymphs however, Korno *et al.*(1990) observed nymphs to be more sensitive than adults.

5.1.1.5 Relative toxicity for larval and adult-stage

The estimated LC_{50} values for fenpyroximate, flufenzin and dicofol for larvae were 2.52, 0.57 and 166.25 ppm, whereas for adults, the values were 4.37, 1153.57 and 309.19, respectively. This indicated that fenpyroximate showed excellent larvicidal and adulticidal action while standard check, dicofol exhibited moderate action. Flufenzin although showed a good performance against the larvae, the adults were found much less susceptible to it, particularly at the field dosage.

For dicofol, Nassar *et al.* (1984) and Kaneria and Bharodia (1991) reported the LC_{50} for adults of *T. cinnabarinus* to be 224 and 275 ppm, respectively. While Cheng and Pan (1994) estimated values for adults of *T. urticae* to be 1791.43 ppm. Kimura and Kushita (1994) reported the LC_{50} value of fenpyroximate for adults of *T. urticae* and *Panonychus ulmi* as 2.69 and 0.18 ppm, respectively. Cheng and Pan (1994) estimated the value of fenpyroximate to be 237.93 ppm for adults of *T. cinnabarinus*. Pap *et al.* (2002) estimated the LC_{50} values for larvae and adults of the Tetranychid mites for fenpyroximate to be 2.0 and 4.0 while for flufenzin to be 0.6 and > 1000 ppm, respectively. Under the present studies the findings obtained were in similar range to that reported by Pap *et al.* (2002).

The bioassays carried out for evaluating overall laboratory bioefficacy of the acaricides against the test mite indicated that the standard check and most commonly recommended acaricide, dicofol still shows efficiency to control the mite to a moderate level however, it exerts deleterious effects on beneficials. Flufenzin was an

excellent ovicide, showed good efficacy against larvae and exhibited moderate action against nymphs but it was ineffective against adult. On the contrary, fenpyroximate at intermediate dose, provided excellent control against larvae, nymphs and also possessed a moderate ovicidal action. Besides, the fenpyroximate exhibited quick knockdown effects.

5.1.2 Field bioefficacy

In bioassays studies, dicofol was found fairly good ovicide, larvicide, nymphicide and adulticide. Under field conditions, the efficient kill of the mite was noticed in between 3 to 5 DAT and its efficiency persisted upto 7 DAT, offering the protection to the extent of 88 per cent.

Fenpyroximate showed moderate ovicidal action however, appeared to be excellent larvicide, nymphicide and adulticide and exhibited a quick knockdown effect. Under field conditions, it proved to be the efficient acaricides extending the protection > 95 per cent till 15 DAT. The maximum kill was noticed in between 3 and 5 DAT and extended the promising control for little more than 15 DAT. All the test-dosages were observed more or less equally effective.

In bioassay studies, flufenzin proved to be excellent ovicide, fairly good larvicide and moderate nymphicide. However, adults were found less susceptible. Under field conditions, the protection offered by the test dosages was dose-dependent. The mortality of mite increased with the corresponding increase in the dose levels. Efficient kill of the individuals was noticed in between 13 and 15 DAT. The extent of protection offered was in the range of 87 to 95 per cent.

The standard check, dicofol although found to be efficient acaricide, offered less protection in comparison with the new test acaricides and was found promising only for a week. Amongst the candidate acaricides, fenpyroximate was observed to be

more efficient over flufenzin in almost all respects. Moreover, it exhibited a quick knockdown effect on motile mites wherein; affected individuals spin down from leaves, which was an added advantage of minimizing the crop damage from their feeding/ovipositing. On the contrary, the crop damage still continued with the individuals in the plots treated with flufenzin, at least up to 11 to 13 DAT.

Promising control of *T. urticae* with fenpyroximate has been reported by Veire *et al.* (1992), Cho *et al.* (1993), Tang and Tang (1998), Piao *et al.* (1999), Kimura (1999), Chen (2000) and Tjosvold *et al.* (2001). It was also found to be extremely effective against *Panonychus ulmi* and has been advocated by Decraek and Sterk (1992), Sterk (1994), Forti *et al.* (1994), Arnaudov (1995), Curckovic *et al.* (1997 and 1999) and Stamenkovic *et al.* (1999). Similarly, it was found very effective against *T. viennensis* (Cho *et al.*,1997) and against false spider mite, *Brevipalpus* spp. (Rezk *et al.*, 2001). Fenpyroximate exerted a rapid initial effect and remained effective for about 30 days (Arnaudov, 1995). It offered good protection for 25 days (Cho *et al.*,1995), for 27 days (Raga *et al.*,1996) and for 28 days (Stamenkovic *et al.*,1999). Pap *et al.* (2002) reported that flufenzin was found superior over dicofol against *T. cinnabarinus*. Roman *et al.* (1997) reported that it gave satisfactory control of *T. urticae*. The results obtained under the studies in respect of fenpyroximate were in agreement to those reported above.

5.1.3 Effect on general health of plants

The plants in all the dosages of three acaricides were found to be healthy. Thus, no apparent adverse effect/ phytotoxicity symptoms were exhibited by any of the acaricides. The results are in confirmation with Askari and Zare (1976), Veire *et al.* (1992) and Izwa (2001) wherein, no phytotoxic effect on the crop plants was reported.

5.1.4 Effect on yield

The results revealed that, higher (25 g a. i./ha) and intermediate (20 g a. i./ha) dosages of fenpyroximate and higher dose of flufenzin (100 g a. i./ha) were found at par and produced more yield of marketable brinjal fruits. The lower dose of fenpyroximate (15 g a. i./ha) and the intermediate dose of flufenzin (80 g a. i./ha) gave more or less equal yields and observed on par with each other. The lower dose of flufenzin (60 g a. i./ha), dicofol (250 g a. i./ha) and the untreated control were found statistically in similar range.

The relationship of the profit-margins contributed by the acaricides with that of extent of protection offered by them suggested by all the three dosages of fenpyroximate and the higher dose of flufenzin effectively controlled the mite under field conditions and extended better monitory returns.

5.2 Safety of beneficials

The impact of the acaricides on safety of beneficials was evaluated by selecting representative organisms under laboratory/field conditions for observing their adverse effects.

5.2.1 Impact of predatory mite

The data on abundance of phytoseiid mites revealed that dicofol was found to be the most harmful to predatory mites while flufenzin to be the safest. Fenpyroximate appeared to be moderately toxic. Laboratory bioassays on the predatory mite, *Amblyseius* spp. indicted that dicofol and flufenzin were very toxic and very safe, respectively. Moreover, fenpyroximate exhibited comparatively lesser toxicity than depicted in the field bioassays.

Curckovic *et al.* (1999) observed dicofol to be highly toxic to *Amblyseius andersoni* while in the present studies, it proved to be highly toxic to *Amblyseius* spp.

Pap *et al.* (1994) reported that flufenzin did not cause any adverse effect on predatory mites. Under this study, it appeared to be safest to the mite.

Fenpyroximate was found harmless to the predatory mites (Forti *et al.*, 1994 and Curckovic *et al.*, 1999) while it was observed less toxic to phytoseiid mite, *Amblyseius womersleyi* (Park *et al.*, 1996) and *Neoseilus chilenensis* (Curckovic *et al.*, 1999). Fenpyroximate was found harmful to predatory mite, *Typhodromus pyri* (Sterk, 1994), *Iphiseiodes zuluagri* (Reis *et al.*, 1998), *Euseius alatus* (Reis *et al.*, 1999) and *Neoseilus californicus* (Curckovic *et al.*, 1997). Fenpyroximate was found harmful to prevailing predatory mites leading to 80 per cent population reduction within 8 days after the treatment (Sato *et al.*, 1995). Hazardous effects of fenpyroximate were also noticed by Muther (1998) wherein, the population density of *Neoseilus californicus* was reduced between 56 to 99 per cent over a 13 weeks period. However, Veire *et al.* (1992) reported that the residual contact toxicity of fenpyroximate to predatory mite, *Phytoseiulus persimilis* was rather small so that the predatory mite was found all the time during experimental period, but in very limited numbers, as it host *T. urticae* was efficiently killed by fenpyroximate. Under the present studies, similar conditions might have occurred and the predatory mites would have dispersed to other sources.

5.2.2 Impact on green lacewing

The data on larval mortality of green lacewing, *Chrysoperla carnea* indicated that dicofol was more toxic, fenpyroximate was slightly toxic and flufenzin was relatively safer. Treng and Kao (1997) reported that fenpyroximate was found to be harmless, exhibiting the mortality < 50 per cent to larvae of green lacewing, *Mallada basalis*. Thus, the finding obtained in the present investigation are in agreement to the findings of Treng and Kao (1997).

5.2.3 Impact on honeybee

Role of entomophilic pollinators in plant pollination is well known. Amongst these, hymenopterous insects like *Apis*- bees, eg. honeybee and non- *Apis*-bees, eg. *Megachile* spp., *Xylocopa* spp., *Trigona* spp. etc. play an immense role. Generally, the bees work for longer time than the other entomophilic pollinators. Therefore, studies on the deleterious effects on pesticides of such hymenopterous, non-target organisms are of greater significance. Under the present studies, forager worker, the most sensitive stage of honeybee was considered as a representative test-organism.

The data pertaining to the bee-mortality indicted that dicofol, the standard check was observed to be extremely toxic while both the candidate acaricides were found to be slightly toxic. The toxicity of the test acaricides was in the order of flufenzin < fenpyroximate < dicofol. The laboratory studies carried out by Veire *et al.* (1992) revealed that 24 h exposure of a parasitic wasp, *Encarsia formosa* to 40 ppm concentration of fenpyroximate applied on glass plate did not cause any mortality however, its parasitisation capacity was slightly hampered. Saito *et al.* (1996) reported that dicofol and fenpyroximate were found harmless to the hymenoptorous parasitoid- complex of serpentine leaf miner occurring on vegetables in Japan. Under the present investigations, fenpyroximate at the same concentration exhibited about 30 per cent mortality, over and above the untreated control mortality. Slight mortality observed herein, may be due to other ingredients used in the formulation, which needs to be tested alongwith the technical grade of fenpyroximate.

5.2.4 Impact on earthworm

The data on mortality parameters pertaining to the earthworm obtained by using contact filter paper test method revealed that dicofol was found more harmful,

fenpyroximate was observed slightly harmful and flufenzin was found relatively safe to the earthworms.

The results obtained for dicofol are in agreement to those reported by Roberts and Dorough (1984) wherein, ninety agro pesticides were screened against the earthworm, *Eisenia foetida* by using similar test method and dicofol was found to be very toxic among them. The toxicity of the test acaricides to earthworms in this study cannot be compared with the earlier reports, since there is a lack of information in literature on fenpyroximate and flufenzin, being newly introduced molecules.

The contact test is a simple, cheaper and quicker method however, it does not accurately represent the situations in the soil system (Neuhauster *et al.*,1985). It is now well established that apart from abiotic and biotic factors that influence the soil system, the rate of mineralisation and adsorption of organic molecules of pesticides mostly depends upon the clay and organic matter contents prevailing within the soil. Thus, fenpyroximate showing a slight toxicity to earthworm in contact filter paper test method may prove more safer under the field conditions.

5.2.5 Impact on soil microbial biomass

Raised microbial biomass (microbial population) play important role in the retention and release of nutrients and energy. It may be affected by many factors including environmental changes and pollution with xenobiotic chemicals thus, the aim of the present investigation was to assess the cumulative effects of the acaricides on soil microbial biomass, under field conditions.

The data on microbial biomass carbon was found statistically non-significant. Numerically, flufenzin showed slightly higher levels of microbial biomass carbon than fenpyroximate indicating that latter had slightly influence while the former did not influence the soil microbial activity. The results obtained in respect of flufenzin

are in agreement with that of Ferenczi *et al.* (1998). Under different field conditions, fenpyroximate may influenced the microbial activity in soil, to a lesser extent. In laboratory studies carried out by White *et al.* (2001), fenpyroximate did not show any adverse effect. However, interpretation of these observed effects is quite difficult because many factors, including the environmental changes affect the soil microbial population. Since, the data was found statistically non-significant, it appears that the acaricides did not influence the soil microbes significantly.

Although, several approaches have been described in literature, the method adopted under the present studies is more easily applicable and rapid procedure for total microbial biomass determination in soil. The perusal of literature revealed that the information of the pesticidal fate in tropical soils is very scanty. Its seems that there is a need to initiate systematic studies on environmental fate (metabolism and transportation) of newer pesticides in tropical soils. Careful experiment to assess the rate of degradation from knowledge of factors influencing it, are needed to understand the behaviour of the pesticide in biosphere. Although, laboratory tests with soils are convenient, tests with field soils under natural conditions are more useful and valid. Thus, these findings need confirmation by taking rigorous studies.

5.3 Estimation of acaricide residues

The residues of the candidate acaricides were determined by high performance liquid cromatograph (HPLC). Flufenzin at 100 and 200 g a. i./ha and fenpyroximate at 25 and 50 g a. i./ha were studied for residue analyses in/on brinjal fruits, wherein, the limit of detection (LOD) was 0.05 ppm

5.3.1 Effect on dissipation of residues

In flufenzin treatment at 100 and 200g a.i./ha dosages, the initial residue level was 0.20 and 0.37 ppm, respectively which fell down below the limit of detection on

7th and 9th day thereafter, respectively. The half-lives (RL_{50}) were estimated to be 2.52 and 2.72 days for the former and later dosages, respectively. The initial levels of fenpyroximate residues were estimated to be 0.10 and 0.18 ppm at 25 and 50 g a.i./ha dosages, respectively which, fell down rapidly below the limit of detection on 3rd and 5th day after the application. The estimated half-lives were 1.36 and 2.25 days for the recommended and double the recommended dose, respectively.

In studies conducted in apple and grape by Pap *et al.* (1994), flufenzin when applied at 60 g a. i./ha, its residues were detectable upto 61 days. Under the present studies, in brinjal fruits it was dissipated within 7 days when applied at 100 g a. i./ha. In the studies carried out in green chillies by Pentareddy (2003), the residues dissipated below the detectable limit of 0.05 ppm at 3.6 and 5.92 days in case of field application of fenpyroximate at 25 and 50 g a. i./ha, respectively. Under the studies, in brinjal fruits it was dissipated within two and four days for the same dosages. Although, results obtained in respect of fenpyroximate are similar to those reported by Pentareddy(2003),the same cannot be compared as the crops are different. FAO pannel has advocated its use on various crops as a safer acaricide (Anonymous, 1996).

The studies on dissipation of residues under field conditions revealed that flufenzin and fenpyroximate at the recommended rate of 100 and 25 g a. i./ha, dissipated at faster rate and reach the limit of detection of 0.05 ppm within 7 and 3 days, respectively. On the basis of the initial residue of 0.37 and 0.18 ppm found on zero day in double the recommended dose of 200 and 50 g a. i./ha, the MRL of 0.4 and 0.2 ppm on brinjal is proposed, respectively. The initial i.e. zero day residues in both the dosages of the candidate acaricides were within the MRL, indicating a pre-harvest interval (PHI) of zero day. However, in both the test acaricides a waiting period of one day would be advisable to offered better safety to consumers.

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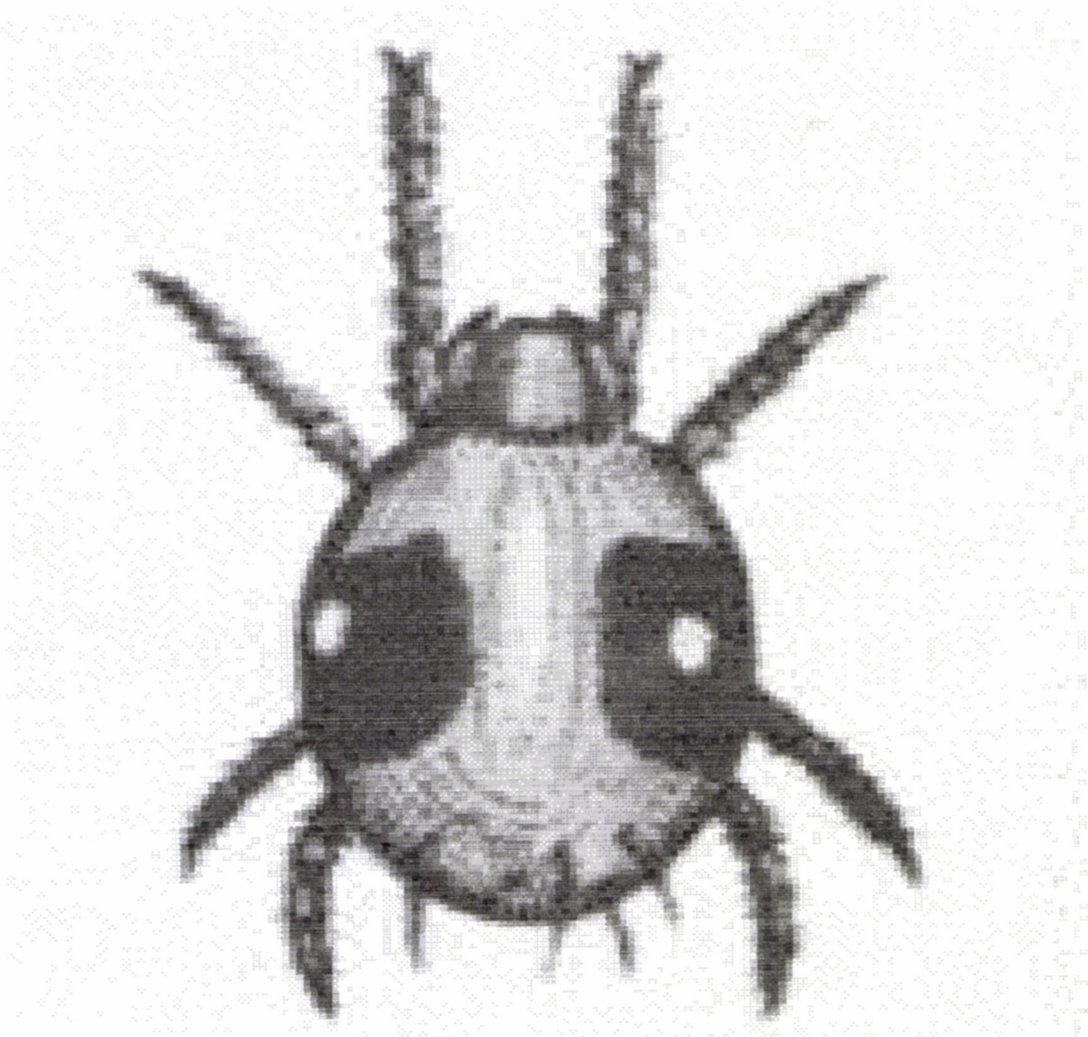
5.3.2 Effect of home processes on decline of residues on fruits

The simple processes such as washing, peeling, and cooking are very helpful in removing the residues from fruits and vegetables.

The residue level due to the process of washing was reduced in the range of 43 to 48 per cent in flufenzin and 46 to 55.6 per cent in fenpyroximate. Combining effect of washing and cooking further reduced the reside levels in the range of 67.6 to 70.0 per cent in flufenzin and 70 to 75 per cent in fenpyroximate. Thus, it is clear that routine process of washing as well as cooking, before the consumption certainly helps in minimizing pesticidal load on the vegetable-fruits. Earlier studies on other pesticides also exhibited similar results in respect of various other vegetables (Agnihotri, 1999).



Chapter Six



SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

In recent years, the red spider mite, *Tetranychus cinnabarinus* (Boisduval) has become serious menace in the cultivation of brinjal crop. Heavy infestation results in shedding of leaves with no fruiting leading to total failure of the crop. The yield losses due to tetranychid-mites are estimated to the tune of 13 to 31 per cent. In order to control the spider mite, dicofol and several other non-selective acaricides/insecticides are recommended and being used. However, due to its short life-cycle, very high reproductive potential and ability of quick development of the resistance, field management has become a more difficult task. Especially in recent years, few new molecules of the selective acaricides have been introduced in the market, which are efficient in their action against the target mite species and moreover have little or no effects on non-target beneficials. Such newly introduced two molecules *viz.*, flufenzin, 200 SC (20%) and fenpyroximate, 5 per cent EC were selected for the present investigations. Laboratory and field experiments were carried out during the year 2003-2004 for evaluating these candidate acaricides on brinjal crop. The studies included laboratory and field-bioefficacy, safety against the beneficial arthropods and their dissipation in/on fruits.

6.1 Summary

Laboratory bioefficacy was evaluated by conducting bioassays for each of the life-stages of the test mite, using residual leaf-disc-dip method. Observations on the number of eggs that failed to hatch at 7 days and the number of dead and alive individuals at 72 h after the treatment application were recorded. Dicofol the standard check, was found fairly good ovicide, larvicide, nymphicide and adulticide. Fenpyroximate showed moderate ovicidal action however, it appeared to be excellent larvicide, nymphicide and adulticide, exhibiting a quick knockdown effect. Besides,

the adults were observed to be more sensitive than the nymphs. Flufenzin proved to be excellent ovicide, fairly good larvicide and moderate nymphicide. However, adults were found less susceptible. The relative toxicity of the acaricides was evaluated by conducting the series of concentration-mortality bioassays against larvae and the mixed sexes of adults. The toxicity (LC_{50}) was computed for fenpyroximate, flufenzin and dicofol in respect of larvae which was estimated to be 2.52, 0.57 and 166.25 ppm, whereas for adults the values were 4.37. 1153.57 and 309.19 ppm. respectively

Field bioefficacy was evaluated by conducting two separate sets of experiments in *kharif,* 2003 and summer, 2004 particularly in the endemic pockets. Two foliar applications were given with high volume sprayer at middle of the fruiting phase of the brinjal crop, synchronizing with moderate to high and uniform infestation of the mite and noticeable build-up of natural population of predatory phytoseiid mites. The observations on motile mites were recorded at every alternate day starting from the treatment application till 15 days and lastly at 21 days The mean pre-treatment population of motile mite per leaf was found in the range of 273.9 to 257.57 in the *kharif* season while in the summer season. it ranged from 179.10 to 186.90. The results indicated that dicofol was found to be although efficient, it offered comparatively less (88%) protection moreover, extended promising control only for a weeks period. Flufenzin offered < 95 per cent protection and the efficient kill was noticed in between 13 to 15 DAT. Fenpyroximate was found to be the most promising acaricide extending the protection in between 15 and 21 DAT to the extent of > 95 per cent. Besides, none of the acaricide even at higher dosages exhibited any phytotoxic effects on brinjal plants

The yield data revealed that higher (25 ga.i./ha) and intermediate (20 g a. i./ha) dosages of fenpyroximate and higher dose of flufenzin (100g a. i./ha) were at par

while, lower dose of fenpyroximate (15 g a. i./ha) and intermediate dose of flufenzin (80 g a.i./ha) were observed on par with each other. The lower dose of flufenzin (60 g a.i./ha), dicofol (250 g a. i./ha) and the untreated control were found statistically in similar range. The comparison of the profit-margins contributed by the acaricides with that of the extent of protection they offered, suggested that all the three dosages of fenpyroximate and the higher dose of flufenzin prominently controlled the mite and extended better returns

Conservation of beneficial fauna and flora prevailing within the brinjal ecosystem is of immense importance. Therefore, certain representative beneficial arthropods were selected and the evaluation of the impact of the acaricides on them was carried out by laboratory and field bioassays. The laboratory bioassays on the predatory phytoseiid mite, *Amblyceius* spp indicated that dicofol was very toxic while flufenzin was safe. The data on abundance of phytoseiid mites species-complex revealed similar results Fenpyroximate was found moderately toxic whereas, in the laboratory bioassays it exhibited comparatively lesser toxicity than that depicted in the field bioassays. In respect of the another polyphagous predator-green lacewing, *Chrysoperla carnea*, dicofol, fenpyroximate and flufenzin were found more toxic, slightly toxic and relatively safer, respectively. Dicofol and both the test acaricides were observed to be extremely toxic and slightly toxic, respectively against the forage worker honeybee, *Apis cerana indica*. Dicofol, fenpyroximate and flufenzin were observed to be more harmful, slightly harmful and safer to the earthworm, *Eisenia foetida*, respectively

The data pertaining to microbial biomass carbon was found statistically on par with each other indicating no significant influence of the acaricides caused on soil microorganisms.

The residue analyses indicated that flufenzin when applied twice at 100 and 200 g a. i./ha, the residues were dissipated to below detectable limit within 7 and 10 days, respectively. The residue levels were dissipated within 3 and 5 days in fenpyroximate when applied twice at 25 and 50 g a. i./ha. respectively The estimated half-life and T_{BDL} values were 2 52 and 5.20 days for flufenzin at lower dose while for the higher dose they were 2.72 and 8.28 days, respectively. In fenpyroximate, those values were estimated to be 2.25 and 4.03 days for the higher dose while for the lower dose they were found same i.e 1.36 days The studies on effect of home processes on fruits on reduction of residues revealed that residue level due to process of washing was reduced in the range of 43 to 48 per cent in flufenzin and 46 to 55.6 per cent in fenpyroximate. The combine effect of both washing and cooking further reduced residue levels in the range of 67.6 to 70 per cent in flufenzin and 70 to 75 per cent in fenpyroximate. The maximum residue limit (MRL) proposed under the studies for flufenzin and fenpyroximate is 0.4 and 0 2 ppm, respectively and the estimated dissipation pre-harvest interval of both the acaricides arrived to be zero days, but one day is proposed to be more safe to consumer. Besides, the estimated consumer risk of the flufenzin and fenpyroximate was found to be 0 36 and 1.67 per cent, respectively

6.2 Conclusions

Both the new acaricides under the studies were found efficient in controlling the test mites. None of the acaricides, even at higher dosages, exhibited any phytotoxicity to brinjal plants. The profit-margins contributed by all the three dosages of fenpyroximate and higher dose of flufenzin (100 g a.i./ha) were found to be higher while by remaining two dosages of flufenzin and dicofol to be moderate

The standard check, dicofol is recommended organochlorine which is the most commonly used conventional non-selective acaricide. It possesses good ovicidal.

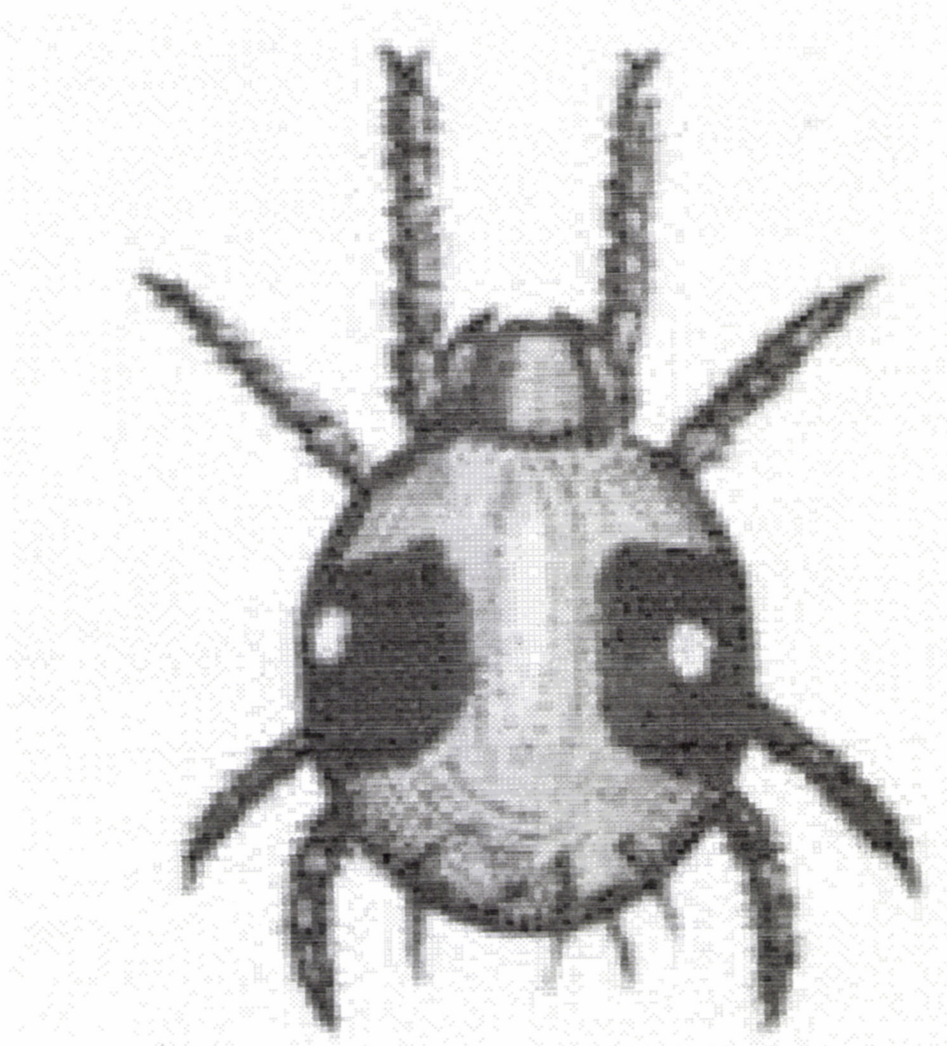
larvicidal, nymphicidal and adulticidal properties. Although, it proved to be efficient acaricide under filed conditions and offered about 88 per cent control for a week, it was found to be harmful to beneficial arthropods, especially to phytoseiid mites (selective predators of the spider mites).

Flufenzin is a newer molecule belonging to tetrazine group of the selective acaricide. It possesses excellent ovicidal, fairly good larvicidal and moderately nymphicidal action with least susceptibility to adults. Under field conditions, it offered < 95 per cent control and the promising protection was extended between 13 and 15 DAT. In comparison with others, it proved to be relatively more safe to beneficials. On the basis of the initial residues of 0.37 ppm found on zero day in the treatment with 200 g a.i./ha, the MRL of 0.4 ppm on brinjal is proposed. The initial i.e. zero day residues in both the dosages were within the MRL, indicating a pre-harvest interval of zero days. However, pre-harvest interval of one day would be advisable to the cultivators. Based on the overall performance evaluated under the studies, the dose of 100 g a.i./ha could be recommended for the field use, especially as a suitable component of IPM.

Fenpyroximate is another new molecule belonging to pyrazole group of the selective acaricides. It possesses excellent larvicidal, nymphicidal, and adulticidal action alongwith moderate ovicidal action too. The adults were more susceptible than nymphs. Moreover, it exhibited quick knockdown effect as an added advantage. It prevents further crop damage by interruption in mite-feeding/ovipositing. Under field conditions it offered > 95 per cent control, exhibited efficient kill between 3 to 5 DAT and extended the promising control for little more than 15 DAT. However, it was found slightly harmful to the beneficials. On the basis of the initial residues of 0.18 ppm found on zero day in treatment with 50 g a.i./ha, the MRL of 0.2 ppm on brinjal

is proposed. The initial i.e. zero day residues in both the dosages were within the MRL indicating a pre-harvest interval of zero day. In practice a waiting period of one day would be more appropriate on brinjal. Based on the overall performance evaluated under the present studies, 15 to 20 g a.i./ha could be recommended for the field use.

Chapter Seven



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7. LITERATURE CITED

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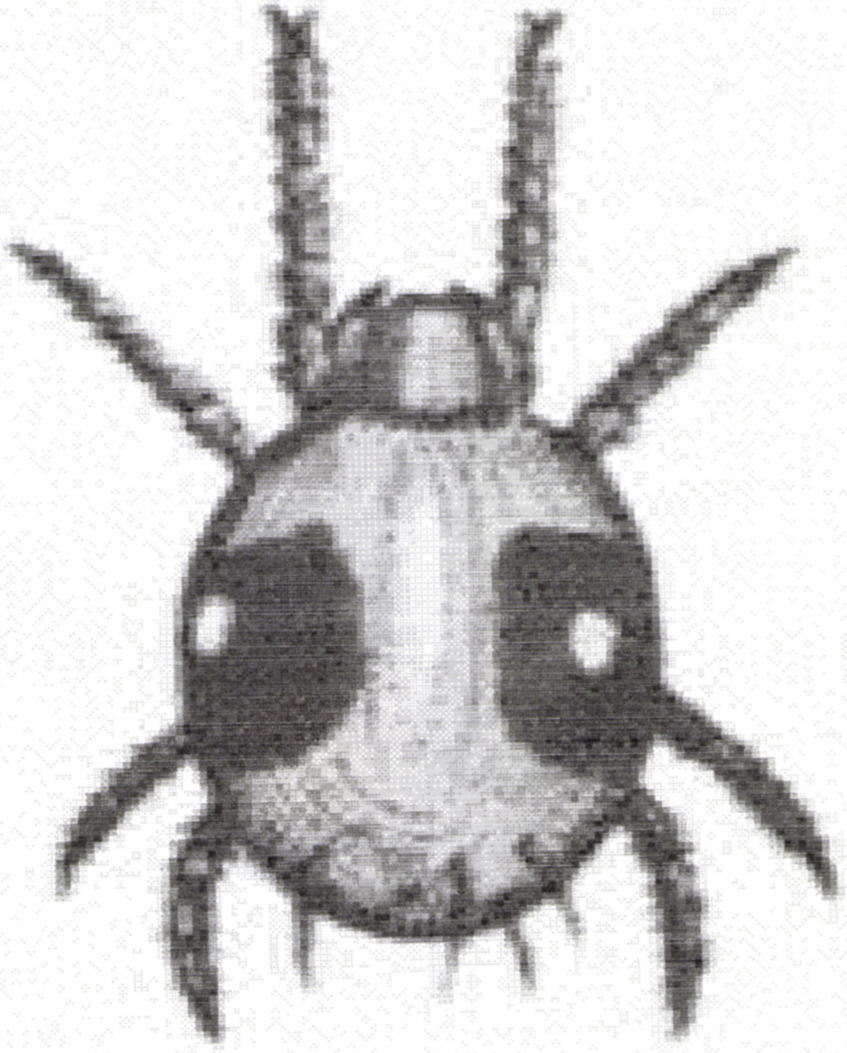
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* Original not seen



APPENDIX

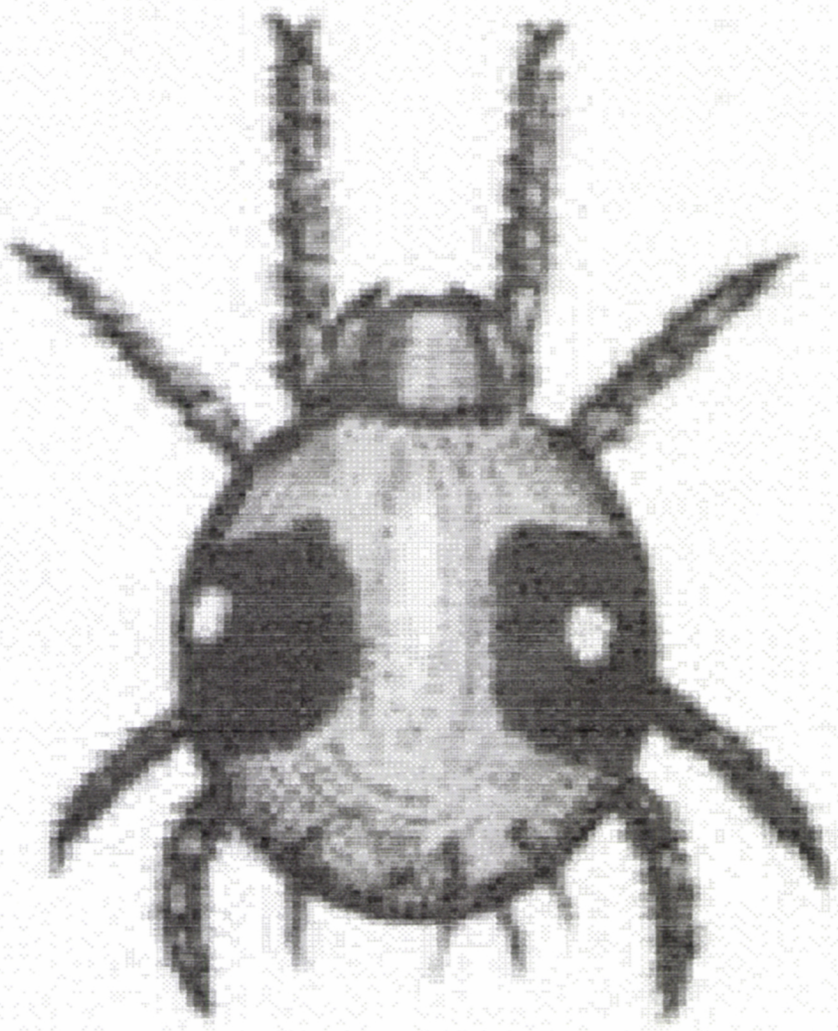
APPENDIX

Meteorological data from January, 2003 to September, 2004

Meteoro0.0 logical week	Mean temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (No.)
	Max.	Min.	Morning	Evening		
January, 2003						
01-.07	26.5	12.8	75	43	0.0	0
08-14	27.2	12.7	84	39	0.0	0
15-21	29.2	13.2	70	27	0.0	0
22-28	31.6	12.5	79	26	0.0	0
February, 2003						
29-04	32.9	13.1	77	33	0.0	0
05-11	31.8	13.0	72	32	0.0	0
12-18	33.5	12.9	62	23	0.0	0
19-25	32.0	13.0	65	24	1.6	1
March, 2003						
26-04	34.5	15.0	58	21	0.0	0
05-11	33.6	12.2	46	13	0.0	0
12-18	35.4	13.4	47	14	0.0	0
19-25	31.7	14.8	49	17	0.0	0
26-01	37.8	17.0	40	16	0.0	0
April, 2003						
02-08	37.7	17.9	60	26	0.4	1
09-15	32.1	17.7	38	19	0.0	0
16-22	39.0	19.8	42	18	0.0	0
23-29	40.2	19.5	36	15	0.0	0
May, 2003						
30-06	40.2	19.8	41	14	0.0	0
07-13	40.0	21.0	38	11	0.0	0
14-20	40.3	23.3	47	13	0.0	0
21-27	39.1	22.5	58	33	0.0	0
28-03	39.6	22.4	56	34	0.0	0
June, 2003						
04-10	39.1	23.7	66	30	2.6	1
11-17	34.3	24.0	76	56	7.6	1
18-24	32.5	24.1	74	61	11.0	3
25-01	32.2	23.9	72	53	1.8	0
July, 2003						
02-08	30.7	24.0	79	56	57.6	2
09-15	32.3	23.7	75	56	7.4	1
16-22	40.7	23.7	73	57	8.8	0
23-29	28.4	23.7	77	65	24.0	1

August, 2003						
30-05	30.8	22.3	77	56	0.2	0
06-12	30.6	22.5	80	58	11.6	2
13-19	32.1	18.4	76	48	2.6	0
20-26	29.8	21.8	81	59	64.0	2
27-02	30.5	22.0	77	54	3.0	1
September, 2003						
03-09	30.9	20.8	78	49	2.6	1
10-16	31.6	19.5	75	49	0.0	0
17-23	32.5	20.4	80	51	3.8	1
24-30	30.1	21.9	89	66	57.0	3
October, 2003						
01-07	30.3	19.4	80	46	34.8	3
08-14	31.9	20.4	70	38	0.0	0
15-21	33.8	16.4	60	23	0.0	0
22-28	32.8	13.6	53	20	0.0	0
November, 2003						
29-04	32.9	0.0	76	42	0.0	0
05-11	32.0	14.2	60	24	0.0	0
12-18	31.1	14.9	66	37	0.0	0
19-25	31.5	14.4	65	31	0.0	0
26-02	32.0	14.8	66	32	0.0	0
December, 2003						
03-09	30.1	10.0	68	24	0.0	0
10-16	30.9	9.0	68	30	0.0	0
17-23	29.1	8.2	64	30	0.0	0
24-31	28.5	9.6	68	42	0.0	0
January, 2004						
01-07	29.9	10.5	73.6	31.1	0.0	0
08-14	28.4	8.4	83.4	32.1	0.0	0
15-21	31.6	10.1	75.9	27.7	0.0	0
22-28	28.0	10.2	84.9	36.1	0.0	0
29-04	29.2	11.0	85.1	35.0	0.0	0
February, 2004						
05-11	30.6	7.5	84.3	26.3	0.0	0
12-18	32.9	12.9	84.1	27.1	0.0	0
190.025	34.1	11.5	87.0	23.0	0.0	0
26-04	35.4	13.3	86.5	22.5	0.0	0
March, 2004						
05-11	36.0	12.8	85.3	20.9	0.0	0
12-18	37.2	14.7	85.0	17.3	0.0	0
19-25	39.1	14.7	82.9	16.0	0.0	0
26-01	37.1	16.9	82.3	21.6	0.0	0

April, 2004						
02-08	37.8	17.9	84.3	19.9	0.0	0
09-15	38.9	17.2	81.0	17.6	0.0	0
16-22	38.6	18.0	79.9	19.1	0.0	0
23-29	39.3	20.1	81.1	20.3	0.0	0
May, 2004						
30-06	39.4	21.3	79.3	22.4	0.0	0
07-13	37.0	22.3	87.3	35.3	0.0	0
14-20	34.5	22.6	85.0	45.1	0.0	0
21-27	36.4	20.9	83.7	32.3	0.0	0
28-03	36.5	22.6	87.7	37.7	0.0	0
June, 2004						
04-10	35.9	22.5	89.4	43.7	0.9	1
11-17	31.2	21.5	93.1	70.1	71.7	3
18-24	30.5	20.8	91.1	58.4	3.0	1
25-01	32.9	20.9	92.1	52.4	0.1	1
July, 2004						
02-08	32.3	21.2	89.3	53.1	0.5	1
09-15	33.2	19.9	74.9	46.6	0.0	0
16-22	33.4	20.8	85.6	50.1	0.4	1
23-29	30.0	19.9	87.1	46.1	10.0	2
30-05	27.5	20.7	95.1	75.0	4.8	1
August, 2004						
06-12	28.8	21.0	95.3	79.7	1.0	1
13-19	29.5	17.6	93.1	59.7	0.8	1
20-26	30.2	20.8	92.9	58.1	0.3	1
27-02	31.3	18.7	89.3	48.9	0.0	0
September, 2004						
03-09	30.1	20.2	89.9	63.4	7.2	1
10-16	29.8	18.5	89.3	60.7	3.0	1
17-23	31.6	19.5	92.1	57.0	13.5	2
24-30	30.6	19.7	93.9	65.1	29.7	2
01-07	31.1	19.9	92.6	59.5	17.6	2



VITA

VITA

A candidate for the degree of Doctor of Philosophy (Agriculture)
in Agricultural Entomology

Title of thesis : "Studies on bioefficacy, safety and residues of fenpyroximate and flufenzin used against red spider mite on brinjal"

Major field : Agricultural Entomology



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Professional experience : Earlier worked as a Research Assistant in National Chemical Laboratory, Pune, later on in 1981 resumed in MPKV, as an Assistant Professor of Entomology and still working as Asstt. Prof.(Selc. Grade) at College of Agriculture, Pune. Recipient of the 'Best Teacher Award' honored by Pune Municipal Corporation at University level. Published 30 research papers in various journals. Guided six postgraduate students from MPKV and two from Pune University. Conducted five national level short-term courses on Vermi-culture / compost.

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