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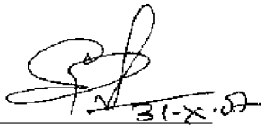
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**CERTIFICATE-I**

This is to certify that the thesis entitled, “**Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**” submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **ENTOMOLOGY AND APICULTURE** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) is a record of bonafide research work carried out by **Mr. Vinay Kumar Jandial (H-2003-11-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

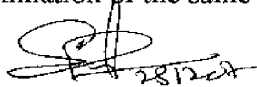
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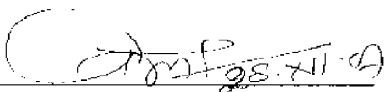
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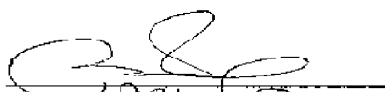
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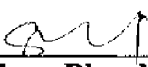
  
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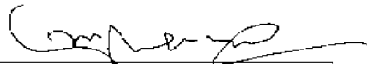
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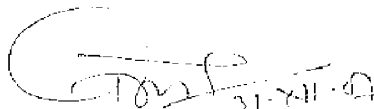
  
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Last, but certainly not the least, "TO ERR IS HUMAN" so needless to say that all the errors and omissions are mine.

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Date: 31 October, 2007

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## ABBREVIATIONS USED

$\chi^2$	chi square
$\chi^2_{cal}$	chi square calculated
$\chi^2_{tab}$	chi square tabulated
@	at the rate
amsl	above mean sea level
CD	critical difference
Conc.	concentration
CSA	cross sectional area
df	degree of freedom
E	east
EC	emulsifiable concentrate
g	gram
HMO	horticultural mineral oil
LC <sub>50</sub>	median lethal concentration
Ltd.	limited
ml	millilitre
MSS	mean sum of square
N	north
nm	nano metre
ppm	parts per million
psi	pond per square inch
Pvt.	private
SC	soluble concentrate
SS	sum of square
TSS	total soluble solids
V/V	volume by volume

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Chapter-1

# INTRODUCTION



## Chapter-I

# INTRODUCTION

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Apple is an important temperate crop of India and grown mainly in the Western Himalayan region comprising areas of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and some parts of the north-eastern states. Apple occupies 2, 41,600 hectare area with a 1,320,590 metric tonnes production in the country (Awasthi and Kamal, 2005). Apple plants are attacked by over 1,000 insects and mites throughout the world and nearly 800 of them are recorded from India (Bhardwaj and Bhardwaj, 2005). Nearly 50,000 species of mites have been described throughout the world so far (Walter and Proctor, 1999) and nearly 660 species described from India of which 30 species have been reported as potential pests (Gupta, 1991). Among phytophagous mites infesting temperate fruits particularly apple, European red mite, *Panonychus ulmi* (Koch) (Acarina: Prostigmata: Tetranychidae) is considered most significant throughout the world and was first described in 1878 from Italy and reported infesting apple plants for the first time from the state of Oregon in North America by Ewing in 1912. It became common pest of fruit crops in the Pacific North-West California, Indiana and Utah (Newcomer and Yothers, 1929).

In India, *P. ulmi* was reported for the first time from north-western Himalayan regions of Jammu and Kashmir, Himachal Pradesh and Uttarakhand on apple plants, plum, peach, apricot, quince, jack fruit, hibiscus, rose, tomato seedlings and Ivy (Prasad, 1974). Though virtually unknown before 1991, it was observed attacking apple foliage in Thanedhar area of Shimla district and has now established as a major pest in apple orchards in Himachal Pradesh (Kumar and Bhalla, 1993). Since then it has been observed in an epidemic form in all the apple growing districts of the State (Bhardwaj and Bhardwaj, 2000), and assumed the pest status in almost entire apple growing areas of north-western Himalayas.

Control of European red mite has been a major challenge in commercial apple orchards due to rapid development of resistance against acaricides (Pree *et al.*, 2002). Several integrated mite management programs have been implemented successfully (Asquith and Hull, 1979; Croft *et al.*, 1983; Thwaite *et al.*, 2002) and various methods have been developed and adopted to use control tactics more efficiently.

A key component of integrated pest management (IPM) system is the establishment of economic threshold level (ETL) and is the pest density at which the control decisions should be taken and is the key component of IPM system. Without this component, the research on other components viz., biological control, sampling, timing and pesticide efficacy can not be fully implemented. Barriers to development of ETLs for fruits plants include multiple season effects, large inherent variability in crop response, multiple interactions with horticultural and environmental factors, and prohibitive costs of large field studies (Hull and Beers, 1990). However, indirect pests present some of the best opportunities for integrated control because more injury can generally be tolerated.

In recent years, the loss of effective synthetic acaricides through regulatory decisions and/or the development of resistance to these materials have resulted in a situation where petroleum derived oils appear to be the only available and effective option (Agnello *et al.*, 1994; Thwaite *et al.*, 2002; Dokras *et al.*, 2002). Petroleum oils have been used for the control of crop pests over more than 200 years in agriculture (Lawson and Weires, 1991) and have been considered to be the best pesticides available to control mites and other pests present on dormant fruit plants (Chapman, 1967; Johnson, 1980). However, refinement of petroleum oils through recent advances in hydrogenation, hydro-cracking and iso-dewaxing to summer spray oils commonly called as Horticultural Mineral Oils (HMOs) or Agricultural Mineral Oils (AMOs) have made it possible to use them all the year round without any danger of phytotoxicity at normal rate of application (Davidson *et al.*, 1991; Agnello, 2002).

Oils are relatively non-toxic, classified as category III chemicals, i.e. pesticides of least acute toxicity, rely completely on contact activity having negligible fuming or

residual value and no species of insects or mites are known to have developed resistance to oils, even after many decades of continuous use in orchards (Chapman, 1967; Rock and Crabtree, 1987). Moreover, oils are relatively safe to natural enemy complex and are unlikely to be detrimental to wild life, human health or quality of air, water or soil (Davidson *et al.*, 1991; Agnello *et al.*, 1994). Owing to many such attributes, oils have emerged as an important tool for pest management in horticultural ecosystem particularly to control mites, scale insects, aphids, whiteflies, psyllids and eggs of lepidopterous pests on fruit and nut plants during both dormant and active growing seasons (Cranshaw and Baxendale, 1999; Thwaite *et al.*, 2002).

In many parts of the world, petroleum derived spray oils (PDSOs) have established themselves as permanent component of many pest management programmes, and are expected to continue to be developed and adapted to increasingly specialized needs of modern agriculture (Agnello, 2002). In India, crude petroleum oils have been mainly employed as dormant sprays for the control of insect pests. However, recent introduction and evaluation of horticultural mineral oils and aggravated European red mite problem in apple orchards opened up a new chapter of pest management, with a potential to replace some conventional pesticides. Therefore, large scale testing of HMOs against *P. ulmi* is required before their final inclusion in package of pest control recommendations and large scale adoption by growers.

European red mite, *P. ulmi* (Koch) has a long history of developing resistance to acaricides/insecticides that have been used for its control (Jeppson *et al.*, 1975; Georghiou and Mellon, 1983; Cranham and Helle, 1985; Welty *et al.*, 1987; Pree *et al.*, 2002). With the loss in efficacy of existing acaricides, research has shifted to incorporate new acaricides into integrated mite management programs. So, it is important to determine baseline levels of susceptibility of different life stages of *P. ulmi* to some new acaricides before their widespread field usage.

**Keeping in view the above scenario/facts the present studies have been proposed with the following objectives:**

- i) Determination of economic threshold level for European red mite, *P. ulmi* on apple
- ii) Evaluation of bioefficacy of HMOs against eggs and motile stages of *P. ulmi* under laboratory and field conditions.
- iii) To assess the intrinsic toxicity of some new acaricides against eggs and motile stages of *P. ulmi*.
- iv) To record the phytotoxicity of HMOs, if any, on the apple plants.



Chapter-II

# REVIEW OF LITERATURE



## Chapter-II

# REVIEW OF LITERATURE

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Numerous Arthropod pests have been known to attack fruit crops. Apple trees are attacked by over 1,000 insect and mite pests throughout world and nearly 800 of them are recorded from India (Bhardwaj and Bhardwaj, 2005). Of the total mite fauna nearly 50,000 species have been described throughout the world so far (Walter and Proctor, 1999) and nearly 660 species of phytophagous mites from India of which 30 species have been reported as potential pests (Gupta, 1991). The mites belonging to class Arachnida are cosmopolitan with wide host range (Pritchard and Baker, 1955). Among phytophagous mites, the fruit tree red spider mite often known as European red mite, *Panonychus ulmi* (Koch) is an important foliar feeding pest on apples worldwide. Control of European red mite in commercial apple orchards is becoming increasingly difficult and expensive due to rapid development of resistance to acaricides (Hull and Greene, 1983; Croft *et al.*, 1987; Welty *et al.*, 1987; Pree *et al.*, 2002). The ability of mites to develop resistance to acaricides has forced growers to spend considerable resources on mite control and stimulated crop protection scientists to find alternative methods for controlling phytophagous mites.

Litreature search has revealed that considerable amount of research work has been done to understand biology, bionomics, population dynamics and control of European red mite all over the world but comprehensive information is not available on economic threshold level of *Panonychus ulmi* and its management through horticultural mineral oils and some new safe acaricides under Indian conditions. The litreature pertaining to the present studies has been reviewed under the following headings:

- 2.1 **Economic threshold level for *Panonychus ulmi* on apple**
- 2.2 **Efficacy of horticultural mineral oils against *P. ulmi***
- 2.3 **Toxicity of acaricides against *P. ulmi***

## **2.1 Economic threshold level for *Panonychus ulmi* on apple**

The key component of integrated pest management system is the establishment of economic threshold level on which the control decisions are based. Without this component, the research on other components viz., biological control, sampling method, timing of pesticide application, pesticide efficacy etc. can not be fully implemented.

### **2.1.1 Validated/proposed economic threshold level for *P. ulmi***

Various workers have proposed different economic threshold levels for *P. ulmi* on apple. Tentative injury level of 500-550 cumulative mite days (peak=30 mites/leaf) for healthy vigorous trees with mite damage occurring only after June was proposed by Hull and Greene (1983) on 'Yorking' apple trees. In Pennsylvania, USA, tentative thresholds varied between 600 and 1,000 cumulative mite days (CMDs), depending on the year and time of season of mite injury to apple trees (Hull *et al.*, 1985; Hull *et al.*, 1986; Bears and Hull, 1990). Subsequently, Hull and Bears (1990) validated injury thresholds for European red mite on apple by considering four target injury thresholds (0, 250, 750 and 1250 cumulative mite days/leaf) and proposed an injury threshold of 750 CMDs for 'Yorking' and 'Delicious' apples.

On the other hand, Beers and Hull (1990) determined the effect of *P. ulmi* infestation on apple (1000 CMDs) based on the time of injury i.e. early season (mid May - mid June), mid season (mid June - early August), and late season (early August – mid October) and reported that mid season injury resulted in the greatest reduction in mean fruit weight at harvest as well as return bloom and fruit loads, whereas, late season injury resulted in a reduction of return bloom. However, early season injury did not result in significant differences for any of the response variables measured. Further it was determined that time of injury plays a significant role for the development of economic threshold level for European red mite and there was no single economic threshold level (Hoyt and Tanigoshi, 1983; Marini *et al.*, 1994).

In Virginia, Marini *et al.* (1994) studied the influence of European red mite and crop density on fruit size and quality and proposed the adoption of economic injury levels

of 1000, 500 and 300 cumulative mite days for spur 'Delicious' with light, moderate and heavy crop loads, respectively.

In Israel, Palevsky *et al.* (1994–96) studied the impact of European red mite on 'Golden Delicious' and 'Oregon spur' to develop an action threshold for the control of mite and recommended an action threshold of 150 cumulative mite days for *P. ulmi* on apples.

In Oregon, USA, Zwick *et al.* (1976) determined the effect of mite population density on 'Newton' and 'Golden Delicious' apple trees and concluded that vigorously growing, non-stressed apple trees poses relatively high tolerance to seasonal average mite densities of 30 mites per leaf without adverse effects.

Economic threshold level of 5-7 mites per leaf was established by Bulgak (1982) in USSR for the whole season. During the first half of the vegetative period, economic threshold level established was 4-5 mites per leaf and increased to 7-8 mites per leaf during the second half of vegetative growth period. Similarly, an economic threshold of 5 mites per leaf until April, 10 mites per leaf during May and 15 mites per leaf during rest of the season was established by Hoyt *et al.*, (1979).

### **2.1.2 Effect of mite injury on yield and fruit quality of apples**

Studies on the feeding of mite and its effect on fruit yield and quality has been reported by many workers. The European red mite, *Panonychus ulmi* (Koch) has been reported to destroy the functional photosynthetic surface of apple trees leading to a variety of current year and second year effects ((Croft *et al.*, 1983); Hardman *et al.*, 1985). Current year damage, depending upon the timing, duration, and severity of the damage can lead to fewer fruit and lower yields (Chapman *et al.*, 1952; Light and Ludlam, 1972; Baker, 1984; Hardman *et al.*, 1985), adverse effects on fruit size (Hoyt *et al.*, 1979; Baker, 1984), skin colour and fruit firmness (Lathrop, 1951; Briggs and Avery, 1968; Ames *et al.*, 1984) and total soluble solids (Briggs and Avery, 1968; Ames *et al.*, 1984). Second year effects of mite damage resulted in reduced bloom (Lienk *et al.*, 1956; Asquith, 1961; Lienk and Minns, 1980; Beers *et al.*, 1987) and consequently reduction in

numbers of apples and yield (Lienk *et al.*, 1956; Klopfenstein and Holdsworth, 1978; Lienk and Minns, 1980; Baker, 1984).

#### **2.1.2.1 Effect on fruit size and weight**

The lack of effect of mite feeding on fruit size and weight has been recorded on apple by various workers (Zwick *et al.*, 1976; Klopfenstein, 1977; Bulgak, 1982; Ames *et al.*, 1984). Similarly, Hull and Bears (1990) reported that mean fruit weight was not affected by any level of mite injury (250, 750 and 1250 CMDs/leaf) during the current year and in the year following mite injury. However, other workers have found reduction in fruit weight due to mite injury (Chapman *et al.*, 1952; Lienk *et al.*, 1956; Asquith, 1961; Baker, 1984). Klopfenstein and Holdsworth (1978) also reported that intermediate and high mite density levels had an adverse effect on fruit number and weight. Similarly, Marini *et al.* (1994) demonstrated that fruit weight declined with increasing crop densities, and at high crop densities fruit weight declined with increasing cumulative mite days on 'Delicious' apple trees.

#### **2.1.2.2 Effect on fruit firmness**

Various workers have reported adverse effects of mite feeding on fruit firmness (Lathrop, 1951; Briggs and Avery, 1968; Ames *et al.*, 1984). Ames *et al.* (1984) reported that high mite levels significantly reduced fruit firmness only within the heavy load fruits, and light fruit loads and heavy mite feeding had a negligible effect on fruit firmness. However, Chapman *et al.* (1952) reported that mite injury did not affect fruit firmness of 'Cortland' and 'Red Delicious' at harvest or after storage. The fruit firmness of 'Newton' fruits was not affected by mite feeding at harvest and after 5 months of storage (Zwick *et al.*, 1976), whereas, the firmness of 'Golden Delicious' fruits at harvest or after storage was affected by mite feeding but restricted to the higher mite population. Contrary to these reports, Beers and Hull (1990) studied the effect of time of mite injury and reported that fruit firmness was affected by mid-(mid June- early August) and late season (early August-mid October) injury, resulting in lower fruit firmness than early season.

Similarly, Marini *et al.* (1994) observed that fruit firmness significantly reduced by crop densities and by the interactive effects of crop densities and cumulative mite days.

#### **2.1.2.3 Effect on total soluble solids**

The highly mite infested apple trees with medium or heavy fruit loads produced fruits with lower soluble solids than less infested mite trees with comparable fruit loads (Ames *et al.*, 1984). Similarly, Marini *et al.* (1994) reported that soluble solids declined with increasing cumulative mite days at high, but not at low crop density. Contrary to these reports, Chapman (1959) found no influence of mite feeding on total soluble solids of 'Cortland' and 'Delicious' fruits. Beers and Hull (1990) also showed that soluble solids were not affected by mite injury. Similarly, Hull and Beers (1990) reported that soluble solids were not affected by any level of mite injury (250, 750, and 1250 CMDs per leaf) during the current year and in the year following mite injury on 'Yorking' and 'Delicious' apple fruits.

#### **2.1.2.4 Effect on fruit skin colour**

Fruit skin colour is extremely important in determining commercial acceptability, price and subsequent return to the growers. Mite injury has been shown to be inversely related to fruit colour (Lathrop, 1951; Briggs and Avery, 1968; Ames *et al.*, 1984). Marini *et al.* (1994) also reported that red colour of fruit surface declined with increasing levels of cumulative mite days and crop densities on 'Delicious' apples. Whereas, Chapman *et al.* (1952) and Hoyt *et al.* (1979) reported a positive relation between fruit colour and mite injury. Beers *et al.* (1990) also studied the effect of mite injury on 'Rome Beauty' apple trees and observed that fruit colour was slightly increased (2.1 %) with mite injury. On the other hand, Ames *et al.* (1984) found that fruit load dominates colour considerations regardless of mite infestation on 'Miller Sturdeespur' apple.

#### **2.1.2.5 Effect on flowering and return bloom**

The mite damage reduced flowering on mature and bearing trees of apple (Lienk *et al.* 1956; Asquith, 1961). Lienk *et al.* (1956) reported that seasonal mite population of 50 mites per leaf significantly reduced the return bloom on 'Delicious' and 'Cortland' apple trees. Similarly Hardman *et al.* (1985) studied the effect of mite injury on the apple variety 'Red Delicious' and reported reduction in return bloom in the following year of injury. Beers and Hull (1990) also reported that mid-and late season mite injury resulted in reduction of return bloom and fruit load. On the contrary, Briggs and Avery (1968) and Zwick *et al.* (1976) reported no effect of mite infestation on return bloom and crop load of apple. Similarly, Lienk and Minns (1980) reported that similar populations of mite which adversely affected 'Cortland' and 'Delicious' did not affect return bloom of 'Rome Beauty'. Hull and Beers (1990) also reported that return bloom was not affected by any level of mite injury (250, 750 and 1250 CMDs) during the current season, however, return bloom was significantly lower in the 1250 CMD level than in the control during the next season.

#### **2.1.2.6 Effect on percentage fruit set**

Zwick *et al.* (1976) studied the effect of mite population density on 'Newton' and 'Golden Delicious' apple trees and reported that seasonal mite population caused no significant reduction in fruit set. Beers *et al.* (1990) also reported that percentage of fruit set or fruit load in the following season of mite injury was not influenced by any level of mite injury on apple cultivar 'Bisbee Delicious'. On the contrary, Lienk *et al.* (1956) and Beers and Hull (1987) reported reduced fruit set subsequent to mite damage. Chapman *et al.* (1952) also reported a substantial reduction in fruit set when high mite population occurred during early season. Whereas, Beers and Hull (1990) studied the effect of mite injury on apple variety 'Red Yorking' and observed that early season mite injury had no effect on fruit set.

## **2.2 Efficacy of Horticultural mineral oils against *P. ulmi***

Petroleum derived spray oils (PDSOs) have emerged as an important tool for pest management because of their special attributes like environmental safety, no risk of resistance to pests and least human health hazards. As the use of petroleum derived spray oils for pest management in agriculture is a vast subject of discussion, therefore, in view of present investigations the literature on the effectiveness of petroleum derived spray oils against European red mite, *Panonychus ulmi* (Koch) infesting apple is reviewed under the following headings:

### **2.2.1 Brief history of petroleum derived spray oils use in agriculture**

### **2.2.2 Management of *P. ulmi* (Koch) with petroleum derived spray oils on apples**

### **2.2.3 Effect of petroleum derived spray oils on plants**

### **2.2.1 Brief history of Petroleum derived spray oils use in agriculture**

Petroleum derived oils have been used in agriculture for pest control for more than 200 years (Lawson and Weires, 1991). Though the use of oils as an insecticide was first mentioned in literature as early as in 1787 (Goeze, 1787), it was not until about 1865 that a petroleum distillate (kerosene) was first used against scale insects on orange (*Citrus sinensis* L. Osbeck, Sapindales: Rutaceae) trees (Shepard, 1951). However, a kerosene soap emulsion first introduced by A. J. Cook of the Michigan Agricultural Experiment Station in 1877 was the first petroleum product widely used to control aphids and scale insects (Miller, 1983). According to Agnello (2002), kerosene became a standard treatment as 10 per cent emulsion for the control of aphids and other soft bodied citrus insects and 25 per cent emulsion for more resistant scale insects by the year 1880, and remained almost an ideal contact insecticide for general use till 1900. Near the turn of nineteenth century, pestilence activities of the San Jose scale, *Quadraspidotus perniciosus* (Comstock) generated interest in other distillates and even crude petroleum oil (Lodeman, 1896; Ebeling, 1950; Chapman, 1967). The crude petroleum oil was apparently first used by Smith in 1897 (Smith, 1899), who applied 25 per cent

mechanically mixed hot soap oil emulsion as a dormant spray on fruit trees with fairly good results.

According to Smith (1952), progress in the development of petroleum derived spray oil was temporarily slowed around 1900 by the introduction of lime sulphur for scale insects. However, Parrott *et al.* (1906) documented availability of safer spray oils by 1905 in the form of emulsion or emulsifiable oil to combat the problems of these pests. **The next development in the field of petroleum insecticides was the use of lubricating oils** which came into existence as a result of unsatisfactory uniformity of crude oils; impurities often caused undesirable results. The use of lubricating oils was started first time on citrus in Florida in 1906 (Yother, 1918), and it was accepted for general use by 1920 (Shepard, 1951). In 1923, an important transition event was achieved by Ackerman (1923) following success with 2 per cent lubricating oil against the San Jose scale that had not been controlled by lime sulphur. The results contributed so immensely that there was supplanting of oil over lime sulfur as a scalcicide. Thereafter, petroleum oil eventually became the principal dormant or semi dormant treatment in deciduous fruit orchards.

During 1914-16, some breakthrough experiments by Gray and deOng (1926) established the relationship between oil unsaturates and plant damage by showing that the hydrocarbons which could be removed from petroleum oils by treatment with concentrated sulphuric acid were the one's largely responsible for foliage burn. However, the increased cost of acid refined oil limited its use because the stable emulsion made it necessary to use a high concentration of spray mixture. During 1926-27, deOng *et al.* (1927) reported that quick breaking emulsions utilized maximum degree of insecticidal action. In their studies, 2 per cent non-volatile lubricating oil with 98 per cent water as carrier when applied as quick breaking emulsion produced complete kill of citrus red scale *Aonidieta aurantii* (Maskell) on lemon. The stable emulsions of similar ingredients were found ineffective against this pest even at 4-8 per cent concentration of the oil. According to Cox (1938), the quick breaking principle of deOng *et al.* (1927) made it possible to obtain oil deposits adequate for pest control with relatively low concentrations of oil in the spray mixture which overcomes the obstacle of cost in the use of acid refined

oils, i.e. oil with a high unsulphonated residue (UR). In 1932, intensive studies carried out by Smith (1932), on factors involved in the effect of oils used against red scale (*A. aurantii*) and other pests in citrus, revealed that weight of spray oil accounted for both its insecticidal efficacy and its potentially deleterious effects on the plants. He found these properties related to oil distillation range and recommended distillation to provide a better basis for classifying and grading of spray oils.

According to Chapman *et al.* (1952), the California Department of Agriculture established a series of grades of summer or foliage type oils in 1932. Five grades of oils were set up based on a minimum unsulfonated residue (UR) per cent (90-94) and the percentage of oil that distilled at 335.6° C (636° F). The viscosity of such oils ranged between 55 and 105 Saybolt at 100° F (37.8° C). The standards established by California were the first to use distillation properties in official specifications for spray oils and were judged to be suitable that they were used unchanged for more than 30 years (Anonymous, 1966).

In 1942, Pearce *et al.* (1942) developed specifications for dormant oils having viscosity, 90-120 Saybolt at 100° F; viscosity index, 65 kinematic (minimum); API gravity, 28° (minimum); and pour point less than 30 with a relatively narrow distillation range. The specifications for more highly refined dormant or semidormant oil were developed 5 year later by Pearce and Chapman (1947). This oil was termed as 'superior type' and was specified on the basis of viscosity, 90-120 Saybolt (at 100° F); viscosity index, 90 kinematics (minimum); API gravity, 31 (minimum); unsulfonated residue, 90 per cent (minimum); pour point, 30° F; and a relatively narrow boiling distillation range. This oil was intended for use on deciduous fruit trees and woody plants in early spring as dormant or semi-dormant treatment.

Chapman *et al.* (1962) described 70 s and 60 s superior oils for summer application. The specifications for such oils included viscosity, 66-74 and 56-62 Saybolt at 100° F; API gravity, 33 and 34 (minimum); unsulfonated residue, 92 per cent (minimum); pour point, 20° F; 50 per cent distillation point, 425 ± 2° F and 408 ± 10° F (at 10 mm of Hg ) or 670 ± 10° F and 645 ± 8° F (at 760 mm of Hg) and 10-90 per cent

distillation range of 95° F and 80° F (at 10 mm of Hg) or 90° F and 75° F (at 760 mm of Hg), respectively. Chapman (1967) summed up the major criteria resulting from previous research and came up with a profile known as narrow range oils (NR oils). Principal characteristics included UR per cent (> 92); 50 per cent distillation point, 420-440° F (at 10 mm of Hg); 10-90 % range, 55-85° F (at 10 mm of Hg); minimum paraffinic carbons (C<sub>p</sub>), 60 per cent; pour point, 5 to +20° F; viscosity 60-200 seconds (at 100° F); molecular weight, 290-330 (approximate); and API gravity, 31-37.

According to Davidson *et al.* (1991), most of the present day petroleum derived oils marketed as summer spray oils, horticultural mineral oils or agricultural mineral oils are the one's, those described by Pearce and Chapman (1947) or Chapman *et al.* (1962) or Chapman (1967). However, recent technical advances in hydrogenation, hydro-cracking, and iso-dewaxing of petroleum oils have made these oils safer to plants and more potent to insect-pests and have extended its use to a variety of crops even during their active growth periods (Agnello, 2002).

### **2.2.2 Management of *P. ulmi* with Petroleum derived spray oils on apples**

Among various species of phytophagous mites infesting apples all over the world European red mite, *Panonychus ulmi* (Koch) is most damaging pest of apple (Chapman and Lienk, 1950; Agnello *et al.*, 1994; Bhardwaj, 1998; Thwaite *et al.*, 2002). In India severe outbreak of phytophagous mites was observed during 1990 in some parts of Himachal Pradesh (Kumar and Bhalla, 1993) and now within a decade it has spread to all apple growing belts of the State causing huge economic losses to growers (Khajuria and Sharma, 1996). The outbreaks of phytophagous mites have largely been attributed to indiscriminate use of pesticides which usually decimate the biological control agents, and in many instances pesticide resistance has also contributed for such situation. In recent years the loss of effective synthetic miticides through regulatory decisions and/or the development of resistance to these materials (Welty *et al.*, 1987; Dennehy *et al.*, 1988; Agnello *et al.*, 1994; Thwaite *et al.*, 2002; Dokras *et al.*, 2002) had resulted in situations where petroleum oil appears the only available and effective option.

Petroleum oils have been used in agriculture for pest control for over 200 years (Lawson and Weires, 1991) and they are considered to be the best pesticides available to control mites present on dormant fruit trees (Chapman, 1967; Johnson, 1980). Recent improvements in refining, however, have produced oils with an increased safety to plants with enhanced pesticidal efficiency and thus extended their potential uses to control the pests year around on deciduous as well as on evergreen plants (Davidson *et al.*, 1991; Cranshaw and Baxendale, 1999).

As early as 1923-25, Newcomer and Yother (1927) documented 35 per cent mortality of overwintering eggs of European red mite with 2 and 3 per cent lubricating oils under field conditions while complete mortality was obtained with 0.5-0.67 per cent oil under laboratory conditions in Washington. Marshal (1948) reported significant reduction in hatching of overwintering eggs of European red mite, treated with 1.5 or 3.0 per cent petroleum oil (220 viscosity) in British Columbia. Chapman and Pearce (1949) documented 99.7, 99.1 and 97.4 per cent egg mortality with 2, 1 and 0.5 per cent 'superior type' [Viscosity 90-120 Saybolt; viscosity index, 90 (minimum); API gravity, 31 second (minimum); unsulfonated residue, 90 per cent (minimum); pour point, 30 (maximum)] petroleum oil when applied one day before hatching, coinciding with prepink stage in apples. An equivalent mortality of 99.4, 97.2 and 96.4 per cent was reported with 3, 2 and 1.0 per cent 'superior type' petroleum oil when applied at 6 day prior to the egg hatch, coinciding with delayed dormant stage in apples. They concluded that susceptibility of eggs increased as the interval between spraying time and hatching was reduced.

Chapman and Lienk (1950) confirmed the results of Chapman and Pearce (1949); they documented 99.6, 96.7, 93.2 and 89.9 per cent egg mortality with 3, 2, 1 and 0.5 per cent superior oil, respectively, when applied at delayed dormant stage. The comparable per cent mortalities of 98.9, 98.1, 93.4 and 75.0 were obtained with 4, 3, 2 and 1 per cent oil when applied at mid dormant period. In summers fairly less number of mites were recorded on oil treated plants, it varied from 0.06 to 17.76 mites per leaf on trees receiving 3, 2 or 1 per cent oil at delayed dormant stage, 0 to 25.29 mites per leaf

receiving 4, 3 and 2 per cent oil at mid dormant period and 0.06 to 8.48 mites per leaf on trees receiving 1.0 per cent oil at full pink or prior to bloom. In control, the mite population varied between 2.72 and 148.14 per leaf. Shca (1957) evaluated oils of same structural composition as the 'superior oils' (Chapman and Pearce, 1949) but of lighter viscosities (59, 74 and 82 Saybolt at 100° F) against overwintering eggs of *P. ulmi* and 0.7 to 12.54, 0.7 to 25.05, 0.1 to 27.66 and 0.6 to 40.36 mites per leaf on trees treated with 1 or 2 per cent of 82, 74 and 59 second viscosity oils and 108 second viscosity dormant oil, respectively as against 2.4 to 247.96 mites per leaf on control trees. In these studies, 59 second viscosity product was less effective than either 74 or 82 second oil. Chapman *et al.* (1962) compared various superior types or paraffinic petroleum fraction of 60 s and 70 s viscosity; they documented almost equivalent (98.5 to 99.1 %) mortalities of over wintering eggs of European red mite with either oils at 2 per cent concentration; however, 60 s products were believed to combine full pesticidal efficiency with minimum phytotoxic hazards.

Nickel and Wong (1966) documented season long control of European red mite with 70 s viscosity oil (Humble 70 or Pennsalt 70) at 1 per cent concentration, applied as preventive (12 May) or curative (3 August) sprays. Summer mite population per leaf varied from 0.0 to 5.4 and 0 to 6.8 on trees receiving single application of 1 per cent Humble 70 and/or Pennsalt 70 oils as preventive sprays, respectively. In curative sprays, Humble 60, Humble 70 and Volck Supreme oil each at 1 per cent concentration reduced average mite number per leaf from 6.1, 6.5 and 10.2 in pre-treatment (July, 28) to 0.5, 1.5 and 1 (August, 10), 4.1, 2.1 and 3.3 (August, 24) and 1, 5.5 and 2.2 (September, 15), respectively, as against 8.6, 7.1, 51.7 and 14.9 mites per leaf on untreated trees on these respective dates. Dibble (1971) reported effective control of low to moderate infestation of *P. ulmi*, two spotted spider mite, *T. urticae* and Pacific mite, *T. pacificus* on deciduous fruit trees with 1.5 to 2.0 per cent summer spray oils. Lienk (1972) recorded 0 to 11.8 and 0.01 to 5.9 mites per leaf on 'Rome' and 'Red Delicious' apple trees treated with 2 per cent 'superior type' oil at full pink stage (May, 7). Mite population on control trees of 'Rome' and 'Red Delicious' apple cultivars varied from 4 to 173 and 3 to 98 per leaf, respectively.

Agnello *et al.* (1994) evaluated highly refined horticultural petroleum oil, Sun Spray Ultra Fine (viscosity, 68 s; 50 % distillation point, 212.2° C; 10-90 % distillation range, 18.3° C; UR, 94 %) under laboratory and field conditions for efficacy against summer eggs and larvae of *P. ulmi*. Oil exhibited significant ovicidal and residual larvicidal activity in dip treatments at rates as low as 0.05 per cent. High contact mortality of mite larvae was obtained at rates of 0.25-1.00 per cent. Under field conditions, effective control was achieved with three applications of oils at 3 and 2 per cent starting at petal fall stage and continuing on a 2-3 weeks schedule. A rate of 1 per cent provided control under conditions of moderate population pressure but required an additional spray in late July under severe population pressure. Botha *et al.* (1995) documented fairly good control of *P. ulmi* with light summer oil in apple orchards in South Africa; treatments with Sunspray Ultrafine were compared with a standard treatment of flufenoxuron and untreated control. All the treatments significantly reduced the mean number of females of *P. ulmi* per leaf in all the three field trials.

Bhardwaj (1998) reported 2 per cent IPOL orchard spray oil (viscosity 14.3 KV at 100° F; API gravity, 34.5 at 60° F; 50 % distillation point, 358° C; 10-90 % distillation range, 44° C at 760 mm of Hg; UR, 95 %; Cp, 74 %) checked 85 per cent egg hatching of European red mite. Combination of IPOL or Servo Orchard Spray oil 2 per cent with lindane 0.05 per cent resulted in preventing 90 per cent egg hatch. Bhardwaj and Bhardwaj (1999) obtained 85 per cent mortality of overwintering eggs of *P. ulmi* treated with 1.5 per cent summer spray oil, Orchex 796, prior to pink bud stage; two subsequent sprays of Orchex 796 (1 %) during May and June provided 95 and 87 per cent control of *P. ulmi* and *T. urticae*, respectively, while Caltex DC-Tron Plus (1 %) resulted in 83 and 79 per cent control of respective species.

Eslick *et al.* (2002) documented no difference in efficacy of either C27 Caltex Winter oil or C24 Caltex (formerly Ampol) DC-Tron Plus (2 %, v/v) at green tip (September), pink and full bloom (October) to *P. ulmi* on apples in Australia. The mite population actively increased in all the treatments during January to reach damaging numbers by early February. The full bloom treatment was effective until January 22

(9 mites/leaf), on the same date there were 33 mites/leaf in green tip treatment, 32 mites per leaf in pink treatment and 73 mites per leaf in untreated control.

In pennsylvavania, USA, Krawczyk and Hull (2005) evaluated three horticultural mineral oils viz. J M S Stylet, Damoil and Mite E-Oil for mite management on three apple cultivars i.e. 'Red Delicious', 'Yorking Delicious' and 'Golden Delicious' and reported that under high mite pressure, all the horticultural mineral oil at 1 per cent concentration applied as complete sprays were found effective in controlling mite population.

### **2.2.3 Effect of Petroleum derived spray oils on plants**

The journey of spray oils from bare crude petroleum oil in 1900 to today's highly refined oils is mainly attributed to its effect on plant responses and insecticidal efficacy. The concept of oil effects on plants has been a most widely discussed subject since its first use as insecticide. As early as 1914-16, some breakthrough experiments by Gray and deOng (1926) established the relationship between oil unsaturates and plant damage by showing that the hydrocarbons which could be removed from petroleum oils by the treatment of concentrated sulphuric acid were the ones largely responsible for foliage burn.

During 1924-25 and 1925-26, deOng (1926) applied a series of sprays of French prune trees to determine the effect of oil (API Gravity 25; flash point, 310°F; viscosity, 96 Saybolt; UR, 56 %) at varying degrees of dormancy (every two weeks from November 15 to March 15). The results showed no injury during December to February sprays in both years while, severe twig killing was observed in March application with 6 per cent oil emulsion.

Ross (1926) reported that 2 or 4 per cent dormant or delayed dormant sprays of lubricating oils applied properly did not cause injury to deciduous trees. Newcomer and Yother (1927) observed no appreciable leaf injury to apple, pear, prune or cherries with thoroughly emulsified lubricating oil sprays at 0.5 or 0.67 per cent. Spuler *et al.* (1931)

noticed that within certain limits insecticidal values of oil increased with its viscosity, however, injurious effects also increased with its viscosity. They reported reduction in fruit size on apple trees with heavy loads of fruits that have received six applications of oil of medium (70-75 Saybolt) to heavy (110-120 Saybolt) viscosity.

Swingle and Snapp (1931) detected no evidence of cumulative injury from yearly application of oils with high percentage of unsulphonated residue on peaches. They suggested 3 applications of 6 per cent oil that a one year old peach tree can withstand. Farrar and Kelley (1935) documented to injury to fruits or foliage of apple tree sprayed in summer with an unsaturated oil of 32 second viscosity. An unsaturated oil of 83 second viscosity was found to cause injury to both fruits and foliage. Little or no injury was observed with saturated oils (2 %) applied as 3 sprays between June 15 and August 15.

Bogdarina (1940) investigated influence of water supply on shedding of apple leaves during spraying with mineral oil emulsions and showed that oil emulsions caused fewer leaves of apple to drop on irrigated trees than on unirrigated trees. Spraying the large branches with 2 per cent emulsion of 3 mineral oils at 25° C (77° F) and 52 per cent relative humidity caused shedding of the leaves, which however, was invariably less in case of irrigated trees from 3 per cent oil emulsion sprayed each year. A certain amount of damage was caused by 10 and 12 per cent emulsion though no tree was killed, some severe injury was observed by 15, 20 and 25 per cent emulsion. Chapman *et al.* (1962) compared oils of different viscosities and compositions as delayed dormant treatment and documented a superior type or paraffinic fraction of 60 seconds viscosity (allowable range 56 to 62 seconds) to combine full pesticidal efficiency with minimum phytotoxic hazards.

Lawson and Weires (1991) observed Volck Supreme oil (viscosity, 104 s; 50% distillation pt., 246.1° C; 10-90 % distillation range, 29.4° C; UR, 99 %) more injurious to apple fruit and foliage, particularly at the higher rate (3 %) than Sun Spray 6E (viscosity, 75 s; 50 distillation pt., 212.2° C; 10-90 % distillation range, 26.7° C; UR 94 %) or Sun Spray 6E + (viscosity, 68 s; 50 % distillation point, 212.1° C; 10-90 % distillation range,

18.3° C; UR, 94 %) at 3 per cent. However, they explained that increased phytotoxicity with the Volck Supreme oil was not unexpected because of its naphthenic constitution.

Schrader and Kammereck (1996) evaluated the effect of Orchex WS 2928 (heavy oil), Orchex 796E (medium oil) or Orchex 692E (light oil) each at 2 per cent aqueous emulsion on foliage and fruits of 'Bartlett' pear, and 'Red Fuji' and 'Red Delicious' apple trees. All the treatments were found to reduce photosynthesis and transpiration rates. Significant but temporary marking on Bartlett and permanent marking on Fuji were observed. Fruits of Red Delicious showed no marking with any of the oil, phytotoxicity (mostly leaf tip burn) was noticed on some leaves but it had minimal effect on photosynthesis and transpiration.

Williams *et al.* (1996) studied horticultural effects of summer application of 3 different oils (Orchex 796, Orchex 692 and Orchex WS 2928) at 1 and 2 per cent in three different timing patterns on pears (Bartlett and d' Anjou) and apples (Mature Delicious, Golden Delicious and Fuji). Early summer oil sprays particularly at 2 per cent were noticed to cause phytotoxicity in all cultivars tested. With the exception of Fuji, the heaviest oil (WS 2928) did not seem to cause more phytotoxicity than the relative lighter molecular weight oils (Orchex 692 and Orchex 796). Varietal differences in terms of sensitivity were detected with d' Anjou being the most sensitive of all. The delayed summer oil application did not appear to induce the same degree of phytotoxicity response in either leaves or fruits as compared to the early season oil applications.

In Pennsylvania, USA, Krawczyk and Hull (2005) evaluated three horticultural mineral oils viz. J M S Stylet, Damoil and Mite E-Oil for mite management under commercial fruit orchard conditions on three apple cultivars i.e. 'Red Delicious', 'Yorking Delicious' and 'Golden Delicious' and reported no negative effects (phytotoxicity) on the foliage as well as on the fruit finish.

### 2.3 Toxicity of acaricides to *P. ulmi*

Chemical control of mites had a dynamic history especially during last four decades. Control of European red mite, *P. ulmi* (Koch) became especially important after the introduction of pesticides, probably because of disruptive effects on natural enemies (Pickett *et al.*, 1946) but chemical control has been hindered mostly by the development of resistance in many populations (Jeppson *et al.*, 1975; Cranham and Helle, 1985; Welty *et al.*, 1987; Pree, 1990). Populations of *P. ulmi* often remain synchronous, i.e. one life stage is predominant at any given time for several months (Marshall and Pree, 1991). Most acaricides affected more than one life stages of *P. ulmi* and showed greater toxicity to a specific stage (Marshall and Pree, 1991; Pree *et al.*, 1992). In most Integrated Pest Management programmes, pesticide applications are timed to coincide with the predominance of most sensitive life stage(s) of the target insect (Pree, 1979; Marshall and Pree, 1986; Marshall *et al.*, 1988; Pree *et al.*, 1992) to enhance the effectiveness of acaricide treatment and to extend the intervals between acaricide treatments.

Clofentezine and hexythiazox are the acaricides that offer a great potential for use on apple and other crops that have spider mites as important pests. These materials are compatible with biological control because they selectively kill eggs and larvae of spider mites and have little effect on predaceous mites (Hoy and Ouyang, 1986). Clofentezine and hexythiazox both have ovicidal and larvicidal activity (Bryan *et al.*, 1981; Read, 1983; Aveyard *et al.*, 1986; Neal *et al.*, 1986; Hoy and Ouyang, 1986; Welty *et al.*, 1988) and reduce the number of viable eggs produced by adult female mites (Chapman and Marris, 1986). Both compounds possess a degree of physiological selectivity for spider mites versus predatory mites (Hoy and Ouyang, 1986). Moreover, their selectivity is enhanced because they allow availability of mite eggs as a food source for mite predators (Hoy and Ouyang, 1986). Both compounds have low toxicity against apple rust mite, *Aculus* sp., which is often an important alternative prey for mite predators (Croft *et al.*, 1987). Because of their low dosage, selective action and lack of toxicity to predators, they are especially valuable for protecting the environment and for the development of integrated pest management (Baillod *et al.*, 1986; Hoy and Ouyang, 1986; Aveyard *et al.* (1986).

Clofentezine and hexythiazox have been reported non toxic to *Typhlodromus occidentalis* Nesbitt (Bryan and Peregrine, 1983; Bouron, 1985; Hoy and Ouyang, 1986; Bower, 1990; Ioriatti *et al.*, 1998) and clofentezine has been reported safe to *Typhlodromus pyri* Scheuten (Bryan and Peregrine, 1983; Read, 1983; Hardman *et al.*, 2003) and *Amblyseius andersoni* (Nicotina and Caprio, 1996). According to Nicolas and Rykewaert (1986) and Baillod *et al.* (1986) clofentezine and hexythiazox caused little mortality of predator coccinellid (*Stethorus* spp.) and anthocorid (*Orius* spp.).

In laboratory test using *T. urticae*, Aveyard *et al.* (1986) observed that clofentezine showed good activity against eggs, larvae and protonymphs, but very little activity against the later nymphal stage (deutonymph) and adults. Clofentezine was intrinsically more active against the egg stage by a factor 40-60 times ( $LC_{50} = 0.16$  ppm) compared with larva and protonymph stages ( $LC_{50}=6.20$  and  $10.0$  ppm, respectively). They further reported that pre-blossom application of clofentezine at 100 ppm against winter eggs gave excellent control of *P. ulmi* (99.6 %).

In experiments conducted against eggs and motile forms of *Tetranychus urticae* Koch and *T. cinnabarinus* (Boisduval), clofentezine at 0.85, 8.48 and 84.82 g a.i./378.5 litre water demonstrated 98, 99 and 100 per cent mortality, respectively, against eggs and poor contact activity (<35 %) against motile forms (Neal *et al.*, 1986). Motile forms were significantly reduced when clofentezine was combined with either Pentac or diazinon. They further reported that clofentezine was less effective against spider mite eggs at 22° C than 16° C, when tested at low rates of 0.85 g a.i./378.5 litre of water.

Welty *et al.* (1988) developed laboratory bioassay techniques to establish susceptibility of hexythiazox to eggs and larvae and observed that summer eggs were nine times more susceptible to hexythiazox than winter eggs ( $LC_{50}=2.2$  and  $20.0$  ppm, respectively). The mean percentage mortality ( $\pm$  SEM) of winter eggs at 3, 10, 32 and 100 ppm hexythiazox was  $27 \pm 7$ ,  $34 \pm 8$ ,  $64 \pm 6$  and  $89 \pm 1$  per cent, respectively, and the slope  $\pm$  SE of the regression line estimated by probit analysis was  $1.8 \pm 0.1$ , and the  $LC_{50}$  value was 20.0 ppm, while mean mortality of summer eggs at concentrations of 1, 2, 3, 6, 10, 32 and 100 ppm hexythiazox was  $24 \pm 7$ ,  $49 \pm 9$ ,  $57 \pm 12$ ,  $72 \pm 7$ ,  $78 \pm 6$ ,  $93$

$\pm 4$  and  $100 \pm 0$  per cent, respectively and a slope of  $1.4 \pm 0.1$  and  $LC_{50}$  value was 2.2 ppm. They further reported mortality (95 % CL) of larvae emerging from winter eggs was 94-100% after exposure to leaves previously treated with 100 ppm hexythiazox and larvae that emerged from summer eggs were not able to survive foliar residues when eggs and leaves were dipped in  $\geq 6$  ppm hexythiazox.

In laboratory tests, Marshal and Pree (1991) reported that miticides affected more than one life stage of the *P. ulmi* but most showed greater toxicity to one specific stage. Clofentezine and hexythiazox were more toxic to eggs and nymphs of *P. ulmi* but adults were unaffected. Both compounds were highly toxic at low concentrations (1 and 10 ppm). Clofentezine and hexythiazox at 10 ppm provided mortality of 97.0 and 94.3 per cent in eggs, 95.0 and 81.0 per cent in nymphs and 9.0 and 7.0 per cent in adults, respectively.

Khan and Zhu (2006) conducted studies to evaluate toxicities ( $LC_{50}$ ) of Apollo and Ordoval against *P. ulmi* and revealed that egg stage was most susceptible, while the adult non-mated as well as mated females were found most tolerant against these pesticides. Apollo was found comparatively more toxic against the egg ( $LC_{50}$ = 0.067 ppm) and nymphal stage ( $LC_{50}$  0.125 ppm), while Ordoval against the mated- ( $LC_{50}$ = 0.214 ppm) and non-mated adult females ( $LC_{50}$  =0.275 ppm) of *P. ulmi*.

Tuovinen (1990) documented that clofentezine at 250 and 500 ppm when sprayed on winter eggs of *P. ulmi* at 0-63 day-degrees above 7 degree C had a 68-92 per cent effect, but if sprayed just before the beginning of egg hatch (128 day-degrees) the effect was only 35 %. Hexythiazox at 50 and 100 ppm diminished hatching of undeveloped winter eggs (92-99 %), but the effect was poor after some development had occurred (77 days-degrees C).

Zhou *et al.* (2005) tested the sensitiveness of *P. ulmi*, *T. viennensis* (Zacher) and *T. urticae* (Koch) against 7 acaricides, including 1.8 % abamectin, 20 % Pridaben, 10 % Manjisi, 5 % Nissoum (hexythiazox), 20 % Apollo (Clofentezine), 20 % azocyclotin and

5 % fenpyroximate and found that hexythiazox and clofentezine were highly effective against eggs and *T. viennensis* was most sensitive to all these acaricides.

Pap *et al.* (1996) carried out the biological evaluation of SZI-121, a new acaricide and found it 4 times more active as an ovicide ( $LC_{50}=0.05$  ppm) than the reference clofentezine ( $LC_{50}=0.23$  ppm), when administrated to eggs directly. In contrast to clofentezine which had slow contact mode of action, SZI-121 had translaminar activity acting on eggs already laid ( $LC_{50}=18.66$  ppm) or those in females feeding on the opposite and untreated side of the leaf ( $LC_{50}= 5.11$  ppm).

In Yugoslavia, Stamenkovic *et al.* (1984) studied the effectiveness of Apollo (clofentezine) against *P. ulmi* and reported that clofentezine at 0.04 and 0.06 per cent gave good protection of winter eggs prior to hatching. The compound was also effective against newly hatched individuals.

Mandersloot (1987) studied the effect of acaricides Apollo (clofentezine) at 60 ml/hl and cyhexatin (Plictran) at 100 g/hl on apple to control *P. ulmi*, *T. urticae* and *Aculus schlechtendali* (Nalepa). One application of Apollo in late April was more effective than cyhexatin application in late May and as effective as 2 cyhexatin sprays in late May and early June. Apollo has its greatest effect against eggs and the early larval stages. A winter application of Apollo did not prevent egg hatching but the larvae failed to develop.

In France, Rauch (1985) studied the physical, chemical and toxicological properties of chlofentezine (Apollo 50 SC), against *P. ulmi* on apple together with its low toxicity to vertebrates and to useful mites and insects. He further suggested a spray of clofentezine 0.04 l/hl until run-off before the hatching of the winter eggs at bud-burst in apple and at petal fall or at the beginning of fruit formation in peaches provided effective mite control.

A strategy for the control of *P. ulmi* using clofentezine in apples and pear was established by Buendia and Roca (1983). Two applications maintained the trees free of mites from mid-March to mid-September with first application at 30 g a.i./hectare before,

but close to egg hatching, followed by a second application at the same rate 60 days after the first application at 20 g a.i./hectare in tank mix with amitraz (or other suitable compound against adult mites) at two-third the standard rate when the mite population exceeded 5-6 motile stages per leaf.

A single preventive application of hexythiazox (50 g/hl) and clofentezine (40 g/hl) in April protected the trees from *P. ulmi* until at least mid August, provided that no insecticide or fungicide favouring mite development was applied during the campaign (Nicolas and Rykewaert, 1986). Hexythiazox and Clofentezine caused little mortality of coccinellid (*Stethorus* spp.) or anthocorid (*Orius* spp.) predators (Baillod *et al.*, 1986).

In Belgium, Sterk and Peregrine (1989) tested two acaricides in the field against *P. ulmi* on apple and observed that clofentezine (Apollo 50 SC at 15 g a.i./hl) was effective irrespective of the time of application on winter eggs, but hexythiazox (Nissorun 10 WP at 3 g a. i/hl) was effective when the eggs were close to hatching. Both compounds were effective when applied at post-blossom against larvae, but hexythiazox gave better control.

Bhardwaj and Bhardwaj (2004) conducted studies to evaluate twelve different acaricides against the motile stages of *P. ulmi* under laboratory conditions and reported that excellent control of the mite was obtained with formetanate hydrochloride (0.01-0.04 %), dicofol (0.037 %), amitraz (0.02 %), fluvalinate (0.008 %), acarex (0.025 %), clofentezine (0.01-0.04 %) and lindane (0.04 %), while chlorpyrifos (0.02-0.04 %), demeton-S-methyl (0.025 %) and malathion (0.05 %) were less effective against *P. ulmi*.

Kovaleski and Salles (1984) carried out a trial with several acaricides against *P. ulmi* and observed that Folimat (omethoate) at 150 ml/100 gal water, Omite (propargite) at 100 ml, and Neothrin (fenpropathrin) at 100 ml gave very good control of *P. ulmi* with two applications. Fenpropathrin besides providing good control of red spider mite also killed its predators (Vigl and Giuliani, 1981).

Rana and Bhardwaj (2004) studied the efficacy of fourteen different acaricides and reported that 14 days after spraying, only fenpropathrin (2.16 and 1.91 mites/leaf), fenazaquin (1.84 and 2.24 mites/leaf) and monocrotophos (3.31 and 2.00 mites/leaf) showed significant mortality compared to other treatments during 2000 and 2001, respectively. These acaricides managed the mite population effectively upto 21 days after spraying.

Smolarz and Suski (1983) reported that Flucythrinate at 45-112 g/ha and fenpropathrin at 37-150 g/ha applied once in the season when population reached 2 mites per leaf in May-June or 5 mites per leaf in July gave satisfactory control of *P. ulmi* on apple.

A single spray application in the pre-flowering period with fenpropathrin (30 EC at 500 g/ha) and fenbutatin oxide (550 SC at 1.5 lt/ha) gave good control of *P. ulmi* and *A. schlechtendali* on apple (Pitre and Bostanian, 1980).

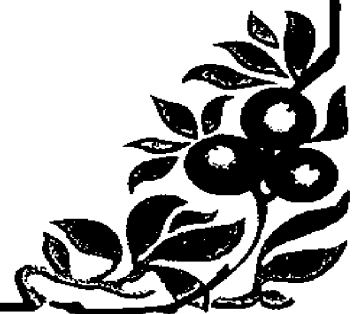
Lu and Wang (2005) evaluated different acaricides against five species of spider mite viz. *Tetranychus kanzawi* (Kishida), *T. cinnabarinus* (Boisd.), *T. urticae* (Koch), *Panonychus citri* (McGregor) and *Eutetranychus orientalis* (Klein) and reported that halfenprox 5% SC (500-fold) and milbemectin 1% EC (1500-fold) were more toxic to *T. kanzawi*, the survival rate of adults and immature stages were below 26.3 % after 72 hours. Halfenprox 5 % SC and milbemectin 1 % EC and fenazaquin 18.3 % SC (3000-fold) had good action on *P. citri*.

In Bangalore, Sridhar and Rani (2004) carried out experiment to evaluate the efficacy of milbemectin (1 % EC) against *Tetranychus urticae* and concluded that milbemectin (1 % EC) at rates 4.5 and 5.0 g/ha were highly effective against the mites and recorded 99.69-100 per cent mortality from the fifth day until the 21<sup>st</sup> day while 1.86-3.52 per cent mortality was recorded in control.



Chapter-III

**MATERIALS AND METHODS**



## Chapter-III

# MATERIALS AND METHODS

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The present investigations entitled, “**Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**” were carried out during 2005-2006 and 2006-2007 at the laboratory of the Entomology Section, Regional Horticultural Research Station (RHRS), Dr. Y.S. Parmar University of Horticulture and Forestry, Mashobra, Shimla, Himachal Pradesh (2286 m amsl, 31°N, 77.6°E). Field trials were carried out at the experimental orchards of RHRS, Mashobra and two private orchards located at Theog and Kathasu (Jubbal) in district Shimla. The experimental details, materials used and methodology adopted during the course of study are reported in this chapter under the following heads:

### **3.1 Determination of Economic threshold level for *P. ulmi* on apple**

### **3.2 Evaluation of Horticultural Mineral Oils against *P. ulmi***

### **3.3 Toxicity studies of acaricides against *P. ulmi***

#### **3.1 Determination of economic threshold level**

A naturally mite infested apple orchard of ‘Royal Delicious’ was selected at Kathasu (Jubbal) in district Shimla, Himachal Pradesh (Plate 1a & 1b) during 2004 and experiments were conducted during 2005 and 2006 for the determination of Economic threshold level for European red mite, *Panonychus ulmi* on apple. The trees were stressed with mites during 2005 and 2006 growing seasons. The experiment was laid out in randomized block design, with five levels of target injury thresholds of 0, 250, 500, 750, and 1000 cumulative mite days (CMDs) per leaf. Each treatment was replicated seven times, an individual limb per tree served as a replicate. Mite days have been defined by Hull and Beers (1990) as one mite per leaf present for one day. The mite days

were calculated as the mean of two successive counts multiplied by the number of intervening days. These figures were summed over the season to give CMDs.

CMDs were calculated using the formula suggested by Hull and Beers (1990) as:

$$\text{CMDs} = \sum 0.5 (P_a + P_b) D_{a-b}$$

Where,

- $P_a$  - Population density (mean mites per leaf for sampling date 1) at time a,
- $P_b$  - Population density (mean mites per leaf for sampling date 2) at time b and
- $D_{a-b}$  - Number of days between time a (sampling date 1) and b (sampling date 2)

One of the lower scaffold limb was selected and tagged on each experimental trees, and observations were recorded on this limb. Mite infestation was allowed to develop normally during April. Weekly mite counts were taken by counting all the motile forms on 10 randomly selected leaves per limb using 10 X hand lens. When an individual limb reached its target CMD level, the entire tree was sprayed with the recommended acaricides (fenazaquin @ 0.002 % or propargite @ 0.057 %). Limbs with a target value of 0 CMDs were treated as necessary to prevent mite population build up. Other pests and diseases were controlled with a recommended schedule of pesticides (Anonymous, 2004). The effect of mite feeding was determined by recording yield attributes and physico-chemical parameters of fruits.

### **3.1.1 Yield attributes**

#### **3.1.1.1 Percentage fruit set**

Data on fruit set was recorded by counting the total number of flowers at full bloom (Plate 2a) on the selected limb of each experimental tree and number of fruits per limb after primary abscission. The percentage fruit set on selected limb was calculated as per the procedure suggested by Westwood (1978).

$$\text{Per cent fruit set} = \frac{\text{Number of fruits per limb}}{\text{Number of flowers}} \times 100$$

### 3.1.1.2 Return bloom

The return bloom was determined by counting the number of flower clusters on the selected limb in the following year. Cross sectional area of the limb was calculated by measuring the limb circumference at a point near the junction with the main axis of the tree. The return bloom was calculated as:

$$\text{Return bloom} = \frac{\text{Number of flowers}}{\text{Cross sectional area of the limb}}$$

### 3.1.2.3 Fruit load

The fruit load was calculated by dividing the number of fruits per limb (Plate 2b) with cross-sectional area (CSA).

## 3.1.2. Physico-chemical parameters of fruits

### 3.1.2.1 Fruit Weight

All fruits on the tagged limb of each experimental tree were weighed individually on an electronic top pan balance at harvest. Mean fruit weight was calculated as:

$$\text{Mean fruit weight} = \frac{\text{Weight of all fruits on a limb}}{\text{Total number of fruits on a limb}}$$

The mean fruit weight was expressed in grams per fruit.

### 3.1.2.2 Fruit firmness

Fruit firmness was determined from a sample of 15 randomly selected fruits per limb using an Effegi penetrometer-Ft 327, which recorded the pressure required to force a

plunge of 11 mm in diameter into the apple flesh. The readings were taken on diagonally opposite sides of each fruit and results expressed in pound per square inch (psi).

### **3.1.2.3 Total soluble solids**

Soluble solids were determined from a sample of ten apple fruits selected at random per limb. The soluble solid content was recorded with an Erma hand refractometer (0-32 % range) by putting a drop of juice on the prism and taking the readings. A temperature correction was applied when the readings were taken at temperature other than 20°C (Horwitz, 1980).

### **3.1.2.4 Skin colour**

Skin colour was measured in terms of change in anthocyanin pigmentation of the fruits. The anthocyanin pigment of the fruit was determined in accordance to procedure described by Harborne (1973) by taking 1 gram of fruit skin and keeping it over night at 4°C in methanol containing 1 per cent HCl. The absorbance of pink colour was recorded at 530 nm on Spectronic-20 colorimeter. Anthocyanin content was expressed as absorption unit at 530 nm per gram fruit.

## **3.2 Evaluation of Horticultural mineral oils (HMOs)**

Four recently introduced and commercially available Horticultural mineral oils were evaluated against the European red mite, *P. ulmi*, under laboratory and field conditions.

### **3.2.1 Biological and chemical materials**

#### **3.2.1.1 Raising of host plant**

One year old seedlings were collected from the nursery of the Regional Horticultural Research Station, Mashobra and transplanted in dormant stage during February–March in polythene bags of 2.0 kg capacity. The mixture of soil, sand and FYM (1:1:1) was sterilized with formalin (1:6). The polythene bags were then filled with

the sterilized pot mixture. The polythene bags were placed in the laboratory in completely pesticide free environment. Plants were irrigated daily for 15 days and later on alternate days. The seedlings were sprayed with recommended fungicides at specified intervals to control powdery mildew.

### **3.2.1.2 Rearing of European red mite**

The initial culture of *P. ulmi* was raised in the laboratory from field collected twigs containing overwintering eggs. The newly hatched larvae from overwintering eggs were transferred to the seedlings, allowed to settle down and draw their food from the leaves to develop to adult stage. The mass culture was raised from the progeny of these mites for undertaking various experiments during the present studies.

### **3.2.1.3 Horticultural Mineral Oils (HMOs)**

Four commercially available horticultural mineral oils, viz. Orchol-13<sup>®</sup> (R. G. Industries, New Delhi), MAK<sup>®</sup> All Season HMO (Bharat Petroleum Corporation Ltd., Mumbai), Arbofine<sup>®</sup> (Totalfinaelf, Mumbai) and Servo Horticultural Mineral Oil (Indian Oil Corporation Ltd., Faridabad) were used in the present investigations (Table 1).

### **3.2.2 Laboratory Bioassays**

Laboratory evaluation of Horticultural mineral oils was carried out at Regional Horticultural Research Station, Dr. Y.S. Parmar University of Horticulture and Forestry, Mashobra, District Shimla, during the year 2004-2005. Horticultural mineral oils were evaluated against eggs and motile stages of European red mite, *P. ulmi*. All the HMOs used in the present investigation were evaluated at 0.5, 1.0 and 1.5 per cent level, using distilled water treatment as control. The methods employed for each laboratory evaluation are given below:

**Table 1: Specifications of Horticultural minerals oils used in the present study**

Characteristics	MAK All Season HMO	Orchol-13	Servo Horticultural Mineral Oil	Arbofine
Colour	Bright & Clear	Bright & Clear	Bright & Clear	Bright & Clear
Pour point (° C)	-15 Max	-15 Max	-13 Max	-
Kinematic Viscosity (cSt)	12-18	14 Max	-	13 Max
Minimum unsulfonated residue ( % V/V)	98.0	95.0	95.0	92.0
Molecular weight	320-340	-	331	330
Distillation @ 10mm Hg 50 % Point (° C)	-	230-235	240-245	-
90 %-10 % distillation range @ 10 mm Hg (° C)	-	48 Max	-	48 Max
Carbon Type Distribution Paraffinic (% V/V)	60 Min	60 Min	60 Min	60 Min
<i>n</i> -paraffin Carbon number	<i>n</i> C <sub>23</sub>	<i>n</i> C <sub>23</sub>	<i>n</i> C <sub>23</sub>	<i>n</i> C <sub>23</sub>

### 3.2.2.1 Ovicidal activity of HMOs against overwintering eggs of *P. ulmi*

Overwintering eggs of the *P. ulmi* were obtained from a commercial apple orchard growing ‘Royal Delicious’, ‘Golden Delicious’, and ‘Red Delicious’, apple cultivars at Kathasu (Jubbal) in Shimla district. The twigs bearing overwintering eggs were collected from the infested ‘Royal Delicious’ apple trees. Twigs were cut into 8 cm long sections and all the European red mite eggs on each section were counted under a stereoscopic microscope. After counting and marking the egg masses, the twigs containing eggs were dipped for five seconds in 200 ml of a test solution of each HMO, which was stirred constantly until just before the dipping to prevent phase separation.

One end of the twig was inserted 2-3 cm in disposable cups filled up to three-fourth capacity with moist sand for holding the twigs. The experimental twigs were kept at room temperature (15.8 to 22.0°C).

Three concentrations (0.5, 1.0 and 1.5 %) of all the HMOs and a control (distilled water) were evaluated and replicated five times; each replication consisted of nearly 50 eggs (ranging from 50.20 to 54.80 / twig) per concentration. Pre-treatment count of the number of eggs was made just prior to dip treatment. Eggs were checked for hatching at 7, 14, 21 and 30 days of treatment and per cent egg hatch was calculated using the following formula:

$$\text{Per cent egg hatch} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs}} \times 100$$

### 3.2.2.2 Ovicidal activity of HMOs against summer eggs of *P. ulmi*

Summer eggs were obtained by rearing the hatched mites emanating from overwintering eggs collected from the infested apple orchards to the adult stage on the apple seedlings in the laboratory. Adult mites (10 females per leaf) were transferred with a camel hair brush to the top surface of an excised leaf, set on moistened cotton in a Petri dish (Agnello *et al.*, 1994). The excised leaves were bounded at the edges by moist cotton barriers to prevent mites from escaping. Dishes were placed at room temperature to allow the adults to oviposit for 24 hours, after which the cotton barriers and all motile mites were removed and the eggs were counted before the treatment was administered. Serial dilutions of all the HMOs in distilled water were prepared to obtain test solutions of 0.5, 1.0 and 1.5 per cent concentration. Test leaves containing eggs were dipped for 5 seconds in 200 ml of a test solution that was stirred constantly until just before the dipping to prevent phase separation. The leaves dipped in distilled water were kept as check. Each treatment was replicated five times with each excised leaf considered as a replicate. All Petri dishes were placed at room temperature (20 to 22°C) for egg hatching. Leaves were examined for egg hatch at 1, 3, 5, 7, and 10 days of treatment.

### 3.2.2.3 Evaluation of HMOs against motile stages of *P. ulmi*

The motile stages of mite viz. larva, nymphs, and adults were obtained from laboratory reared pure culture maintained on potted apple plants. Fresh leaves of apple were collected and checked under stereoscopic binocular microscope to ensure the absence of test organisms, their quiescent stage and eggs. At least 25 motiles representing same stage of *P. ulmi* were transferred to an excised apple leaf placed over moist cotton in a Petri dish with camel hair brush. The excised leaves were bounded at the edges by moist cotton barriers to prevent mites from escaping. Each leaf was then sprayed by hand atomizer with one of the treatments, each at 0.5, 1.0 and 1.5 per cent concentration. Distilled water treated leaves were kept as control. Each treatment was replicated five times with each excised leaf considered as a replicate. The treated leaves containing mites were kept at room temperature and examined after 24 and 48 hours for mortality. Larva, nymphs and adults present on the leaf not capable of coordinated movements were considered dead. This criterion was similar to that used by Pree and Wagner (1987). Percentage mortality of each stage (larva, nymph, adult) was calculated as follows:

$$\text{Percentage mortality} = \frac{\text{Number of dead mites (specific stage)}}{\text{Total number of mites (specific stage)}} \times 100$$

### 3.2.3 Field evaluation of HMOs for bio-efficacy against *P. ulmi*

Field trials were conducted during the year 2005 and 2006 at private apple orchards at Theog, and Kathasu (Jubbal) in Shimla district of Himachal Pradesh. Power sprayer was employed to spray the plants at specified stage of growth. On each plant approximately 12 litres of spray solution was used.

#### 3.2.3.1 Ovicidal activity of HMOs against overwintering eggs

Moderately mite infested apple orchards were selected for evaluation of HMOs against overwintering mite eggs under field conditions. Trials were conducted during

2005-2006 on overwintering eggs laid on twigs during the previous year (August to November). For this study, five twigs containing overwintering eggs on the periphery of each experimental tree were selected. Among these twigs, one egg mass was selected and marked with oil paint for further observations. The number of overwintering eggs was counted with a 10 X hand lens. Application of all the HMOs under study was done at pink bud stage (Plate 3) of bud development in apple for ovicidal action. Each treatment was replicated four times and one egg mass considered as a replicate. The pre-treatment observation was taken two days prior to spraying and the post-treatment counts on hatchability on overwintering eggs, were made at 7,14,21 and 30 days after spraying.

### **3.2.3.2 Evaluation of HMOs as curative measure against motile forms of *P. ulmi***

Field experiments were conducted to evaluate the comparative performance of four Horticultural mineral oils viz. MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil and Arbofine, each at 0.5, 1.0 and 1.5 per cent concentration against *P. ulmi* in an apple orchard at Theog in Shimla district during 2005 and 2006. Plants supporting nearly homogeneous population of *P. ulmi* were selected and treated with desired concentration of each HMO during June. Each plant was sprayed with approximately 12 litre spray solution to run off stage using a power sprayer. The experiment comprising thirteen treatments including control (water treatment) was laid out in randomized block design and each treatment was replicated four times with single tree serving as replicate.

The data on the mite population were recorded by collecting 20 leaves at random from the outer, middle, and inner canopy of each tree. These leaves were collected in polythene bags, brought to the laboratory and observed under stereoscopic microscope for the presence of live mites per leaf. The pre-treatment counts were taken one day prior to spraying and post treatment counts at 3, 7, 14, 21 and 30 days after the spray.

### **3.2.4 Statistical analysis**

The data from laboratory evaluation of Horticultural mineral oils against eggs and motile forms of the European red mite were transformed using the square root ( $x+0.5$ ) and arcsine transformation as per the method described by Gomez and Gomez (1986), subjected to analysis of variance (ANOVA), and means were compared using a least significant difference test.

Field data on evaluation of HMOs against overwintering eggs were calculated on per cent basis and transformed to arcsine (0-100 %) values. Field data on mite counts per leaf were subjected to square root transformation and analyzed statistically. Least significant difference between treatments in a randomized block design was calculated taking all the possible combinations of factors used for egg and motile forms of mites. The treatment effects were tested at 5 per cent level of significance.

## **3.3 Toxicity studies of acaricides against *P. ulmi* (Koch)**

### **3.3.1 Chemicals and other materials**

The different acaricides used in the present studies are presented in Table 2.

#### **3.3.1.1 Preparation of concentrations of Acaricides**

Desired concentrations of the formulated acaricides were prepared by using distilled water. Different concentrations were prepared from the stock solution of acaricides by making serial dilutions. All the experiments were performed with freshly prepared solutions.

**Table 2: List of acaricides/insecticides used in the present study**

Common name	Trade name	Chemical name	Source
Clofentezine	Apollo 50 SC	3, 6-bis (2-chlorophenyl) - 1,2,4,5-tetrazine	Indofil Chemicals Company, Mumbai
Hexythiazox	Maiden 5 EC	<i>Trans</i> -5-(4-chlorophenyl)- <i>N</i> -cyclohexyl-4-methyl-2-oxo-1,3-thiazolidine-3-carboxamide	Biostadt India Ltd., Mumbai
Milbemectin	Melbeknock 1 EC	(6 <i>R</i> ,25 <i>R</i> )-5- <i>O</i> -demethyl-28-deoxy-6,28-epoxy-25-ethylmilbemycin B mixture with (6 <i>R</i> ,25 <i>R</i> )-5- <i>O</i> -demethyl-28-deoxy-6,28-epoxy-25-methylmilbemycin B	Nagarjuna Agrichem Ltd., Hyderabad
Fenpropathrin	Meothrin 30 EC	( <i>RS</i> ) α-cyaano-3-phenoxybenzyl 2, 2, 3, 3-tetramethyl-cyclopropanecarboxylate	Sumitomo Chemical India Pvt. Ltd., Hyderabad

### 3.3.1.2 Preparation of stock solution

The stock solution in ppm (parts per million) of each chemical was prepared as per the following formula:

$$q = \frac{d}{g} \times m$$

Where,

- q = quantity in ml of the liquid toxicant required  
d = desired per cent concentration of toxicant required  
g = per cent concentration of given acaricide  
m = volume required in ml

For example, the quantity of pesticide required to prepare 1000 ppm (0.1 %) of clofentezine, the quantity of pesticide formulation (Apollo 50 SC) will be

$$q = \frac{0.1}{50} \times 100 = 0.2 \text{ ml}$$

Thus, 0.2 ml of Apollo 50 SC was dissolved in 99.8 ml of distilled water to prepare 100 ml of stock solutions. It was kept in reagent bottle duly marked as stock solution. Similarly, the stock solution of each acaricide/insecticide was prepared.

### 3.3.1.3 Preparation of working concentrations

The working concentrations were prepared from the stock solution by simple dilution with distilled water as follows:

$$N_1 V_1 = N_2 V_2$$

- $N_1$  = Concentration of the stock solution  
 $V_1$  = Volume of the stock solution  
 $N_2$  = Required concentration  
 $V_2$  = Volume of the required concentration

### 3.3.2 Toxicity studies

Toxicity of different acaricides (Table 1) to European red mite was studied with bioassay method giving minimum  $\chi^2$  values. Preliminary experiments were conducted to

find out the approximate ranges, which gave mortality between 20 to 80 per cent. In the bioassay minimum five concentrations of each acaricide and one control were used to establish dose mortality relationships. Each treatment was replicated three times. Abbott's correction was applied to account for mortality of test insect in the control treatment (Abbott, 1925) as per following formula:

$$\text{Corrected per cent mortality} = \frac{\text{Per cent test mortality} - \text{Percent control mortality}}{100 - \text{per cent control mortality}} \times 100$$

### 3.3.2.1 Toxicity to motile stages of *P. ulmi*

The motile stages of *P. ulmi* were treated by leaf dip method. Fresh leaves of apple were collected and checked under stereoscopic binocular microscope to ensure the absence of test organisms, their quiescent stages and eggs. One leaf was dipped in each concentration of test chemical and for the control treatment, the leaf was dipped in distilled water. The excess of insecticide was shaken off from the leaves and then kept in the shade for drying. Thereafter, 25 laboratory reared mites of specific stage viz. larva, protonymph, deutonymph or adult were released on each treated leaf, placed over moist cotton in a Petri dish. The excised leaves were bounded at the edges by moist cotton barriers to prevent mites from escaping. The observations on mortality were taken after 24 hours of treatment. Mortality was assessed on the basis of capability of coordinated movement upon prodding with a brush. Coordinated movement was considered as the ability to move forward at least two steps.

### 3.3.2.2 Toxicity to winter eggs of *P. ulmi*

The twigs bearing overwintering eggs of European red mite were collected from infested apple orchards and brought to the laboratory. Since the overwintering eggs were difficult to pick from the twig, their concentration response was evaluated by dipping the apple twigs (8 cm) bearing the marked counted eggs in different concentrations of the test chemicals. The twigs were dipped for 5 seconds and allowed to dry under shade. Similarly control twigs bearing eggs were dipped in water. All the twigs were kept in

disposable cups filled up to three-fourth capacity with moist sand for holding and providing sufficient moisture. Egg hatching was recorded at weekly intervals up to 30 days from the date of treatment. The experiment was conducted with minimum five concentrations of each acaricide replicated three times, each with 50 eggs per replication.

### **3.3.2.3 Toxicity to summer eggs of *P. ulmi***

The summer eggs were treated by leaf dip method as described by Welty *et al.* (1988). Summer eggs were obtained by collecting European red mites from the infested orchard and 20 adult female mites were transferred per leaf to oviposit for 24 hours on leaves excised from the laboratory grown apple plants and placed on wet cotton pads in Petri dishes. The excised leaves were bounded at the edges by moist cotton barriers to prevent mites from escaping. After 24 hours, female mites and cotton barriers were removed from the leaves, and numbers of eggs laid were recorded. Leaves were immersed in mildly agitated test solutions (500 ml) for 5 seconds, air-dried for 1 hour, placed back in Petri dishes and held at room temperature (20–22°C). The eggs were observed under the stereoscopic microscope for hatchability upto 10 days from the date of treatment. The number of unhatched eggs was counted and the per cent mortality was calculated. Each treatment was replicated three times and the leaves dipped in distilled water were kept as control.

### **3.3.3 Presentation and analysis of toxicity data**

The average per cent mortality for each concentration was calculated and corrected with Abbott's formula wherever, necessary. The corrected per cent mortality was subjected to probit analysis (Finney, 1971) to compute medium lethal concentration (LC<sub>50</sub>) values for different acaricides. The LC<sub>50</sub> values were expressed as concentration required to get at least 50 per cent mortality of test insects. The regression equations were calculated and the slopes of regression lines were established for the test acaricides.



**Chapter-IV**

**EXPERIMENTAL RESULTS**



## Chapter-IV

# EXPERIMENTAL RESULTS

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The results of the present investigation on “**Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**” are presented under the following heads:

### **4.1 Effect of European red mite feeding on yield and quality parameters of apple cv. ‘Royal Delicious’ under field conditions**

#### **4.1.1 Effect of different feeding levels of European red mite on physico-chemical properties of fruits**

The data on fruit weight, fruit firmness, anthocyanin content and total soluble solids as affected by different levels of mite feeding viz. 0, 250, 500, 750 and 1000 cumulative mite days (CMDs) per leaf during 2005 and 2006 are presented in Table 3 and Table 4, respectively.

It is evident from the data that different levels of mite feeding exerted varying effect on the mean fruit weight and total soluble solids of fruits, however, fruit firmness and anthocyanin content remained non-significant during both the years of study. The maximum fruit weight 168.71 g and 170.65 g was recorded during 2005 and 2006, respectively in the control plants, which remained statistically at par with plants subjected to 250 cumulative mite days (CMDs) recording 166.08 g and 167.10 g mean fruit weight during the respective years. The corresponding minimum fruit weight of 144.44 g and 140.71 g was recorded in plants stressed with 1000 CMDs during 2005 and 2006. However, significant reduction in mean fruit weight was recorded at mite feeding level of 500 CMDs with mean fruit weight of 158.32 g and 157.84 g during 2005 and 2006, respectively, and differed significantly at mite feeding level of 750 CMDs with mean fruit weight of 153.25 and 149.99 g during the respective years. In the present study, the

**Table 3: Effect of different feeding levels of European red mite on physico-chemical characteristics of apple cv. 'Royal Delicious' under field conditions during 2005 at Kathasu (Jubbal), Shimla district**

Treatment	Fruit weight		Fruit firmness (psi)	Anthocyanin (A <sub>530</sub> unit)	Total soluble solids	
	Average (g)	Reduction over control (%)			(°B)	Reduction over control (%)
0 CMDs	168.71	-	13.90	0.433	12.80	-
250 CMDs	166.08	1.56	14.10	0.431	12.70	0.78
500 CMDs	158.32	6.16	14.30	0.430	12.00	6.25
750 CMDs	153.25	9.16	14.40	0.429	11.55	9.76
1000 CMDs	144.44	14.38	14.50	0.427	11.10	13.28
<b>CD (p=0.05)</b>	<b>4.32</b>		<b>NS</b>	<b>NS</b>	<b>0.35</b>	

**Table 4: Effect of different feeding levels of European red mite on physico-chemical characteristics of apple cv. 'Royal Delicious' under field conditions during 2006 at Kathasu (Jubbal), Shimla district**

Treatment	Fruit weight		Fruit firmness (psi)	Anthocyanin (A <sub>530</sub> unit)	Total soluble solids	
	Average (g)	Reduction over control (%)			(°B)	Reduction over control (%)
0 CMDs	170.65	-	14.30	0.440	12.60	-
250 CMDs	167.10	2.08	14.40	0.439	12.50	0.79
500 CMDs	157.84	7.51	14.50	0.436	11.85	5.95
750 CMDs	149.99	12.10	14.60	0.434	11.00	12.70
1000 CMDs	140.71	17.54	14.80	0.420	10.65	15.47
<b>CD (p=0.05)</b>	<b>6.61</b>		<b>NS</b>	<b>NS</b>	<b>0.53</b>	

reduction in the fruit weight over control treatment was 1.56, 6.16, 9.16 and 14.38 per cent during 2005, and 2.08, 7.51, 12.10 and 17.54 per cent during 2006 at mite feeding levels of 250, 500, 750 and 1000 CMDs, respectively.

The data recorded on fruit firmness and anthocyanin content showed that these parameters were not affected significantly by different levels of mite feeding (Table 3 and 4) during both the years of study. However, maximum fruit firmness (14.50 psi) was recorded in the fruits harvested from the plants infested with 1000 CMDs and minimum in the control treatment (13.90 psi). Anthocyanin content was maximum (0.433  $A_{530}$  unit) in the fruits harvested from the control plants and minimum (0.427  $A_{530}$  unit) in those harvested from the plants infested with 1000 CMDs.

A perusal of data presented in Table 3 and 4 revealed that total soluble solids of fruits declined with the increasing levels of mite feeding. The maximum total soluble solids were recorded in the fruits harvested from the control plants (12.80 and 12.60°B during 2005 and 2006, respectively), closely followed by those infested with 250 CMDs recording 12.70 and 12.50°B during the corresponding years, both being statistically at par with each other. The total soluble solids were minimum (11.10 and 10.65°B during 2005 and 2006, respectively) in the fruits harvested from the plants infested with 1000 CMDs. However, significant reduction in total soluble solids was recorded at mite feeding level of 500 CMDs with 12.00 and 11.85°B during 2005 and 2006, respectively, which differed significantly from the total soluble solids recorded at 750 CMDs with 11.55 and 11.00°B during the respective years. The data indicated that reduction in total soluble solids over the control was highest in the fruits harvested from the plants stressed with 1000 CMDs (13.28 and 15.47 %, respectively during both the years). However, lowest reduction in total soluble solids was recorded in plants stressed with 250 CMDs (0.78 and 0.79 % during 2005 and 2006, respectively). The reductions in total soluble solids at 500 and 750 CMDs were 6.25 and 9.76 per cent during 2005, and 5.95 and 12.70 per cent during 2006, respectively.

#### **4.1.2 Effect of different feeding levels of European red mite on yield attributes of apple**

The data pertaining to effect of different levels of mite feeding on return bloom, fruit set and fruit load during 2006 and 2007 are presented in Table 5 and Table 6, respectively.

A perusal of the data (Table 5 and Table 6) revealed that return bloom, fruit set and fruit load showed inverse relation with the increase in mite feeding. The maximum return bloom was recorded in the control plants (9.20 and 6.98 blossom /cm<sup>2</sup> limb CSA during 2006 and 2007, respectively), which remained statistically at par with those stressed with 250 CMDs with 9.00 and 6.79 blossom/cm<sup>2</sup> limb CSA during the respective years. The minimum return bloom was recorded in the plants infested with 1000 CMDs with 6.76 and 3.42 blossom/cm<sup>2</sup> limb CSA during 2006 and 2007, respectively. However, significant reduction in return bloom was observed at mite feeding level of 500 CMDs with 7.80 and 5.20 blossom /cm<sup>2</sup> limb CSA during 2006 and 2007, respectively, which differed significantly from return bloom of 7.39 and 4.31 blossom/cm<sup>2</sup> limb CSA recorded at feeding level of 750 CMDs during the respective years. In the present study, the plants stressed with 250 CMDs showed 2.17 and 2.72 per cent reduction in return bloom over control, followed by 500 CMDs with 15.22 and 25.50 per cent, and 750 CMDs with 19.67 and 38.25 per cent during 2006 and 2007, respectively. The highest reduction in return bloom was, however, recorded in the plants stressed with 1000 CMDs (26.52 and 51.00 % during the years 2006 and 2007, respectively) over the control treatment.

The data on fruit set (Table 5 and 6) revealed that fruit set declined with the increasing levels of mite feeding. The highest fruit set of 42.60 and 38.60 per cent was recorded in the control plants, which remained statistically at par with the plants stressed with 250 CMDs with 41.17 and 36.11 per cent fruit set during the respective years. Minimum fruit set was observed in the plants stressed with 1000 CMDs (29.01 and 23.10 % during the years 2006 and 2007, respectively). However, fruit set was affected significantly at mite feeding level of 500 CMDs (37.90 and 32.51 % during 2006 and

**Table 5: Effect of different feeding levels of European red mite on some yield attributes of apple cv. 'Royal Delicious' under fields conditions during 2005-06 at Kathasu (Jubbal), Shimla district**

Treatment	Return bloom		Fruit set		Fruit load	
	(Blossom/cm <sup>2</sup> limb CSA)	Reduction over control (%)	(%)	Reduction over control (%)	(Fruits/cm <sup>2</sup> limb CSA)	Reduction over control (%)
0 CMDs	9.20	-	42.60	-	4.82	-
250 CMDs	9.00	2.17	41.17	3.36	4.60	4.56
500 CMDs	7.80	15.22	37.90	11.03	3.95	18.05
750 CMDs	7.39	19.67	34.51	18.99	3.40	29.46
1000 CMDs	6.76	26.52	29.01	31.90	2.95	38.80
<b>CD (p=0.05)</b>	<b>0.40</b>		<b>2.41</b>		<b>0.43</b>	

**Table 6: Effect of different feeding levels of European red mite on some yield attributes of apple cv. 'Royal Delicious' under fields conditions during 2006-07 at Kathasu (Jubbal), Shimla district**

Treatment	Return bloom		Fruit set		Fruit load	
	(Blossom/cm <sup>2</sup> limb CSA)	Reduction over control (%)	(%)	Reduction over control (%)	(Fruits/cm <sup>2</sup> limb CSA)	Reduction over control (%)
0 CMDs	6.98	-	38.60	-	4.68	-
250 CMDs	6.79	2.72	36.11	6.45	4.46	4.70
500 CMDs	5.20	25.50	32.51	15.78	3.55	24.14
750 CMDs	4.31	38.25	29.02	24.82	3.02	35.47
1000 CMDs	3.42	51.00	23.10	40.15	2.49	46.79
<b>CD (p=0.05)</b>	<b>0.76</b>		<b>3.47</b>		<b>0.51</b>	

2007, respectively), and differed significantly from the feeding level of 750 CMDs with fruit set of 34.51 and 29.02 per cent during the respective years. In the present study, the reduction in the fruit set was 3.36, 11.03, 18.99 and 31.90 per cent during 2006 and 6.45, 15.78, 24.82 and 40.15 per cent during 2007 at mite feeding levels of 250, 500, 750 and 1000 CMDs, respectively over the control treatment.

An appraisal of data (Table 5 and 6) revealed that fruit load showed inverse relation with increasing mite feeding levels. The maximum fruit load of 4.82 fruits/cm<sup>2</sup> limb CSA was recorded in 2006 and 4.68 fruits/cm<sup>2</sup> limb CSA in 2007 in the control plants, which was statistically at par with the plants subjected to 250 CMDs recording 4.60 and 4.46 fruits/cm<sup>2</sup> limb CSA during the respective years. The corresponding minimum fruit load was observed in the plants stressed with 1000 CMDs (2.95 and 2.49 fruits/cm<sup>2</sup> limb CSA during 2006 and 2007, respectively). However, significant reduction in fruit load was recorded at mite feeding level of 500 CMDs with 3.95 and 3.55 fruits/cm<sup>2</sup> limb CSA during 2006 and 2007, respectively, which differed significantly from the fruit load recorded at 750 CMDs (3.40 and 3.02 fruits/cm<sup>2</sup> limb CSA) during the respective years. The data indicated that reduction in fruit load increased with the increase in levels of mite feeding. It was highest in the plants stressed with 1000 CMDs (38.80 and 46.79 %, respectively during both the years) over the control. However, lowest reduction in fruit load was recorded in plants stressed with 250 CMDs (4.56 and 4.70 % during 2006 and 2007, respectively). The reduction in fruit load at 500 and 750 CMDs was 18.05 and 29.46 per cent during 2006 and 24.14 and 35.47 per cent during 2007, respectively.

An appraisal of data presented in Table 3, 4, 5, and 6 clearly indicate that yield and quality parameters of apples were not affected significantly at 250 CMDs. A significant reduction in these parameters started at mite feeding level of 500 CMDs and was recorded maximum at 1000 CMDs feeding level during both the years of study. Therefore, the studies suggested that a population upto 250 CMDs can be tolerated on the plants without any adverse effect on these parameters.

## **4.2 Evaluation of some Horticultural mineral oil (HMO) formulations against European red mite, *P. ulmi***

### **4.2.1 Laboratory evaluation of HMOs against *P. ulmi***

#### **4.2.1.1 Overwintering eggs**

The data on the hatching pattern of overwintering eggs (Plate 4a) of the European red mite treated with horticultural mineral oils are presented in Table 7.

A perusal of data presented in Table 7 showed that the mean number of eggs in the pre-treatment varied from 50.20 to 54.80 per twig. This variation in egg count was non-significant, indicating homogeneous distribution of eggs in the experiment. Seven days after the treatment, maximum hatch of 4.09 per cent was recorded in the control treatment. No egg hatch was observed on the twigs treated with MAK All Season HMO, Orchol-13, and Servo Horticultural Mineral Oil at 1.5 and 1.0 per cent and Arbofine at 1.5 per cent concentration and these treatments were statistically at par with Arbofine (1 %) in which egg hatch of 0.77 per cent was recorded. However, maximum egg hatch of 2.93 per cent was recorded in Arbofine (0.5 %) treated twigs and was significantly inferior to all the treatments.

In the second post treatment observation taken at 14 days after treatment, highest egg hatch was recorded in control (29.48 %). No egg hatching was registered on twigs treated with MAK All Season HMO at 1.5 per cent, closely followed by Orchol-13 (1.5 %) with 0.39 per cent egg hatch, both at par and significantly superior to the remaining treatments. However, Servo Horticultural Mineral Oil and Arbofine at 0.5 per cent were found least effective against winter eggs with egg hatch of 6.62 and 6.21 per cent, respectively, both being statistically at par.

After 21 days of treatment, there was no hatching of eggs on twigs treated with MAK All Season HMO (1.5 %), and was statistically at par with Orchol-13 (1.5 %) with 0.39 per cent egg hatch but were statistically superior to the remaining treatments. The maximum egg hatch of 8.01 per cent was recorded on twigs treated with Arbofine (0.5 %), closely followed by Servo Horticultural Mineral Oil (0.5 %) with 7.78 per cent

**Table 7: Hatchability of winter eggs of *Panonychus ulmi* following dip treatment with some horticultural mineral oil formulations under laboratory conditions during March-April, 2005**

Treatment	Conc. (%)	Pre-treatment egg count /twig	Per cent hatchability days after treatment			
			7*	14*	21**	30**
Orchol-13	0.5	53.00	1.96 (1.56)	4.69 (2.23)	5.86 (13.95)	6.26 (14.48)
Orchol-13	1.0	50.60	0.00 (0.71)	1.17 (1.22)	1.98 (8.10)	2.58 (9.21)
Orchol-13	1.5	53.20	0.00 (0.71)	0.39 (0.88)	0.39 (1.61)	0.78 (3.22)
MAK All Season HMO	0.5	52.00	1.51 (1.37)	4.19 (2.16)	4.94 (12.80)	5.34 (13.33)
MAK All Season HMO	1.0	51.60	0.00 (0.71)	0.74 (1.03)	1.52 (6.34)	2.52 (9.04)
MAK All Season HMO	1.5	53.20	0.00 (0.71)	0.00 (0.71)	0.00 (0.00)	0.39 (1.61)
Servo Horticultural Mineral Oil	0.5	54.40	2.70 (1.70)	6.62 (2.66)	7.78 (16.20)	8.18 (16.61)
Servo Horticultural Mineral Oil	1.0	50.80	0.00 (0.71)	2.30 (1.66)	3.07 (9.98)	3.47 (10.53)
Servo Horticultural Mineral Oil	1.5	52.80	0.00 (0.71)	1.88 (1.54)	1.88 (7.90)	2.28 (8.57)
Arbofine	0.5	54.80	2.93 (1.77)	6.21 (2.58)	8.01 (16.43)	8.97 (17.40)
Arbofine	1.0	51.60	0.77 (1.04)	1.94 (1.56)	3.92 (11.42)	4.52 (12.19)
Arbofine	1.5	50.20	0.00 (0.71)	1.55 (1.39)	2.35 (8.71)	2.35 (8.71)
Control (water spray)	0.0	53.60	4.09 (2.13)	29.48 (5.47)	58.59 (49.95)	69.02 (56.19)
<b>CD (p=0.05)</b>		<b>NS</b>	<b>(0.37)</b>	<b>(0.34)</b>	<b>(2.16)</b>	<b>(2.60)</b>

\* Figures in parentheses are square root (x+0.5) transformed values

\*\* Figures in parentheses are arcsine transformed values

of egg hatch, both statistically at par with each other as against the control treatment in which 58.59 per cent egg hatch was recorded.

In the final observation recorded 30 days after treatment, there was slight increase in hatchability over previous observation. Among the HMO treatments, minimum egg hatch of 0.39 per cent was recorded in MAK All Season HMO (1.5 %) treated twigs, which was statistically at par with Orchol-13 (1.5 %) with 0.78 per cent egg hatch. However, maximum egg hatch (8.97 %) was recorded in Arbofine (0.5 %) treated twigs, closely followed by Servo Horticultural Mineral Oil (0.5 %) with 8.18 per cent egg hatch, and were non-significant with each other and statistically inferior to the remaining treatments. In control, egg hatch increased from 58.59 to 69.02 per cent. After this observation, no further increase in hatchability was observed in any of the treatments.

#### 4.2.1.2 Summer eggs

The results of bioassay of test HMOs against the summer eggs (Plate 4b) of *P. ulmi* are presented in Table 8.

An appraisal of data presented in the Table 8 revealed that in pre-treatment the mean egg count varied non-significantly from 39.00 to 46.60 per leaf. The maximum egg hatch of 15.90 per cent was recorded in the control treatment after 1 day of treatment, while no egg hatch was obtained in treatments with MAK All Season HMO and Orchol-13 both at 0.25, 0.5 and 0.75 per cent, Servo Horticultural Mineral Oil and Arbofine each at 0.5 and 0.75 per cent. However, maximum egg hatch of 0.84 per cent was observed in Arbofine (0.25 %) treated leaves, which was statistically at par with Servo Horticultural Mineral Oil (0.25 %) with 0.48 per cent egg hatch.

In the second post treatment count recorded 3 days after spray, no egg hatch was observed on leaves treated with MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil and Arbofine each at 0.5 and 0.75 per cent concentration and were statistically at par with Orchol-13 and MAK All Season HMO each at 0.25 per cent concentration recording 0.45 and 0.51 per cent egg hatch, respectively. It was superior to Servo Horticultural Mineral Oil (0.25 %) and Arbofine (0.25 %) with 1.53 and

**Table 8: Hatchability of summer eggs of *P. ulmi* on apple leaves following dip treatment with some horticultural mineral oil formulations under laboratory conditions during June 2005**

Treatment	Conc. (%)	Pre-treatment egg count /leaf	Per cent hatchability days after treatment				
			1*	3**	5**	7**	10**
Orchol-13	0.25	46.20	0.00 (0.71)	0.45 (1.72)	0.45 (1.72)	2.16 (8.46)	2.16 (8.46)
Orchol-13	0.50	44.80	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Orchol-13	0.75	39.20	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
MAK All Season HMO	0.25	40.80	0.00 (0.71)	0.51 (1.84)	0.51 (1.84)	2.09 (6.38)	2.09 (6.38)
MAK All Season HMO	0.50	39.60	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
MAK All Season HMO	0.75	45.80	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Servo Horticultural Mineral Oil	0.25	40.00	0.48 (0.96)	1.53 (5.50)	1.53 (5.50)	3.92 (11.28)	3.92 (11.28)
Servo Horticultural Mineral Oil	0.50	44.40	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Servo Horticultural Mineral Oil	0.75	39.00	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Arbofine	0.25	46.60	0.84 (1.07)	1.27 (4.04)	1.68 (4.73)	4.25 (11.77)	4.25 (11.77)
Arbofine	0.50	39.60	0.00 (0.71)	0.00 (0.00)	0.50 (1.82)	0.50 (1.82)	0.50 (1.82)
Arbofine	0.75	41.20	0.00 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Control (water spray)	0.00	45.20	15.90 (4.05)	50.53 (45.30)	84.08 (66.57)	86.71 (68.65)	87.64 (69.48)
<b>CD (p=0.05)</b>		<b>NS</b>	<b>(0.24)</b>	<b>(3.13)</b>	<b>(3.89)</b>	<b>(3.88)</b>	<b>(3.92)</b>

\* Figures in parentheses are square root ( $x+0.5$ ) transformed values

\*\* Figures in parentheses are arcsine transformed values

1.27 per cent egg hatch, respectively. In control treatment, 50.53 per cent egg hatch was recorded.

A drastic increase in egg hatch was observed when recorded 5 days after treatment, maximum being in the control treatment (84.08 %). No egg hatch was recorded on leaves treated with all test Horticultural mineral oil formulations at 0.5 and 0.75 per cent concentration, except Arbofine (0.5 %) which exhibited 0.50 per cent egg hatch. These treatments were statistically at par with MAK All Season HMO (0.25 %) and Orchol-13 (0.25 %) having 0.45 and 0.51 per cent egg hatch, respectively. However, the maximum egg hatch of 1.68 per cent was recorded in the leaves treated with Arbofine (0.25 %), which was statistically at par with Servo Horticultural Mineral Oil (0.25 %) with 1.53 per cent egg hatch.

In the post treatment observation recorded 7 days after treatment, a maximum egg hatch of 86.71 per cent was recorded in the control treatment. No egg hatch was recorded in the leaves treated with 0.5 and 0.75 per cent concentration of MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil, and Arbofine (0.75 %), all statistically at par with Arbofine (0.5 %) which recorded 0.50 per cent egg hatch. However, among the HMO treatments, maximum egg hatch of 4.25 per cent was recorded in Arbofine (0.25 %) treated leaves and was significantly inferior to all the HMO treatments.

In the final observation recorded 10 days after treatment, there was no further increase in hatching percentage in all the HMO treatments. However, egg hatch was marginally increased to 87.64 per cent in the control treatment. All concentrations of test HMOs proved significantly superior to the control treatment.

An appraisal of data presented in Table 7 and 8 revealed that winter and summer eggs of *P. ulmi* were highly susceptible to HMOs. However, summer eggs were relatively more sensitive to all the treatments of test HMOs as compared to winter eggs and showed complete mortality even at 0.5 per cent concentration. Among the test HMOs, MAK All Season HMO proved most effective against winter and summer eggs, followed by Orchol-13, Servo Horticultural Mineral Oil, and Arbofine.

#### 4.2.1.3. Efficacy of HMOs against motile stages of *P. ulmi*

The data on per cent mortality of larvae, nymphs and adults of *P. ulmi* following application of some horticultural mineral oil formulations with hand atomizer under laboratory conditions are presented in Table 9.

##### Larvae

The data on the effect of test HMOs on larval stage recorded 24 hours after treatment revealed all the HMO treatments were significantly superior to the control treatment. Larval stage was found highly sensitive recording 100 per cent mortality except the control treatment which recorded 14.00 per cent mortality.

##### Nymphs

All test concentrations of HMOs showed significant effect on nymphal mortality (Table 9). In the first observation recorded 24 hours after treatment, complete mortality (100.00 %) of nymphal stages was observed in all test HMOs at 1.5 per cent concentration, and was significantly superior to the remaining treatments. MAK All Season HMO and Orchol-13 each at 1.0 per cent concentration were on par with each other and provided 97.06 and 96.00 per cent nymphal mortality. Arbofine and Servo Horticultural Mineral Oil at 0.5 per cent gave nymphal mortality of 92.80 and 93.60 per cent, respectively. All HMOs at 0.5 per cent were least effective with mortality ranging between 71.59 to 94.60 per cent. In contrast, nymphal mortality in control treatment was 10.40 per cent.

The nymphal mortality increased in almost all the treatments when recorded 48 hours after treatment. MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil and Arbofine each at 1.5 per cent concentration proved highly effective and provided cent per cent mortality of nymphal stages of *P. ulmi*, and were statistically at par with MAK All Season HMO (0.5 %) and Orchol-13 (0.5 %) having 99.20 and 98.40 per cent mortality, respectively. Arbofine and Servo Horticultural Mineral Oil each at 0.5 per cent concentration proved least effective with 96.00 and 96.80 per cent mortality as against the control in which 12.80 per cent nymphal mortality was recorded.

**Table 9: Per cent mortality of motile stages of *P. ulmi* treated with some horticultural mineral oil formulations under laboratory conditions during 2005**

Treatment	Conc. (%)	* Per cent mortality hours after treatment				
		Larva	Nymph		Adult	
		24	24	48	24	48
Orchol-13	0.5	100.00 (90.00)	94.40 (76.51)	98.40 (85.39)	90.40 (72.25)	97.60 (83.08)
Orchol-13	1.0	100.00 (90.00)	96.00 (81.12)	100.00 (90.00)	95.20 (78.82)	100.00 (90.00)
Orchol-13	1.5	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	97.60 (83.08)	100.00 (90.00)
MAK All Season HMO	0.5	100.00 (90.00)	94.60 (76.80)	99.20 (87.70)	91.20 (73.02)	97.60 (83.08)
MAK All Season HMO	1.0	100.00 (90.00)	97.06 (83.08)	100.00 (90.00)	96.00 (81.12)	100.00 (90.00)
MAK All Season HMO	1.5	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	98.40 (85.39)	100.00 (90.00)
Servo Horticultural Mineral Oil	0.5	100.00 (90.00)	90.40 (72.35)	96.80 (81.42)	88.80 (70.61)	96.00 (81.12)
Servo Horticultural Mineral Oil	1.0	100.00 (90.00)	93.60 (77.07)	100.00 (90.00)	93.60 (77.07)	98.60 (86.72)
Servo Horticultural Mineral Oil	1.5	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	96.00 (81.12)	100.00 (90.00)
Arbofine	0.5	100.00 (90.00)	89.06 (71.59)	96.00 (81.12)	87.20 (69.18)	95.20 (78.82)
Arbofine	1.0	100.00 (90.00)	92.80 (74.76)	100.00 (90.00)	92.80 (74.76)	98.40 (85.39)
Arbofine	1.5	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	96.00 (81.12)	100.00 (90.00)
Control (water spray)	0.0	14.00 (21.76)	10.40 (18.73)	12.80 (20.83)	4.80 (11.19)	7.20 (15.24)
<b>CD (p=0.05)</b>		<b>(1.33)</b>	<b>(5.85)</b>	<b>(5.16)</b>	<b>(7.87)</b>	<b>(6.12)</b>

Figures in parentheses are arcsine transformed values

## Adults

An appraisal of data presented in Table 9 revealed that all the horticultural mineral oil formulations were effective against the adult stage of *P. ulmi* compared to the control treatment. In the first observation recorded 24 hours after the treatment, maximum mortality of 98.40 per cent was recorded in MAK All Season HMO (1.5 %), which was statistically at par with Orchol-13, Servo Horticultural Mineral Oil, Arbofine each at 1.5 per cent, MAK All Season HMO (1 %) and Orchol-13 (1 %), which provided mortality ranging between 95.20 to 97.60 per cent. Minimum adult mortality of 87.20 per cent was observed with Arbofine (0.5 %), as against 4.80 per cent in the control treatment.

In the final observation recorded 48 hours after treatment, mortality increased in almost all the treatments. Complete mortality of adults was recorded with MAK All Season HMO, Orchol-13 each at 1.5 and 1.0 per cent concentration, Servo Horticultural Mineral Oil and Arbofine at 1.5 per cent concentration. These treatments were statistically at par with Servo Horticultural Mineral Oil (1 %) and Arbofine (1 %) with 98.60 and 98.40 per cent adult mortality, respectively. The lowest concentration of 0.5 per cent of test HMOs provided adult mortality ranging between 95.20 to 97.60 per cent, compared to 7.20 per cent mortality in the control treatment.

An appraisal of data presented in Table 9 clearly showed that all the test horticultural mineral oil formulations were effective against all the motile stages of *P. ulmi*. However, the decreasing order of susceptibility of motile stages was larva, nymph and adult. Among the test HMOs, MAK All Season HMO proved most effective against motile stages of *P. ulmi*, followed by Orchol-13, Servo Horticultural Mineral Oil, and Arbofine.

### 4.2.2 Field evaluation of HMOs against *P. ulmi*

#### 4.2.2.1 Ovicidal effect of HMOs against overwintering eggs

Data on the hatchability of overwintering eggs of *P. ulmi* following treatment with some horticultural mineral oil formulations under field conditions are presented in Table 10.

A perusal of data (Table 10) revealed that hatching of overwintering eggs started one week after treatment (April 2), and a maximum egg hatch of 3.23 per cent was obtained in control, whereas, no egg hatch was recorded in MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil and Arbofine, each at 1.5 and 1.0 per cent and MAK All Season HMO at 0.5 per cent concentration. However, maximum egg hatch of 1.81 per cent was recorded with Arbofine (0.5 %).

In the second post treatment count taken 14 days treatment, a minimum hatch of 0.35 per cent was recorded on twigs treated with MAK All Season HMO (1.5 %), which was statistically at par with Orchol-13 (1.5 %) recording 0.70 per cent egg hatch, both the treatments were significantly superior to the remaining treatments. Among the test concentrations of HMOs, maximum egg hatch of 10.55 per cent was recorded in Servo Horticultural Mineral Oil (0.5 %) treated plants, followed by Arbofine (0.5 %) and Orchol-13 (0.5 %) with 10.43 and 8.17 per cent egg hatch, respectively, all being statistically at par. However, in the control treatment 37.92 per cent egg hatch was recorded.

In the subsequent observation taken 21 days after treatment, 70.73 per cent egg hatch was recorded in the control treatment. MAK All Season HMO (1.5 %) with 1.04 per cent egg hatch was the most effective treatment, followed by Orchol-13 (1.5 %), Servo Horticultural Mineral Oil (1.5 %) and Arbofine (1.5 %) recording 1.40, 2.10 and 2.16 per cent egg hatch, respectively, all being statistically at par. The least effective treatment was Servo Horticultural Mineral Oil (0.5 %) with 21.61 per cent egg hatch, which was statistically at par with Arbofine (0.5 %) with 20.71 per cent egg hatch.

An appraisal of data recorded 30 days after treatment showed a slight increase in egg hatch in almost all the treatments as compared to the previous observation. Highest egg hatch was recorded in Servo Horticultural Mineral Oil (0.5 %) with 24.30 per cent egg hatch, closely followed by Arbofine (0.5 %) with 24.16 per cent, both statistically at par. A minimum egg hatch of 1.76 per cent was recorded in MAK All Season HMO (1.5 %), which was significantly at par with Orchol-13 (1.5 %) with 2.08 per cent egg hatch. Arbofine and Servo Horticultural Mineral Oil at 1.5 per cent concentration recorded

**Table 10: Field evaluation of some horticultural mineral oil formulations against overwintering eggs of *P. ulmi* at pink bud stage during 2005 at Kathasu (Jubbal), District Shimla**

Treatment	Conc. (%)	Pre-treatment egg count /twig	Per cent egg hatch days after treatment			
			7*	14**	21**	30**
Orchol-13	0.5	76.75	0.66 (1.03)	8.17 (16.56)	14.66 (22.48)	15.35 (23.04)
Orchol-13	1.0	72.00	0.00 (0.71)	1.72 (6.46)	3.50 (10.47)	4.15 (11.68)
Orchol-13	1.5	74.25	0.00 (0.71)	0.70 (3.22)	1.40 (5.76)	2.08 (8.12)
Servo Horticultural Mineral Oil	0.5	67.25	1.12 (1.23)	10.55 (18.89)	21.61 (27.59)	24.30 (29.45)
Servo Horticultural Mineral Oil	1.0	82.25	0.00 (0.71)	2.71 (9.31)	6.07 (14.20)	6.37 (14.58)
Servo Horticultural Mineral Oil	1.5	74.75	0.00 (0.71)	1.34 (6.65)	2.10 (8.25)	4.30 (11.36)
MAK All Season HMO	0.5	68.75	0.00 (0.71)	6.18 (14.38)	12.42 (20.53)	14.56 (22.38)
MAK All Season HMO	1.0	79.00	0.00 (0.71)	1.56 (7.11)	3.16 (9.96)	3.84 (10.97)
MAK All Season HMO	1.5	71.50	0.00 (0.71)	0.35 (1.70)	1.04 (4.19)	1.76 (6.54)
Arbofine	0.5	81.75	1.81 (1.51)	10.43 (18.80)	20.71 (27.00)	24.16 (29.43)
Arbofine	1.0	66.25	0.00 (0.71)	2.64 (9.29)	5.31 (13.30)	6.09 (14.23)
Arbofine	1.5	76.25	0.00 (0.71)	1.95 (7.93)	2.16 (8.30)	3.92 (11.27)
Control (water spray)	0.0	77.00	3.23 (1.93)	37.92 (38.00)	70.73 (57.30)	74.27 (59.57)
<b>CD (p=0.05)</b>		<b>NS</b>	<b>(0.23)</b>	<b>(3.35)</b>	<b>(4.18)</b>	<b>(3.27)</b>

\* Figures in parentheses are square root (x+0.5) transformed values

\*\* Figures in parentheses are arcsine transformed values

3.92 and 4.30 per cent egg hatch, and were statistically at par with each other. The highest egg hatch of 74.27 per cent was recorded in the control treatment.

It is evident from the data presented in Table 10 that all the test horticultural mineral oil formulations at 1.5 and 1.0 per cent proved effective against winter eggs under field conditions. However, all test HMOs at 1.5 per cent concentration proved most effective providing 98.24 to 95.70 per cent egg mortality. Among all test HMOs, MAK All Season HMO at 1.5 per cent concentration proved most effective, followed by Orchol-13, Arbofine and Servo Horticultural Mineral Oil, each at 1.5 per cent concentration.

#### **4.2.2.2 Efficacy of HMOs as curative measure against motile stages of *P. ulmi***

The data on efficacy of horticultural mineral oil formulations against motile stages of *P. ulmi* under field conditions during the year 2005 and 2006 are presented in Table 11 and Table 12, respectively.

A perusal of data presented in Table 11 indicated that before the application of HMOs, the populations of mites was almost uniform on all plants marked for treatment and it varied non-significantly from 18.07 to 23.75 mites per leaf. In the first post treatment count recorded three days after spraying, mite populations decreased significantly in all the treatments except control treatment. The data showed that minimum population of mites was recorded in plants treated with MAK All Season HMO, Orchol-13, Servo Horticultural Mineral Oil and Arbofine each at 1.5 per cent concentration with 0.51, 0.68, 0.86 and 0.95 mites per leaf, respectively, all statistically at par with each other and were significantly superior to the remaining treatments. However, among the HMO treatments, maximum motile stages of 6.18 per leaf was observed in Arbofine (0.5 %), followed by Servo Horticultural Mineral Oil (5.76/leaf) and Orchol-13 (4.75/leaf) at 0.5 per cent concentration, all being statistically at par. In the control treatment, the maximum number of motiles was 17.36 per leaf.

Seven days after the treatment, the least average number of motile stages (0.48/ leaf) was recorded in MAK All Season HMO (1.5 %), followed by Orchol-13,

**Table 11: Bio-efficacy of some horticultural mineral oil formulations against *P. ulmi* on apple under field conditions at Theog, Shimla during June, 2005**

Treatment	Conc. (%)	Pre-treatment mite count/leaf	*Average number of mites/leaf days after treatment				
			3	7	14	21	30
Orchol-13	0.5	23.03	4.75 (2.29)	4.66 (2.27)	7.72 (2.86)	12.85 (3.63)	14.97 (3.93)
Orchol-13	1.0	20.10	1.18 (1.33)	1.26 (1.34)	2.02 (1.58)	3.90 (2.09)	6.47 (2.62)
Orchol-13	1.5	23.75	0.68 (1.08)	0.66 (1.07)	1.37 (1.36)	2.03 (1.59)	5.45 (2.42)
Servo Horticultural Mineral Oil	0.5	20.75	5.76 (2.50)	5.83 (2.51)	9.11 (3.10)	14.72 (3.87)	15.46 (3.99)
Servo Horticultural Mineral Oil	1.0	18.95	1.76 (1.47)	1.75 (1.47)	3.16 (1.90)	5.35 (2.41)	7.88 (2.92)
Servo Horticultural Mineral Oil	1.5	22.75	0.86 (1.13)	0.81 (1.12)	2.02 (1.58)	4.03 (2.12)	7.03 (2.74)
MAK All Season HMO	0.5	18.36	4.27 (2.17)	4.15 (2.14)	7.31 (2.79)	12.45 (3.59)	15.02 (3.93)
MAK All Season HMO	1.0	21.85	1.41 (1.37)	1.23 (1.31)	1.98 (1.55)	4.21 (2.15)	7.07 (2.75)
MAK All Season HMO	1.5	23.40	0.51 (0.97)	0.48 (0.97)	1.21 (1.30)	2.13 (1.62)	5.32 (2.41)
Arbofine	0.5	18.07	6.18 (2.57)	6.26 (2.59)	9.42 (3.15)	16.07 (4.06)	17.22 (4.21)
Arbofine	1.0	20.41	2.16 (1.62)	2.13 (1.62)	3.08 (1.99)	5.22 (2.38)	8.10 (2.93)
Arbofine	1.5	20.25	0.95 (1.20)	1.01 (1.23)	2.46 (1.72)	3.97 (2.10)	7.33 (2.79)
Control (Water spray)	0.0	18.92	17.36 (4.20)	18.16 (4.32)	25.14 (5.06)	28.32 (5.37)	32.85 (5.77)
<b>CD (p=0.05)</b>		<b>NS</b>	<b>(0.34)</b>	<b>(0.33)</b>	<b>(0.25)</b>	<b>(0.37)</b>	<b>(0.31)</b>

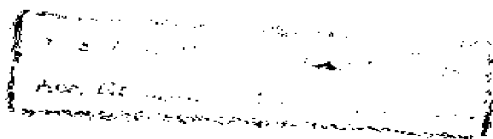
Figures in parentheses are square root (x+0.5) transformed values

Servo Horticultural Mineral Oil and Arbofine, each at 1.5 per cent recording mite population ranging from 0.66 to 1.01 per leaf. All these treatments were statistically at par and significantly superior to the remaining treatments. HMOs treatments at 0.5 per cent recorded higher counts of 4.15 to 6.26 motiles per leaf, as against 18.16 motiles per leaf in the control treatment.

In the subsequent observation taken 14 days after spray, MAK All Season HMO (1.5 %) with 1.21 motiles per leaf emerged as the most effective treatment, which was statistically at par with Orchol-13 (1.5 %) having 1.37 motile per leaf. All the test horticultural mineral oil treatments at 0.5 per cent concentration proved least effective and recorded mite population ranging from 7.31 to 9.42 per leaf. However, in control treatment mite population reached a level of 25.14 per leaf.

Data recorded 21 days after treatment revealed that minimum mite count of 2.03 per leaf was observed in Orchol-13 (1.5 %), followed by MAK All Season HMO (1.5 %) with 2.13 motiles per leaf, both being statistically at par and significantly superior to the remaining treatments recording mite population ranging between 3.97 to 16.07 per leaf. However, among the HMO treatments, maximum mite population was recorded in the plants treated with Arbofine (0.5 %) with 16.07 motiles per leaf, and was statistically at par with Servo Horticultural Mineral Oil (0.5 %) recording 14.72 motiles per leaf. In the control treatment, a much higher population of 28.32 mites per leaf was recorded.

The final observation recorded 30 days after treatment revealed that minimum mite population (5.32 motiles /leaf) was observed in plants treated with MAK All Season HMO (1.5 %), which was statistically at par with Orchol-13 recording 5.45 motiles per leaf. These treatments were significantly superior to the remaining treatments and thus established their superiority over the remaining treatments. All the test horticultural mineral oil formulations at 1.0 per cent concentration were significantly less effective than those at 1.5 per cent with mite population ranging from 6.47 to 8.10 motiles per leaf. Arbofine at 0.5 per cent concentration proved least effective treatment recording 17.22 motiles per leaf, which was statistically at par with Servo Horticultural Mineral Oil, MAK All Season HMO and Orchol-13 each at 0.5 per cent concentration recording mite



population ranging from 14.97 to 15.46 per leaf. However, mite population in control treatment increased further reaching a new high of 32.85 motiles per leaf.

The data on effectiveness of different horticultural mineral oil formulations against European red mite on apple under field conditions during 2006 are presented in Table 12.

A perusal of the data presented in Table 12 showed that European red mite population varied from 14.63 to 18.41 motiles per leaf in the pre-treatment count. This variation in mite population was non-significant, indicating homogenous distribution of mite population in the experimental field. All the test HMO formulations were effective in controlling mite population and were statistically superior to the control treatment. Three days after treatment, all test horticultural mineral oil formulations viz. Orchol-13, MAK All Season HMO, Servo Horticultural Mineral Oil and Arbofine, each at 1.5 and 1.0 per cent concentration proved effective as the motile count varied from 0.46 to 1.03 per leaf, being non-significant as against 13.08 motiles per leaf in control treatment. However, maximum mite population of 3.02 per leaf was observed in Servo Horticultural Mineral Oil (0.5 %) treated plants, followed by Arbofine, MAK all Season HMO and Orchol-13 each at 0.5 per cent concentration with 2.97, 2.67 and 2.61 motiles per leaf, respectively, all statistically at par with each other.

A similar trend in mite mortality was observed when recorded 7 days after treatment. Minimum mite count of 0.37 per leaf was recorded in the plants treated with Orchol-13 (1.5 %) and it was statistically at par with all test HMOs at 1.5 and 1.0 per cent concentration with mean mite population ranging between 0.38 to 0.91 motiles per leaf. The maximum number of motiles (2.95 /leaf) was observed in Arbofine (0.5 %) treated plants, followed by Servo Horticultural Mineral Oil, Orchol-13 and MAK All Season HMO each at 0.5 per cent concentration having 2.77, 2.17 and 2.10 motiles per leaf, respectively, all being statistically at par. In the control treatment, mite population increased from 13.08 in the previous count to 17.97 motiles per leaf.

**Table 12: Bio-efficacy of some horticultural mineral oil formulations against *P. ulmi* on apple under field conditions at Theog, Shimla during June, 2006**

Treatment	Conc. (%)	Pre-treatment mite count/leaf	*Average number of mites/leaf days after treatment				
			3	7	14	21	30
Orchol-13	0.5	17.33	2.61 (1.75)	2.17 (1.62)	4.96 (2.33)	8.26 (2.96)	10.28 (3.28)
Orchol-13	1.0	16.71	0.77 (1.12)	0.58 (1.04)	1.84 (1.52)	4.00 (2.12)	6.21 (2.59)
Orchol-13	1.5	16.55	0.46 (0.97)	0.37 (0.93)	1.21 (1.30)	2.93 (1.85)	5.33 (2.41)
Servo Horticultural Mineral Oil	0.5	18.41	3.02 (1.88)	2.77 (1.79)	6.62 (2.67)	10.75 (3.35)	12.70 (3.63)
Servo Horticultural Mineral Oil	1.0	15.92	1.03 (1.23)	0.88 (1.17)	2.96 (1.86)	5.33 (2.41)	8.11 (2.93)
Servo Horticultural Mineral Oil	1.5	14.63	0.72 (1.10)	0.74 (1.10)	1.88 (1.54)	3.96 (2.09)	6.42 (2.63)
MAK All Season HMO	0.5	17.88	2.67 (1.76)	2.10 (1.59)	4.92 (2.33)	8.17 (2.94)	10.20 (3.27)
MAK All Season HMO	1.0	16.77	0.70 (1.08)	0.50 (0.99)	1.92 (1.55)	3.97 (2.11)	6.01 (2.55)
MAK All Season HMO	1.5	16.52	0.65 (1.00)	0.38 (0.94)	1.26 (1.32)	2.73 (1.79)	5.03 (2.33)
Arbofine	0.5	18.21	2.97 (1.85)	2.95 (1.84)	6.70 (2.68)	10.71 (3.35)	12.88 (3.66)
Arbofine	1.0	17.70	1.02 (1.22)	0.91 (1.17)	2.92 (1.85)	5.56 (2.46)	8.21 (2.95)
Arbofine	1.5	14.20	0.73 (1.10)	0.80 (1.14)	2.02 (1.58)	3.96 (2.09)	6.56 (2.66)
Control (Water spray)	0.0	15.30	13.08 (3.68)	17.97 (4.30)	22.17 (4.76)	25.25 (5.07)	30.28 (5.54)
<b>CD (p=0.05)</b>		<b>NS</b>	<b>(0.30)</b>	<b>(0.26)</b>	<b>(0.19)</b>	<b>(0.28)</b>	<b>(0.21)</b>

Figures in parentheses are square root (x+0.5) transformed values

It was evident from the data recorded 14 days after treatment that Orchol-13 and MAK All Season HMO, both at 1.5 per cent concentration were most effective in controlling mites as 1.21 and 1.26 mites per leaf were recorded in respective treatments. These above treatments were significantly superior to the remaining treatments in which mean mite population ranging from 1.84 to 6.62 per leaf was recorded. Maximum mite population of 6.70 motiles per leaf was recorded in the plants treated with Arbofine at 0.5 per cent concentration, which was statistically at par with Servo Horticultural Mineral Oil (0.5 %) recording 6.62 motiles per leaf, as compared to 22.17 motiles per leaf recorded in the control treatment.

Data taken 21 days after treatment revealed that MAK All Season HMO (1.5 %) was the most effective treatment as it recorded lowest number of motiles (2.73 /leaf), and was statistically at par with Orchol-13 at 1.5 per cent concentration recording 2.93 motiels per leaf. All the test HMOs at 0.5 per cent concentration were significantly less effective as they recorded mite population ranging between 8.17 to 10.75 per leaf, as against the control treatment in which mite population increased to 25.25 motiles per leaf.

Mite population increased in all the treatments when recorded 30 days after treatment. Minimum mite population was recorded in MAK All Season HMO (5.03 motiles/leaf), followed by Orchol-13 at 1.5 per cent concentration with 5.33 motiles per leaf, both being statistically at par and significantly superior to rest of the treatments recording mite population ranging between 6.10 to 12.88 per leaf. Arbofine at 0.5 per cent concentration proved least effective treatment against *P. ulmi* recording 12.88 motiles per leaf, followed by Servo Horticultural Mineral Oil (0.5 %) with 12.70 motiles per leaf, both statistically at par with each other. However, mite population in the control treatment further increased to 30.28 motiles per leaf.

An appraisal of data presented in Table 11 and 12 revealed that all the test horticultural mineral oil formulations at 1.5 and 1.0 per cent resulted in effective control of *P. ulmi* up to 21 days during both the years of study. However, all the test HMOs at 1.5 per cent concentration proved most effective against *P. ulmi*. HMOs at 0.5 per cent

could not provide effective control of *P. ulmi* and recorded mite population ranging between 14.97 to 17.22 per leaf during 2005 and 10.20 to 12.88 per leaf during 2006 after 30 days of treatment. Among all the test HMOs, MAK All Season HMO at 1.5 per cent concentration proved most effective, followed by Orchol-13, Servo Horticultural Mineral Oil and Arbofine, each at 1.5 per cent concentration. The results showed that 21 days after treatment, mite population increased above economic threshold level in all the HMO treatments during both the years of study.

#### **4.2.3 Effect of Horticultural mineral oils on apple**

None of the test concentration of HMOs caused phytotoxicity or any apparent adverse effect on the growth and development of plants during the course of study. Thus, all the test formulations of HMOs were found safe to the plants.

#### **4.3 Toxicity of chemicals against *P. ulmi***

The toxicity studies of different acaricides viz., clofentezine, hexythiazox, millbemectin and fenpropathrin was done for the first time against *P. ulmi* on apple under Indian conditions. Laboratory experiments were carried out to study the median lethal concentration (LC<sub>50</sub>) from dose-mortality response data of different acaricides against motile and egg stages of *P. ulmi*. The results so obtained are presented as follows:

##### **4.3.1 Toxicity of clofentezine (Apollo 50 SC)**

###### **4.3.1.1 Winter eggs**

The winter eggs of European red mite when dipped in different concentrations of clofentezine ranging from 5 to 100 ppm gave mortality range between 19.81 to 82.75 per cent (Table 13). After accounting for control mortality, the data were subjected to statistical analysis to obtain regression which had a slope of 1.3796 (Fig 1). The homogeneity of the test population was revealed by the  $\chi^2$  value of 1.712, being lower than the tabulated value of 7.815 at  $p=0.05$  and 3 degree of freedom (df). The data were then subjected to probit analysis and gave LC<sub>50</sub> value of 17.872 ppm with fiducial limits of 15.165 and 21.062 ppm and LC<sub>90</sub> value of 151.815 ppm with fiducial limits of 107.295 and 214.809 ppm.

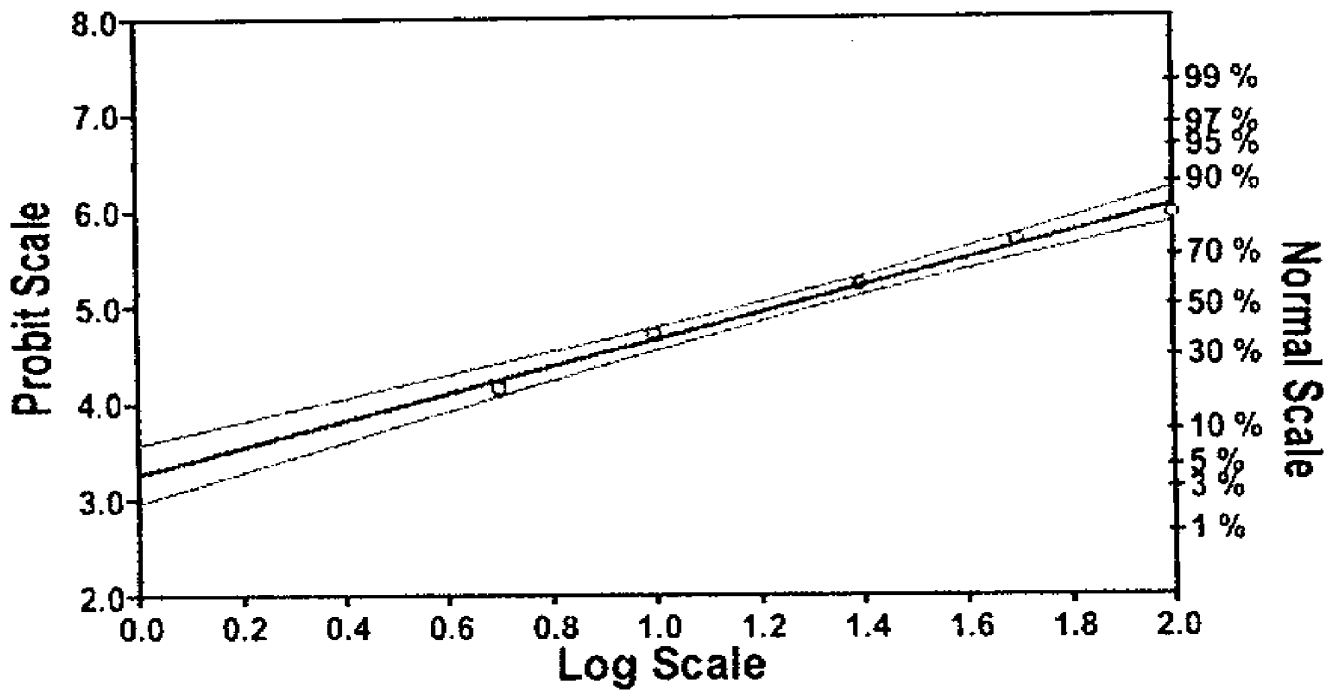
**Table 13: Dose-mortality response of winter eggs of *P. ulmi*, 30 days after dip treatment with clofentezine (Apollo 50 SC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
100	2.000	150	86.66	82.75	5.945	5.941
50	1.699	150	80.66	74.99	5.674	5.673
25	1.398	150	68.00	58.57	5.217	5.217
10	1.000	150	52.66	38.75	4.716	4.716
5	0.699	150	38.00	19.81	4.152	4.154
0	0.000	150	22.66	-	-	-

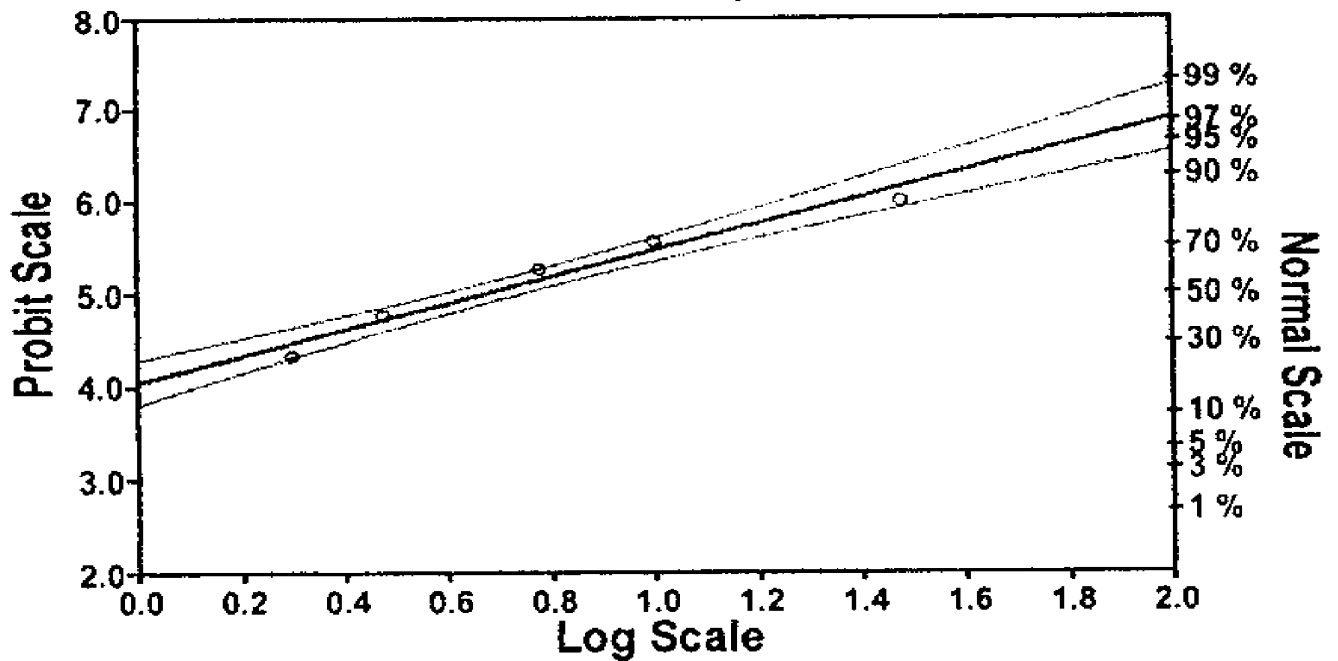
Regression equation	Y	=	3.2725 + 1.3796 X
Heterogeneity	$\chi^2_{cal}$	=	1.7121
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	17.872 ppm
Fiducial limits		=	15.165 and 21.062 ppm
LC <sub>90</sub>		=	151.815 ppm
Fiducial limits		=	107.295 and 214.809 ppm
Slope (b)		=	1.3796

#### 4.3.1.2 Summer eggs

The dose-mortality response of summer eggs of *P. ulmi* studied by leaf-dip method at concentrations ranging between 2 to 30 ppm of clofentezine gave mortality ranging between 25.00 to 84.25 per cent (Table 14). The data were subjected to probit analysis and the regression equation obtained had a slope 1.4268 (Fig. 2). The  $\chi^2$  test showed the homogeneity of the test population since calculated value of  $\chi^2$  (4.00) was lower than the tabulated value (7.815) at p=0.05 and 3 df. The LC<sub>50</sub> value calculated from the regression equation was 4.678 ppm with fiducial limits of 3.920 and 5.582 ppm and LC<sub>90</sub> value of was 37.018 ppm with fiducial limits of 24.724 and 55.427 ppm.



**Fig. 1:** Dose-mortality response of winter eggs of *P. ulmi* to clofentezine



**Fig. 2:** Dose-mortality response of summer eggs of *P. ulmi* to clofentezine

**Table 14: Dose-mortality response of summer eggs of *P. ulmi*, 10 days after leaf-dip treatment with clofentezine (Apollo 50 SC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
30	1.477	120	85.83	84.25	6.005	5.997
10	1.000	120	74.16	71.28	5.562	5.559
6	0.778	120	64.16	60.17	5.258	5.257
3	0.477	120	46.66	40.73	4.766	4.766
2	0.301	120	32.50	25.00	4.326	4.331
0	0.000	120	10.00	-	-	-

Regression equation	Y	=	4.0439 + 1.4268 X
Heterogeneity	$\chi^2_{cal}$	=	4.000
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	4.678 ppm
Fiducial limits		=	3.920 and 5.582 ppm
LC <sub>90</sub>		=	37.018 ppm
Fiducial limits		=	24.724 and 55.427 ppm
Slope (b)		=	1.4268

#### 4.3.1.3 Larvae

The larvae of *P. ulmi* (Plate 5a) when exposed to the leaves dipped in clofentezine gave mortality ranging between 27.27 to 87.11 per cent at concentrations ranging between 5 to 100 ppm (Table 15). The calculated  $\chi^2$  value (1.009) was lower than the tabulated value (7.815) at p=0.05 and 3 df, which revealed that the test population was homogenous. On subjecting the concentration mortality data to probit analysis, the LC<sub>50</sub> value was found to be 12.569 with fiducial limits of 9.705 and 16.277 ppm while LC<sub>90</sub> value was calculated to be 118.250 ppm with fiducial limits of 72.059 and 194.049 ppm. The slope of regression line obtained during the probit analysis was 1.3167 (Fig. 3).

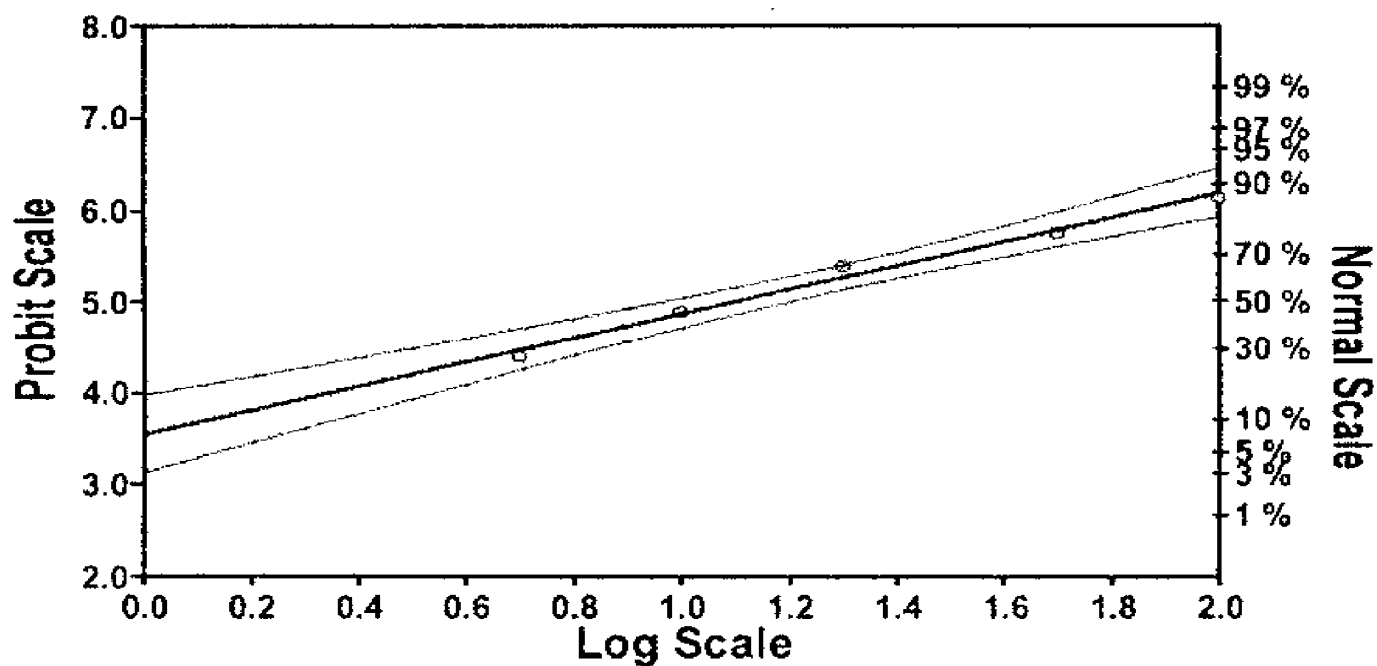
**Table 15: Dose-mortality response of larvae of *P. ulmi*, 24 hours after leaf-dip treatment with clofentezine (Apollo 50 SC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
100	2.000	75	88.66	87.11	6.132	6.131
50	1.699	75	80.00	77.23	5.748	5.747
20	1.301	75	69.33	65.14	5.389	5.386
10	1.000	75	52.00	44.45	4.886	4.885
5	0.699	75	36.00	27.27	4.396	4.397
0	0.000	75	12.00	-	-	-

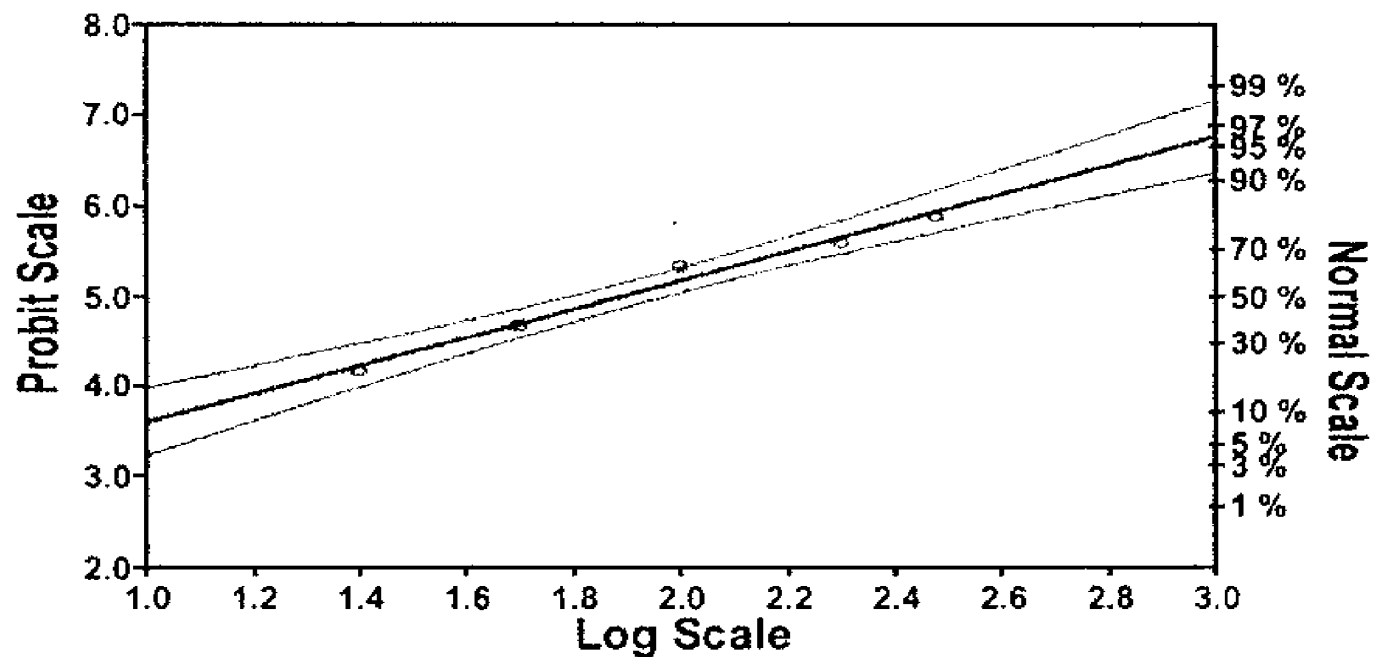
Regression equation  $Y = 3.5525 + 1.3161X$   
Heterogeneity  $\chi^2_{cal} = 1.009$   
 $\chi^2_{tab} = 7.815$  (p = 0.05, 3 df)  
 $LC_{50} = 12.569$  ppm  
Fiducial limits = 9.705 and 16.277 ppm  
 $LC_{90} = 118.250$  ppm  
Fiducial limits = 72.059 and 194.049 ppm  
Slope (b) = 1.3167

#### 4.3.1.4 Protonymphs

The protonymphs of *P. ulmi* (Plate 5b) treated with concentration ranging between 25 to 300 ppm of clofentezine by leaf-dip method gave mortality varying between 19.56 to 81.15 per cent (Table 16). The data were subjected to statistical analysis to obtain regression equation which had a slope of 1.5806 (Fig 4). The homogeneity of test population was revealed by the  $\chi^2$  value of 1.448, being lower than the tabulated value of 7.815 at p=0.05 and 3 df. The  $LC_{50}$  value calculated from the concentration mortality relationship was 77.048 ppm with fiducial limits of 62.945 and 94.312 ppm. The  $LC_{90}$  value was 498.551 ppm with fiducial limits of 322.398 and 770.951 ppm.



**Fig. 3:** Dose-mortality response of larvae of *P. ulmi* to clofentezine



**Fig. 4:** Dose-mortality response of protonymphs of *P. ulmi* to clofentezine

**Table 16: Dose-mortality response of protonymphs of *P. ulmi*, 24 hours after leaf-dip treatment with clofentezine (Apollo 50 SC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
300	2.477	75	82.66	81.15	5.884	5.883
200	2.301	75	74.66	72.45	5.596	5.595
100	2.000	75	66.00	63.04	5.333	5.330
50	1.699	75	42.66	37.67	4.687	4.686
25	1.398	75	26.00	19.56	4.169	4.169
0	0.000	75	8.00	-	-	-

Regression equation  $Y = 2.0176 + 1.5806 X$   
Heterogeneity  $\chi^2_{cal} = 1.448$   
 $\chi^2_{tab} = 7.815$  ( $p = 0.05$ , 3 df)  
 $LC_{50} = 77.048$  ppm  
Fiducial limits = 62.945 and 94.312 ppm  
 $LC_{90} = 498.551$  ppm  
Fiducial limits = 322.398 and 770.951 ppm  
Slope (b) = 1.5806

#### 4.3.1.5 Deutonymphs

Clofentezine when applied at different concentration (25 to 400 ppm) proved ineffective against deutonymphs of *P. ulmi* (Plate 5b). Hence, dose-mortality relationship could not be established as sufficient mortality could not be recorded at different concentrations.

#### 4.3.1.6 Adults

The adults of *P. ulmi* treated with doses of clofentezine ranging between 25-400 ppm were not affected by any of the test concentration used in the present study. Thus, dose-mortality response could not be obtained for clofentezine against adults of *P. ulmi*.

### 4.3.2 Toxicity of hexythiazox (Maiden 5 EC)

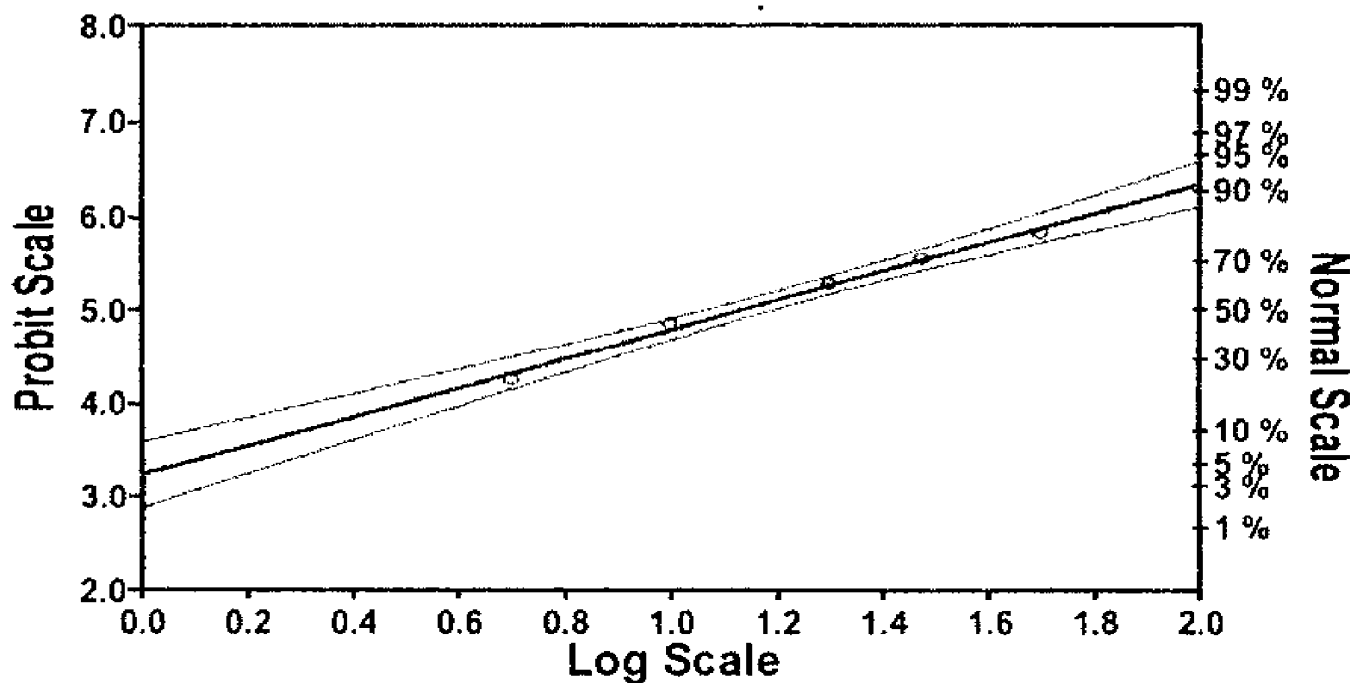
#### 4.3.2.1 Winter eggs

The apple twigs bearing the winter eggs of *P. ulmi* when treated with hexythiazox at concentration range of 5 to 50 ppm gave mortality response ranging from 23.01 to 79.63 per cent (Table 17). On subjecting the mortality data to probit analysis, the LC<sub>50</sub> value of 13.582 ppm with fiducial limits of 11.741 and 15.711 ppm and the LC<sub>90</sub> value of 90.731 ppm with fiducial limits of 64.907 and 126.831 ppm were obtained. The homogeneity of test was observed as the calculated  $\chi^2$  value of 0.924 was lower than the tabulated  $\chi^2$  value of 7.815 at 5 per cent level of significance and 3 df. The regression line had a slope of 1.5541 (Fig.5).

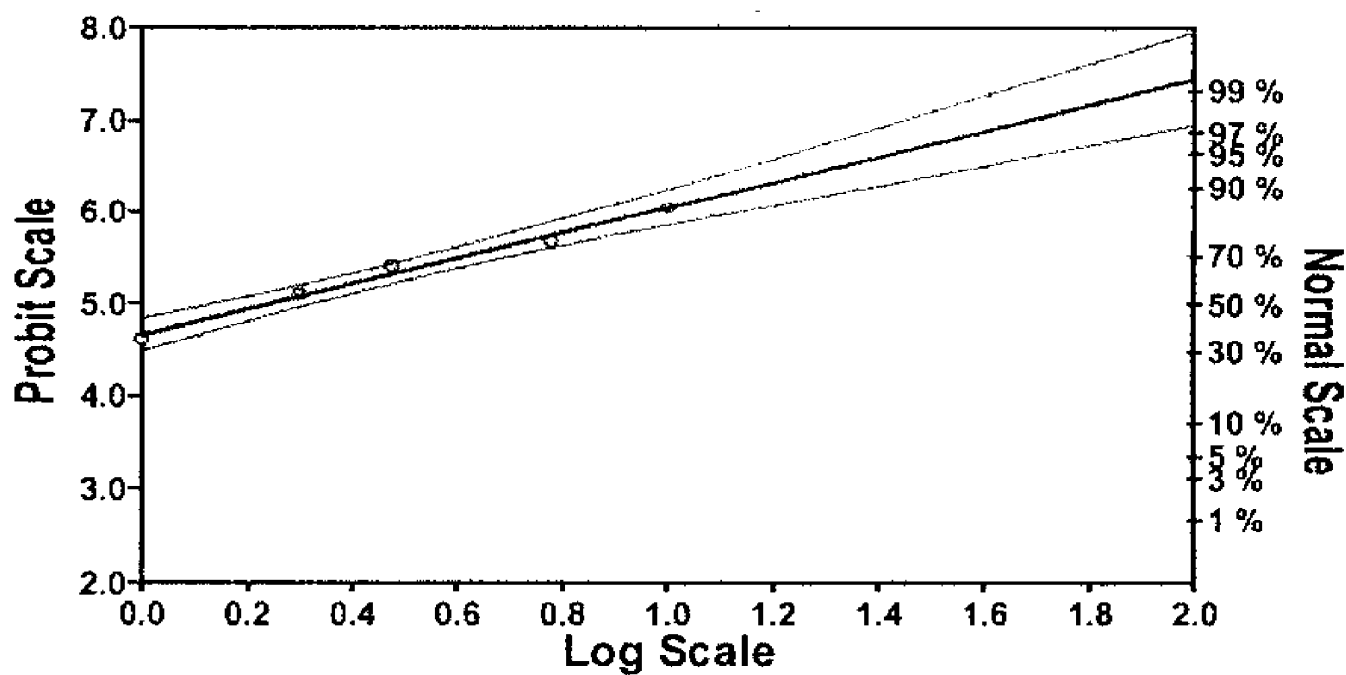
**Table 17: Dose-mortality response of winter eggs of *P. ulmi*, 30 days after dip treatment with hexythiazox (Maiden 5 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
50	1.699	150	84.66	79.63	5.829	5.828
30	1.477	150	78.00	70.79	5.547	5.547
20	1.301	150	70.66	61.05	5.281	5.280
10	1.000	150	58.00	44.25	4.856	4.855
5	0.699	150	42.00	23.01	4.262	4.262
0	0.000	150	24.66	-	-	-

Regression equation	Y	=	3.2392 + 1.5541 X
Heterogeneity	$\chi^2_{cal}$	=	0.924
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	13.582 ppm
Fiducial limits		=	11.741 and 15.711 ppm
LC <sub>90</sub>		=	90.731 ppm
Fiducial limits		=	64.907 and 126.831 ppm
Slope (b)		=	1.5541



**Fig. 5:** Dose-mortality response of winter eggs of *P. ulmi* to hexythiazox



**Fig. 6:** Dose-mortality response of summer eggs of *P. ulmi* to hexythiazox

### 4.3.2.2 Summer eggs

The mortality response of summer eggs of *P. ulmi* was studied against different doses of hexythiazox ranging from 1 to 10 ppm following leaf - dip method. The treatments resulted in mortality range from 34.66 to 85.95 per cent (Table 18). The data were subjected to probit analysis and the regression equation obtained had a slope of 1.3959 (Fig. 6). The  $\chi^2$  test showed that the population was homogenous as the calculated value of  $\chi^2$  was 1.037, lower than the tabulated value of 7.815 ( $p=0.05$ , 3 df.). The  $LC_{50}$  value obtained from the probit analysis was 1.750 ppm with fiducial limits of 1.416 and 2.163 ppm and the  $LC_{90}$  value obtained was 14.501 ppm with fiducial limits of 9.697 and 21.684 ppm.

**Table 18: Dose-mortality response of summer eggs of *P. ulmi*, 10 days after leaf-dip treatment with hexythiazox (Maiden 5 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
10	1.000	120	86.66	85.95	6.050	6.050
6	0.778	120	77.50	75.23	5.862	5.680
3	0.477	120	69.16	66.55	5.414	5.412
2	0.301	120	58.33	54.13	5.103	5.103
1	0.000	120	40.83	34.66	4.611	4.611
0	0.000	120	9.16	-	-	-

Regression equation	Y	=	4.4606 + 1.3959 X
Heterogeneity	$\chi^2_{cal}$	=	1.037
	$\chi^2_{tab}$	=	7.815 ( $p = 0.05$ , 3 df)
$LC_{50}$		=	1.750 ppm
Fiducial limits		=	1.416 and 2.163 ppm
$LC_{90}$		=	14.501 ppm
Fiducial limits		=	9.697 and 21.684 ppm
Slope (b)		=	1.3959

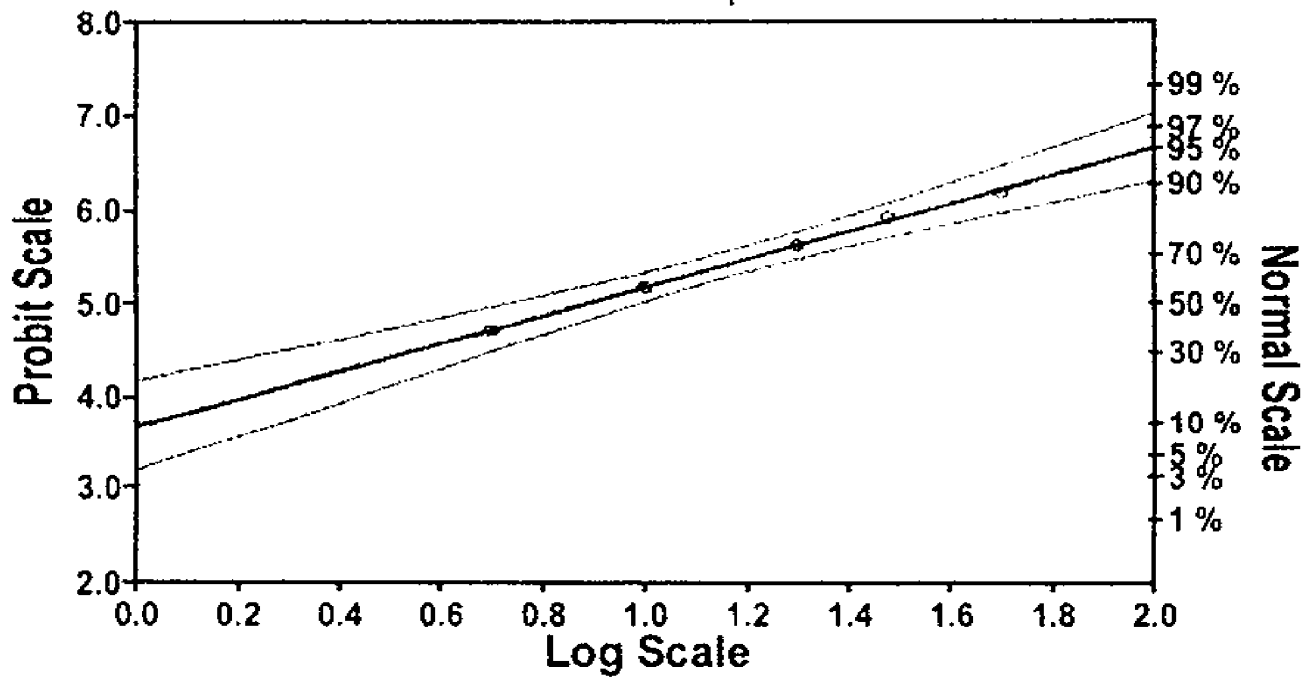
### 4.3.2.3 Larvae

The dose mortality response of hexythiazox against larvae of *P. ulmi* studied after 24 hours of treatment is given in the Table 19 and regression line for the same data is presented in Fig.7. The data given in the Table 19 revealed that when hexythiazox was used in the range of 5 to 50 ppm, the mortality of larvae ranged from 38.80 to 88.05 per cent. The calculated  $\chi^2$  value was 0.083 which was lower than the tabulated value of 7.815 at 5 per cent level of significance and 3 df showing that the data were homogenous. The data were then subjected to probit analysis which gave LC<sub>50</sub> value of 7.694 ppm with fiducial limits of 5.811 and 10.187 ppm and LC<sub>90</sub> value of 55.658 ppm with fiducial limits of 36.730 and 84.342 ppm. The regression line gave best fit and slope of the regression line was calculated to be 1.4916.

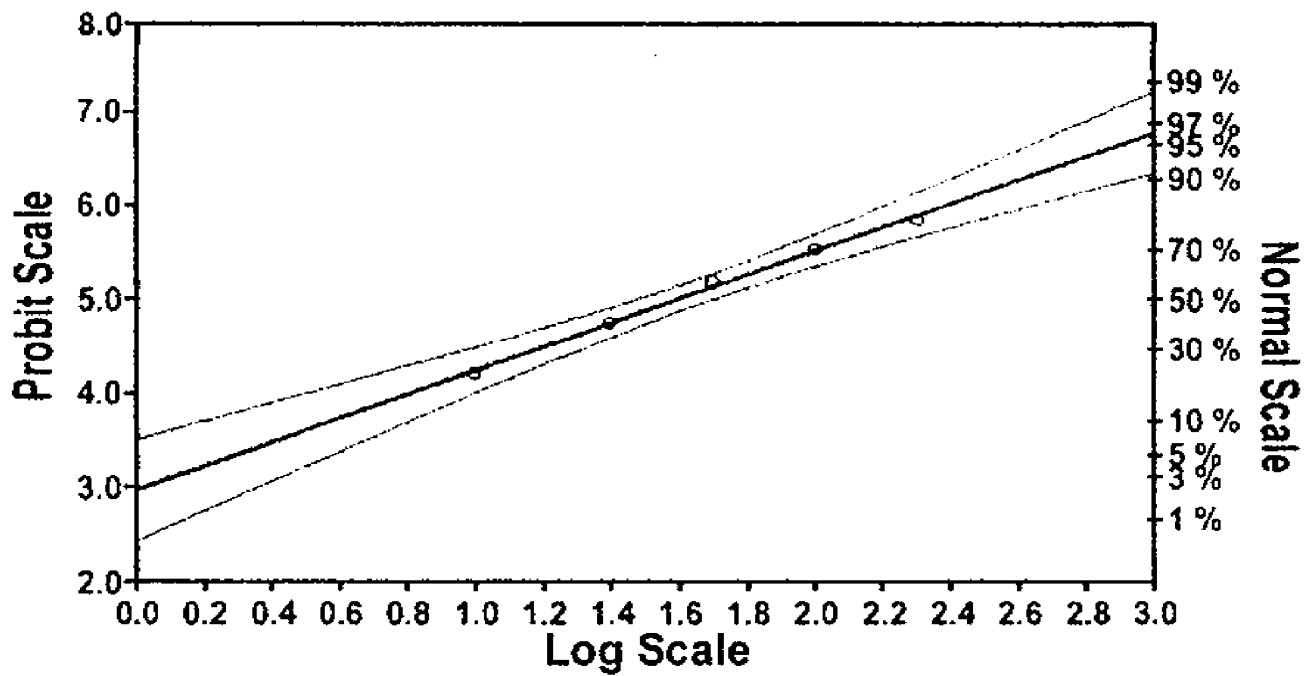
**Table 19: Dose-mortality response of larvae of *P. ulmi*, 24 hours after leaf-dip treatment with hexythiazox (Maiden 5 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
50	1.699	75	89.33	88.05	6.178	6.177
30	1.477	75	84.00	82.09	5.919	5.918
20	1.301	75	76.00	73.13	5.617	5.616
10	1.00	75	61.33	56.71	5.169	5.169
5	0.699	75	45.33	38.80	4.716	4.715
0	0.000	75	10.66	-	-	-

Regression equation	Y	=	3.6782 + 1.4916 X
Heterogeneity	$\chi^2_{cal}$	=	0.083
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	7.694 ppm
Fiducial limits		=	5.811 and 10.187 ppm
LC <sub>90</sub>		=	55.658 ppm
Fiducial limits		=	36.730 and 84.342 ppm
Slope (b)		=	1.4916



**Fig. 7: Dose-mortality response of larvae of *P. ulmi* to hexythiazox**



**Fig. 8: Dose-mortality response of protonymphs of *P. ulmi* to hexythiazox**

#### 4.3.2.4 Protonymphs

The mortality response data of the protonymphs of *P. ulmi* to hexythiazox was studied at concentrations ranging from 10 to 200 ppm. Mortality ranging from 21.42 to 79.99 per cent (Table 20) was recorded after 24 hours of the treatment. The data when subjected to probit analysis gave the regression equation with slope value of 1.2676 (Fig.8). The homogeneity of test population was revealed by the calculated value of  $\chi^2$  (0.270), which was lower than the tabulated value of 7.815 at 5 per cent level of significance and 3 df. The LC<sub>50</sub> value was calculated to be 39.617 ppm with fiducial limits of 30.921 and 50.759 ppm, while LC<sub>90</sub> value was 406.510 ppm with fiducial limits of 226.557 and 729.397 ppm.

**Table 20: Dose-mortality response of protonymphs of *P. ulmi*, 24 hours after leaf-dip treatment with hexythiazox (Maiden 5 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
200	2.301	75	81.33	79.99	5.842	5.840
100	2.000	75	72.00	70.00	5.524	5.524
50	1.699	75	60.00	57.14	5.180	5.179
25	1.398	75	44.00	40.00	4.747	4.746
10	1.000	75	26.66	21.42	4.208	4.208
0	0.000	75	6.66	-	-	-

Regression equation	Y	=	2.9744 + 1.2676 X
Heterogeneity	$\chi^2_{cal}$	=	0.270
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	39.617 ppm
Fiducial limits		=	30.921 and 50.759 ppm
LC <sub>90</sub>		=	406.510 ppm
Fiducial limits		=	226.557 and 729.397 ppm
Slope (b)		=	1.2676

#### **4.3.2.5 Deutonymphs**

Sufficient mortality was not recorded when *P. ulmi* deutonymphs were treated with 10 to 200 ppm of hexythiazox, therefore dose-mortality response could not be established for deutonymphs, using leaf-dip method.

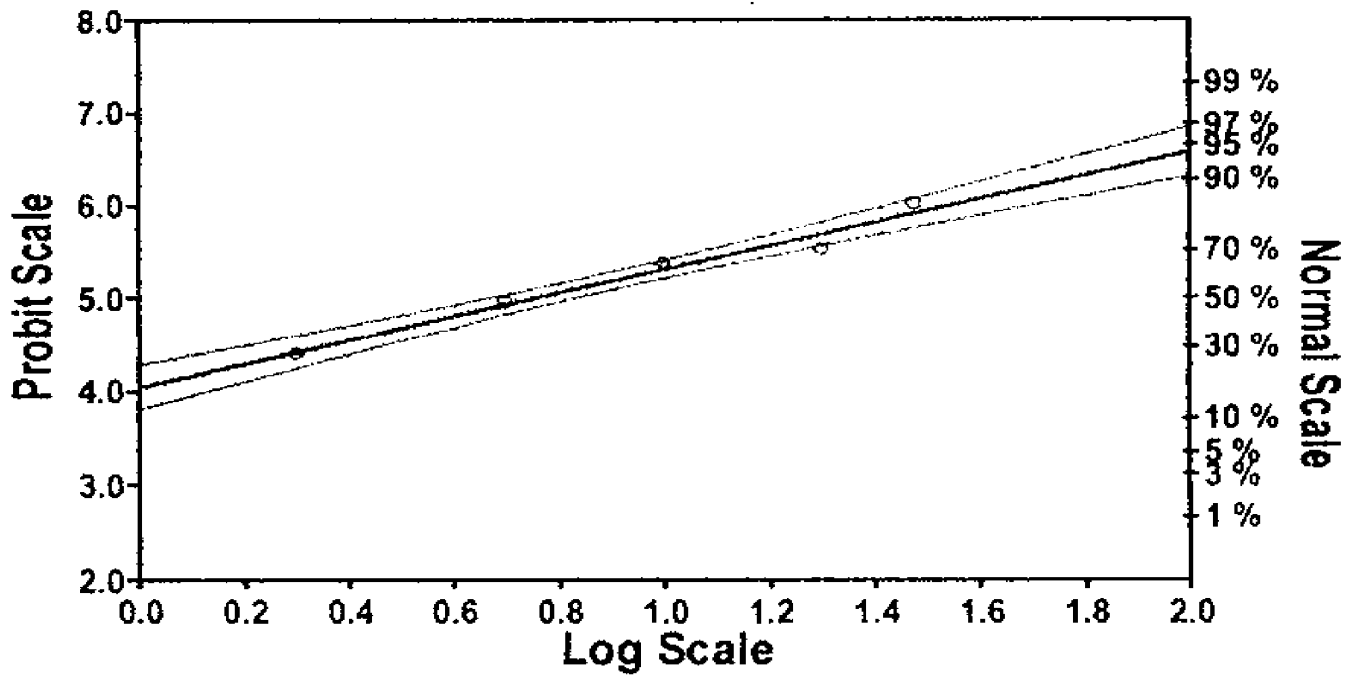
#### **4.3.2.6 Adults**

Hexythiazox was not found to be effective as an adulticide. At 200 ppm concentration very less (5%) adult mortality was recorded. Therefore, dose mortality relationship for adults could not be established.

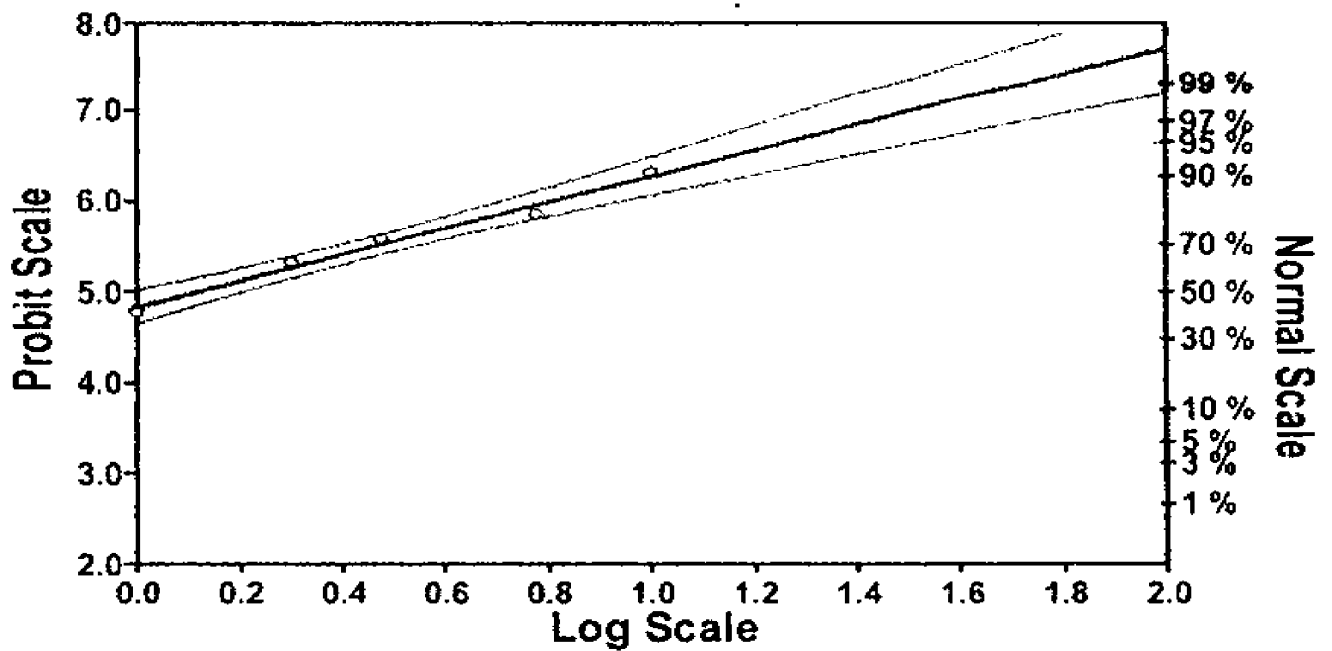
### **4.3.3 Toxicity of milbemectin (Milbeknock 1 EC)**

#### **4.3.3.1 Winter eggs**

The mortality response of winter eggs of *P. ulmi* was studied against different doses of milbemectin ranging from 2 to 30 ppm following leaf-dip method. The treatments resulted in mortality range from 27.27 to 82.29 per cent (Table 21). The data were subjected to probit analysis and the regression equation obtained had a slope of 1.2656 (Fig. 9). The  $\chi^2$  test showed that the population was homogenous as the calculated value of  $\chi^2$  was 3.654, lower than the tabulated value of 7.815 ( $p=0.05$ , 3 degree of freedom). The  $LC_{50}$  value obtained from the probit analysis was 5.726 ppm with fiducial limits of 4.743 and 6.911 ppm and the  $LC_{90}$  value obtained was 59.023 ppm with fiducial limits of 39.668 and 87.821 ppm.



**Fig. 9: Dose-mortality response of winter eggs of *P. ulmi* to milbemectin**



**Fig. 10: Dose-mortality response of summer eggs of *P. ulmi* to milbemectin**

**Table 21: Dose-mortality response of winter eggs of *P. ulmi*, 30 days after dip treatment with milbemectin (Milbeknock 1 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
30	1.477	150	88.66	82.29	6.017	6.012
20	1.301	150	78.00	68.14	5.524	5.514
10	1.000	150	74.00	64.54	5.373	5.372
5	0.699	150	62.00	48.18	4.954	4.954
2	0.301	150	46.66	27.27	4.396	4.395
0	0.000	150	26.66	-	-	-

Regression equation  $Y = 4.0412 + 1.2651 X$   
Heterogeneity  $\chi^2_{cal} = 3.654$   
 $\chi^2_{tab} = 7.815$  ( $p = 0.05$ , 3 df)  
 $LC_{50} = 5.726$  ppm  
Fiducial limits = 4.743 and 6.911 ppm  
 $LC_{90} = 59.023$  ppm  
Fiducial limits = 39.668 and 87.821 ppm  
Slope (b) = 1.2656

#### 4.3.3.2 Summer eggs

The summer eggs of European red mite when dipped in different concentrations of milbemectin ranging from 1 to 10 ppm gave mortality range between 41.13 to 90.55 per cent (Table 22). After accounting for control mortality, the data were subjected to statistical analysis to obtain regression which had a slope of 1.444 (Fig. 10). The homogeneity of the test population was revealed by the  $\chi^2$  value of 1.247, being lower than the tabulated value of 7.815 ( $p=0.05$ , 3 df). The data were then subjected to probit analysis which gave  $LC_{50}$  value of 1.314 ppm with fiducial limits of 1.029 and 1.678 ppm and  $LC_{90}$  value of 10.149 ppm with fiducial limits of 7.187 and 14.332 ppm.

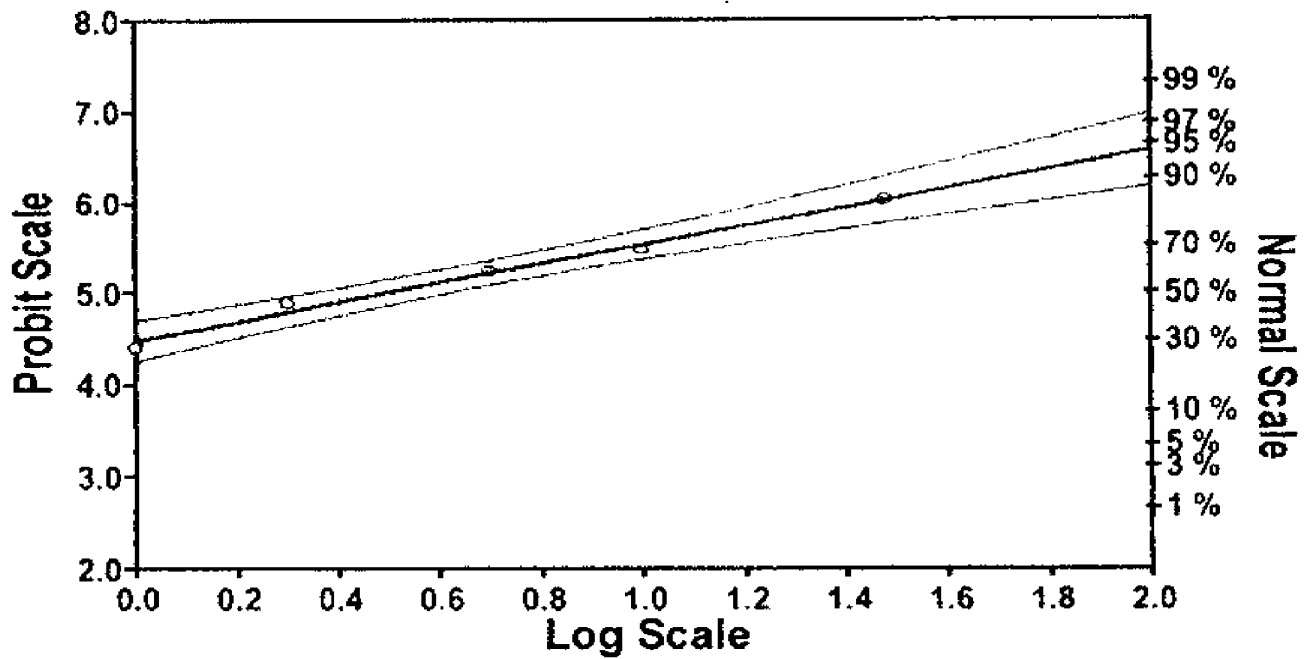
**Table 22: Dose-mortality response of summer eggs of *P. ulmi*, 10 days after leaf-dip treatment with milbemectin (Milbeknock 1 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
10	1.000	120	91.66	90.55	6.315	6.313
6	0.778	120	82.00	76.62	5.848	5.843
3	0.477	120	74.83	71.50	5.574	5.573
2	0.301	120	66.33	61.88	5.312	5.312
1	0.000	120	48.00	41.13	4.786	4.785
0	0.000	120	11.66	-	-	-

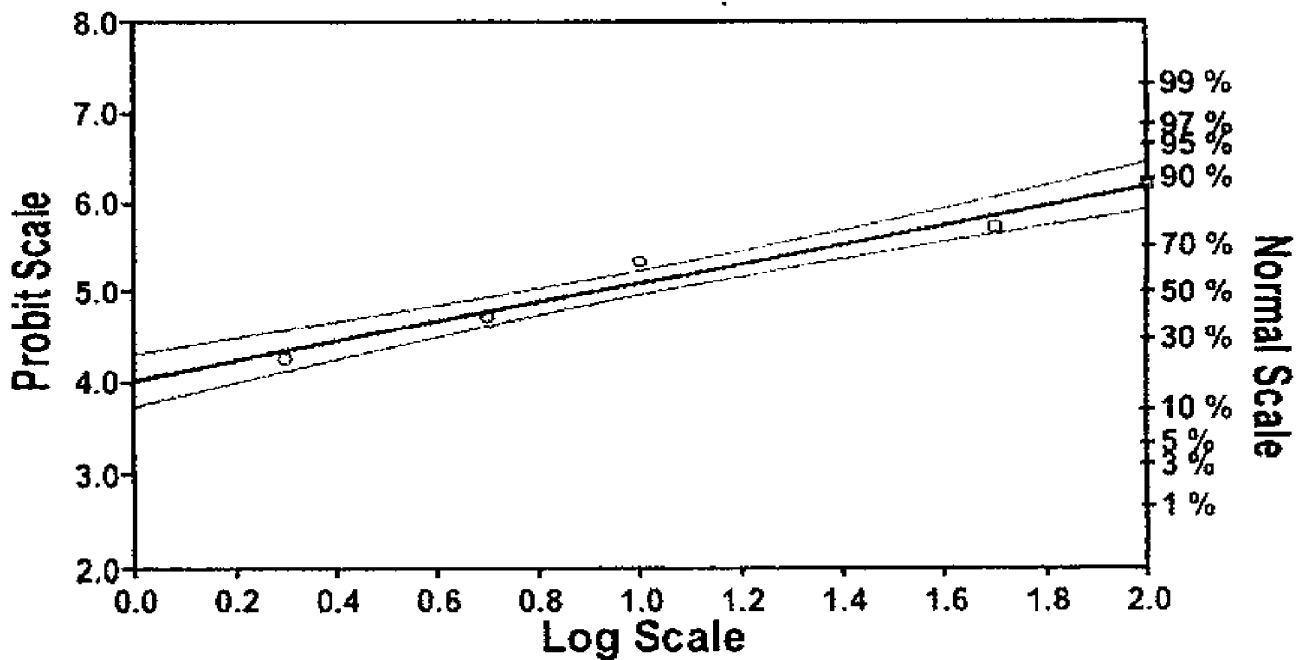
Regression equation	Y	=	4.8285 + 1.4440 X
Heterogeneity	$\chi^2_{cal}$	=	1.247
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	1.314 ppm
Fiducial limits		=	1.029 and 1.678 ppm
LC <sub>90</sub>		=	10.149 ppm
Fiducial limits		=	7.187 and 14.332 ppm
Slope (b)		=	1.4440

#### 4.3.3.3 Larvae

The larvae of *P. ulmi* when exposed to the leaves dipped in milbemectin gave mortality ranging between 27.27 to 86.36 per cent at concentrations ranging between 1 to 30 ppm (Table 23). The calculated  $\chi^2$  value (0.833) was lower than the tabulated value (7.815) at p=0.05 and 3 df, which revealed that the test population was homogenous. On subjecting the concentration mortality data to probit analysis, the LC<sub>50</sub> value was found to be 3.163 with fiducial limits of 2.324 and 4.304 ppm while LC<sub>90</sub> value was calculated to be 52.666 ppm with fiducial limits of 25.941 and 106.925 ppm. The slope of regression line obtained during the probit analysis was 1.0494 (Fig. 11).



**Fig. 11: Dose-mortality response of larvae of *P. ulmi* to milbemectin**



**Fig. 12: Dose-mortality response of nymphs of *P. ulmi* to milbemectin**

**Table 23: Dose-mortality response of larvae of *P. ulmi*, 24 hours after leaf-dip treatment with milbemectin (Milbeknock 1 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
30	1.477	75	87.00	86.36	6.030	6.029
10	1.000	75	72.00	68.18	5.472	5.472
5	0.699	75	64.00	59.09	5.230	5.229
2	0.301	75	52.00	45.45	4.886	4.886
1	0.000	75	36.00	27.27	4.396	4.396
0	0.000	75	12.00	-	-	-

Regression equation  $Y = 4.4751 + 1.0494 X$   
Heterogeneity  $\chi^2_{cal} = 0.833$   
 $\chi^2_{tab} = 7.815$  (p = 0.05, 3 df)  
 $LC_{50} = 3.163$  ppm  
Fiducial limits = 2.324 and 4.304 ppm  
 $LC_{90} = 52.666$  ppm  
Fiducial limits = 25.941 and 106.925 ppm  
Slope (b) = 1.0494

#### 4.3.3.4 Nymphs

The nymphs of *P. ulmi* were treated with different concentrations of milbemectin ranging between 2 to 100 ppm by leaf-dip method gave mortality ranged between 22.34 to 88.27 per cent (Table 24). The data were subjected to statistical analysis to obtain regression equation which had a slope of 1.0859 (Fig.12). The homogeneity of test population was revealed by the  $\chi^2$  value of 3.931, being lower than the tabulated value of 7.815 at p=0.05 and 3 df. The  $LC_{50}$  value calculated from the concentration mortality relationship was 8.085 ppm with fiducial limits of 5.970 and 10.950 ppm. The  $LC_{90}$  value was 122.485 ppm with fiducial limits of 67.759 and 221.410 ppm.

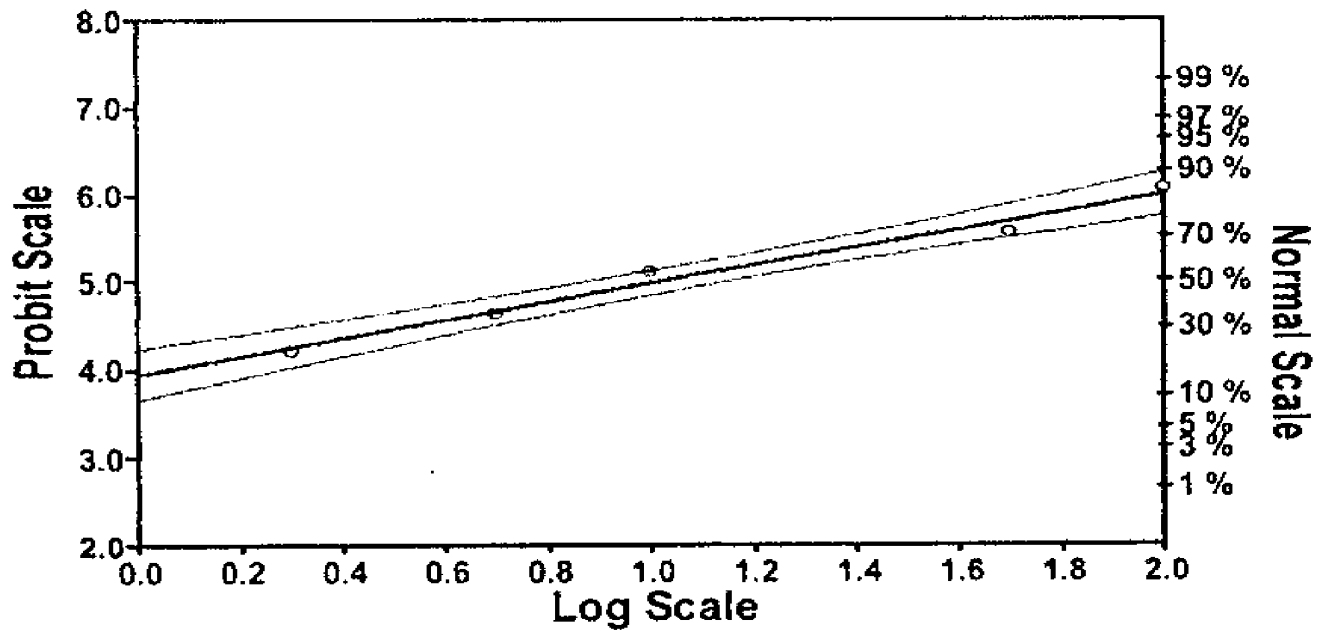
**Table 24: Dose-mortality response of nymphs of *P. ulmi*, 24 hours after leaf-dip treatment with milbemectin (Milbeknock 1 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
100	2.000	75	89.33	88.27	6.191	6.191
50	1.699	75	78.66	76.54	5.727	5.720
10	1.000	75	66.66	63.36	5.345	5.339
5	0.699	75	44.00	38.46	4.713	4.712
2	0.301	75	29.33	22.34	4.249	4.251
0	0.000	75	9.00	-	-	-

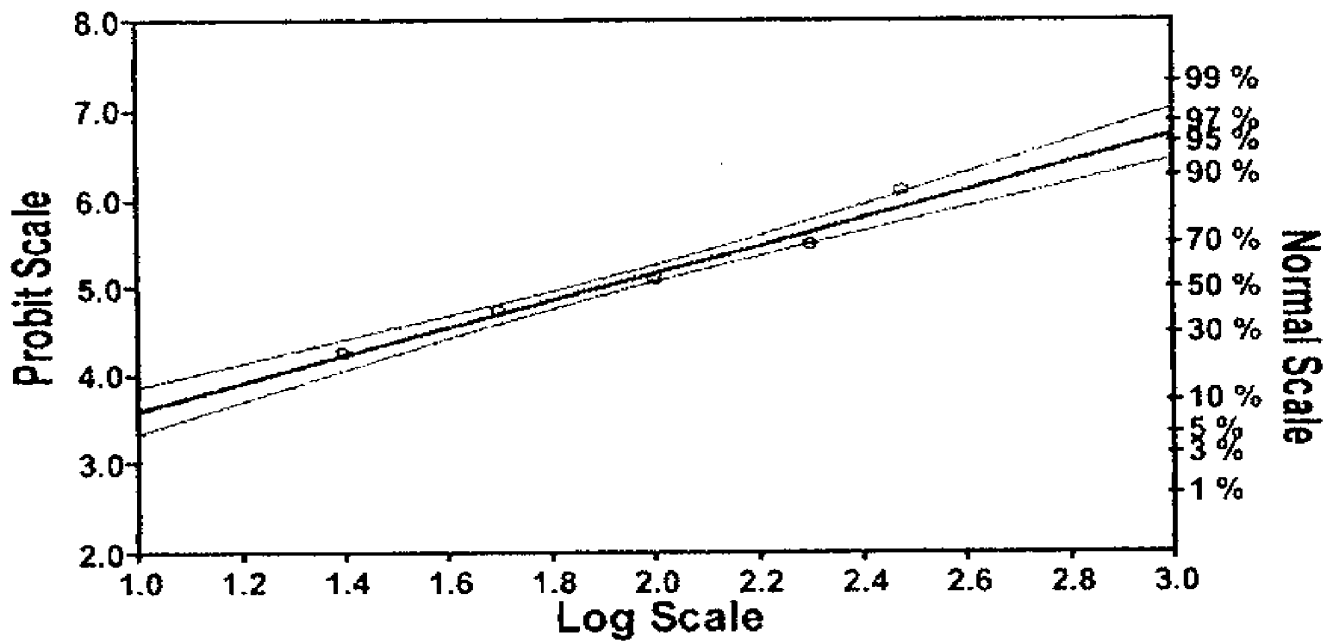
Regression equation	Y	=	4.0142 + 1.0859 X
Heterogeneity	$\chi^2_{cal}$	=	3.931
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	8.085 ppm
Fiducial limits		=	5.970 and 10.950 ppm
LC <sub>90</sub>		=	122.485 ppm
Fiducial limits		=	67.759 and 221.410 ppm
Slope (b)		=	1.0859

#### 4.3.3.5 Adults

The adults of *P. ulmi* (Plate 6a & 6b) when treated with different doses of milbemectin ranging between 2 to 100 ppm by leaf-dip method recorded mortality ranging between 21.42 to 86.77 per cent (Table 25). The mortality response data were subjected to probit analysis and the regression equation obtained had a slope of 1.0290 (Fig.13). The test population was homogenous which was revealed from the  $\chi^2$  test as the calculated value of  $\chi^2$  was 1.809, lower than the tabulated value of 7.815 (p=0.05, 3 df.). Probit analysis of the data gave LC<sub>50</sub> value of 10.604 ppm with fiducial limits of 7.788 and 14.438 ppm and LC<sub>90</sub> value of 186.723 ppm with fiducial limits of 95.044 and 366.835 ppm.



**Fig. 13: Dose-mortality response of adults of *P. ulmi* to milbemectin**



**Fig. 14: Dose-mortality response of winter eggs of *P. ulmi* to fenpropathrin**

**Table 25: Dose-mortality response of adults of *P. ulmi*, 24 hours after leaf-dip treatment with milbemectin (Milbeknock 1 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
100	2.000	75	87.66	86.77	6.068	6.065
50	1.699	75	73.33	71.42	5.566	5.560
10	1.000	75	57.33	54.28	5.107	5.160
5	0.699	75	40.00	35.71	4.634	4.634
2	0.301	75	26.66	21.42	4.208	4.209
0	0.000	75	6.66	-	-	-

Regression equation  $Y = 3.9447 + 1.0290 X$   
Heterogeneity  $\chi^2_{cal} = 1.809$   
 $\chi^2_{tab} = 7.815$  ( $p = 0.05$ , 3 df)  
 $LC_{50} = 10.604$  ppm  
Fiducial limits = 7.788 and 14.438 ppm  
 $LC_{90} = 186.723$  ppm  
Fiducial limits = 95.044 and 366.835 ppm  
Slope (b) = 1.0290

#### 4.3.4 Toxicity of fenpropathrin (Meothrin 30 EC)

##### 4.3.4.1 Winter eggs

The winter eggs of European red mite when dipped in different concentrations of fenpropathrin ranging from 25 to 300 ppm gave mortality range between 25.55 to 87.01 per cent (Table 26). After accounting for control mortality, the data were subjected to statistical analysis to obtain regression which had a slope of 1.5695 (Fig.14). The homogeneity of the test population was revealed by the  $\chi^2$  value of 4.317, being lower than the tabulated value of 7.815 ( $p=0.05$ , 3 df). The data were then subjected to probit analysis which gave  $LC_{50}$  value of 78.237 ppm with fiducil limits of 67.762 and 90.332 ppm and  $LC_{90}$  value of 513.026 ppm with fiducial limits of 374.098 and 703.548 ppm.

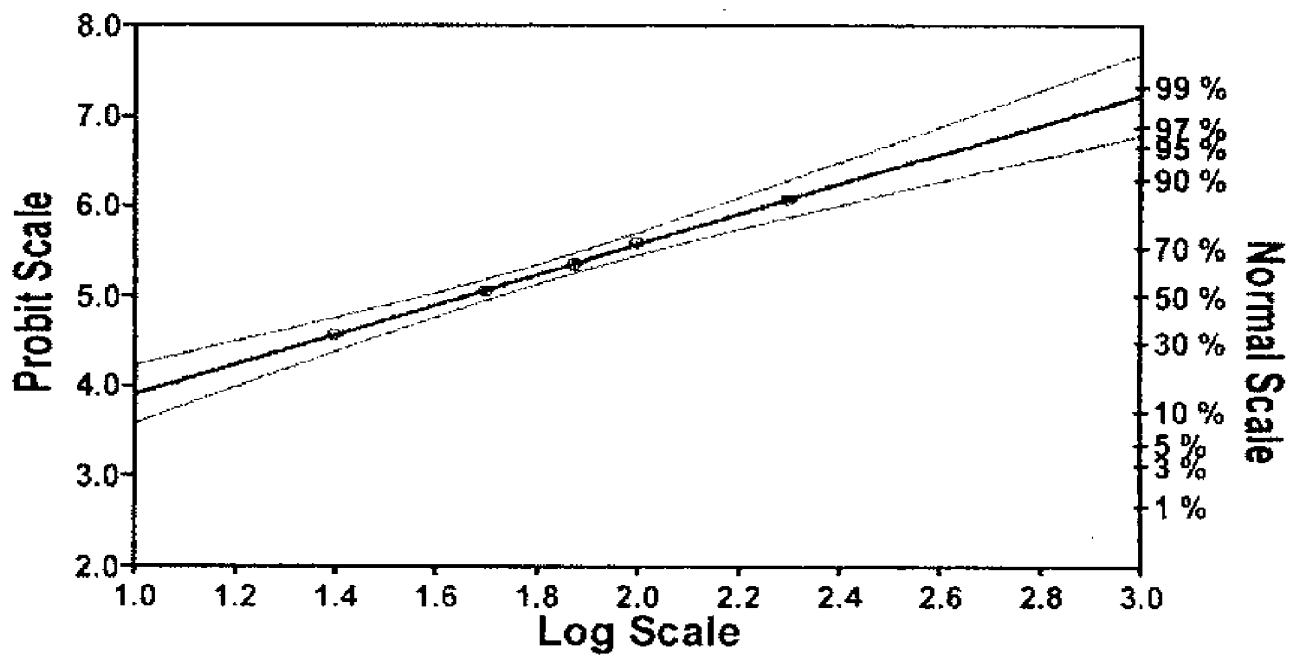
**Table 26: Dose-mortality response of winter eggs of *P. ulmi*, 30 days after dip treatment with fenpropathrin (Meothrin 30 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
300	2.477	150	90.00	87.01	6.103	6.090
200	2.301	150	77.33	70.56	5.506	5.498
100	2.000	150	66.00	55.84	5.102	5.101
50	1.699	150	55.33	41.98	4.738	4.737
25	1.398	150	42.66	25.55	4.245	4.246
0	0.000	150	23.00	-	-	-

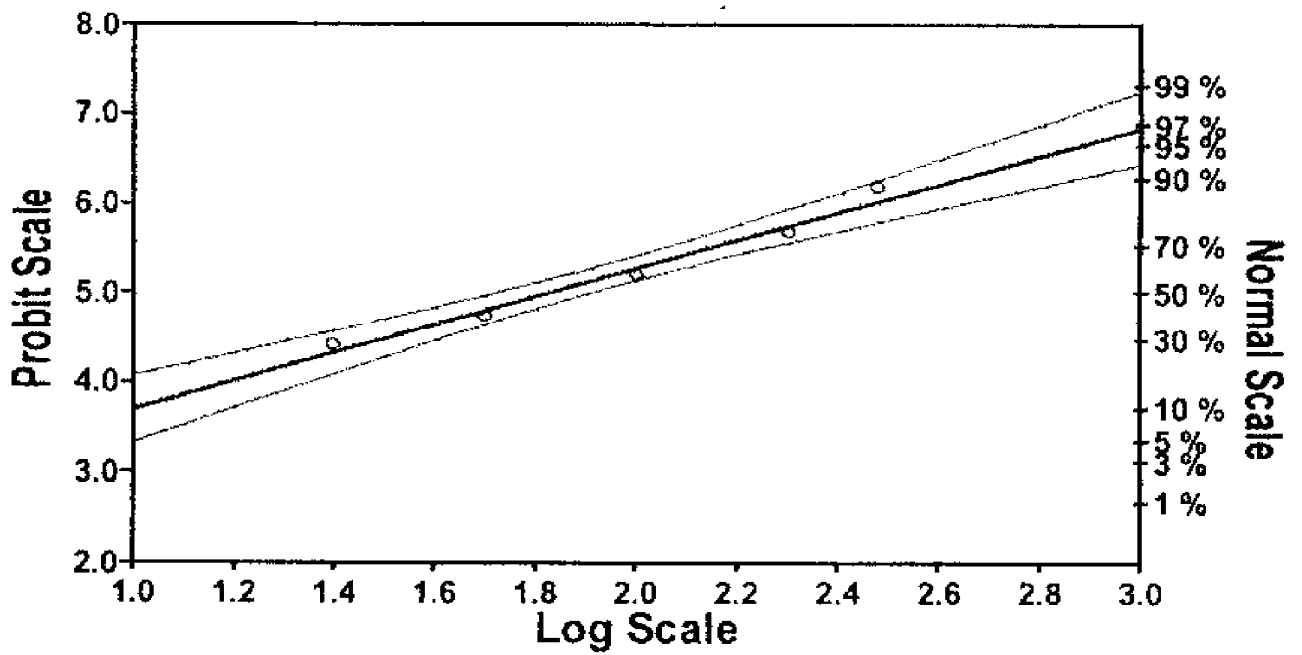
Regression equation  $Y = 2.0283 + 1.5695 X$   
Heterogeneity  $\chi^2_{cal} = 4.317$   
 $\chi^2_{tab} = 7.815$  (p = 0.05, 3 df)  
 $LC_{50} = 78.237$  ppm  
Fiducial limits = 67.762 and 90.332 ppm  
 $LC_{90} = 513.026$  ppm  
Fiducial limits = 374.098 and 703.548 ppm  
Slope (b) = 1.5695

#### 4.3.4.2 Summer eggs

The dose- mortality response of summer eggs of *P. ulmi* studied by leaf-dip method at concentration ranging between 25 to 200 ppm of fenpropathrin gave mortality ranging between 32.96 to 85.50 per cent (Table 27). On subjecting the mortality data to probit analysis, the  $LC_{50}$  value of 45.575 ppm with fiducial limits of 38.459 and 54.008 ppm and the  $LC_{90}$  value of 268.260 ppm with fiducial limits of 190.048 and 378.659 ppm were obtained. The homogeneity of test was observed as the calculated  $\chi^2$  value (0.031) was lower than the tabulated  $\chi^2$  value of 7.815 (p=0.05, 3 df.). The regression line had a slope of 1.6651 (Fig.15).



**Fig. 15:** Dose-mortality response of summer eggs of *P. ulmi* to fenpropathrin



**Fig. 16:** Dose-mortality response of larvae of *P. ulmi* to fenpropathrin

**Table 27: Dose-mortality response of summer eggs of *P. ulmi*, 10 days after leaf-dip treatment with fenpropathrin (Meothrin 30 EC)**

Dose (ppm)	Log dose (X)	Number of eggs treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
200	2.301	120	86.66	85.50	6.062	6.061
100	2.000	120	74.16	71.91	5.585	5.584
75	1.871	120	66.66	63.76	5.357	5.357
50	1.699	120	55.83	51.98	5.056	5.056
25	1.398	120	38.33	32.96	4.570	4.569
0	0.000	120	8.00	-	-	-

Regression equation  $Y = 2.2380 + 1.6651 X$   
Heterogeneity  $\chi^2_{cal} = 0.031$   
 $\chi^2_{tab} = 7.815$  ( $p = 0.05, 3 \text{ df}$ )  
 $LC_{50} = 45.575 \text{ ppm}$   
Fiducial limits = 38.459 and 54.008 ppm  
 $LC_{90} = 268.260 \text{ ppm}$   
Fiducial limits = 190.048 and 378.659 ppm  
Slope (b) = 1.6651

#### 4.3.4.3 Larvae

The exposure of larvae of *P. ulmi* to the leaves following treatment with fenpropathrin by leaf-dip method at concentration ranging from 50 to 600 ppm resulted in mortality ranging between 27.93 to 88.23 per cent (Table 28). On subjected the data to probit analysis, regression equation was calculated which had a slope of 1.5741 (Fig.16). The  $\chi^2$  test showed that the test population was homogenous since the calculated value of  $\chi^2$  was 1.700, lower than the tabulated value of 7.815 at 5 per cent level of significance and 3 df. The  $LC_{50}$  obtained from the regression equation was 67.246 ppm with fiducial limits of 54.513 and 82.954 ppm and the  $LC_{90}$  value was 438.499 ppm with fiducial limits of 287.047 and 669.860 ppm.

**Table 28: Dose-mortality response of larvae of *P. ulmi*, 24 hours after leaf-dip treatment with fenpropathrin (Meothrin 30 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
600	2.778	75	89.33	88.23	6.187	6.176
400	2.602	75	77.00	74.63	5.674	5.671
200	2.301	75	62.00	58.08	5.204	5.203
100	2.000	75	45.33	39.70	4.739	4.739
50	1.699	75	34.66	27.93	4.416	4.418
0	0.000	75	9.33	-	-	-

Regression equation	Y	=	2.1229 + 1.5741 X
Heterogeneity	$\chi^2_{cal}$	=	1.700
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	67.246 ppm
Fiducial limits		=	54.513 and 82.954 ppm
LC <sub>90</sub>		=	438.499 ppm
Fiducial limits		=	287.047 and 669.860 ppm
Slope (b)		=	1.5741

#### 4.3.4.4 Nymphs

The nymphs of *P. ulmi* were treated with concentration ranging between 50 to 600 ppm of fenpropathrin by leaf-dip method and mortality ranged between 27.17 to 84.78 per cent (Table 29). The data were subjected to statistical analysis to obtain regression equation which had a slope of 1.4172 (Fig.17). The homogeneity of test population was revealed by the  $\chi^2$  value of 3.315, being lower than the tabulated value of 7.815 at p=0.05 and 3 df. The LC<sub>50</sub> value calculated from the concentration mortality relationship was 154.253 ppm with fiducial limits of 123.418 and 192.793 ppm. The LC<sub>90</sub> value was 1237.926 ppm with fiducial limits of 730.627 and 2097.459 ppm.

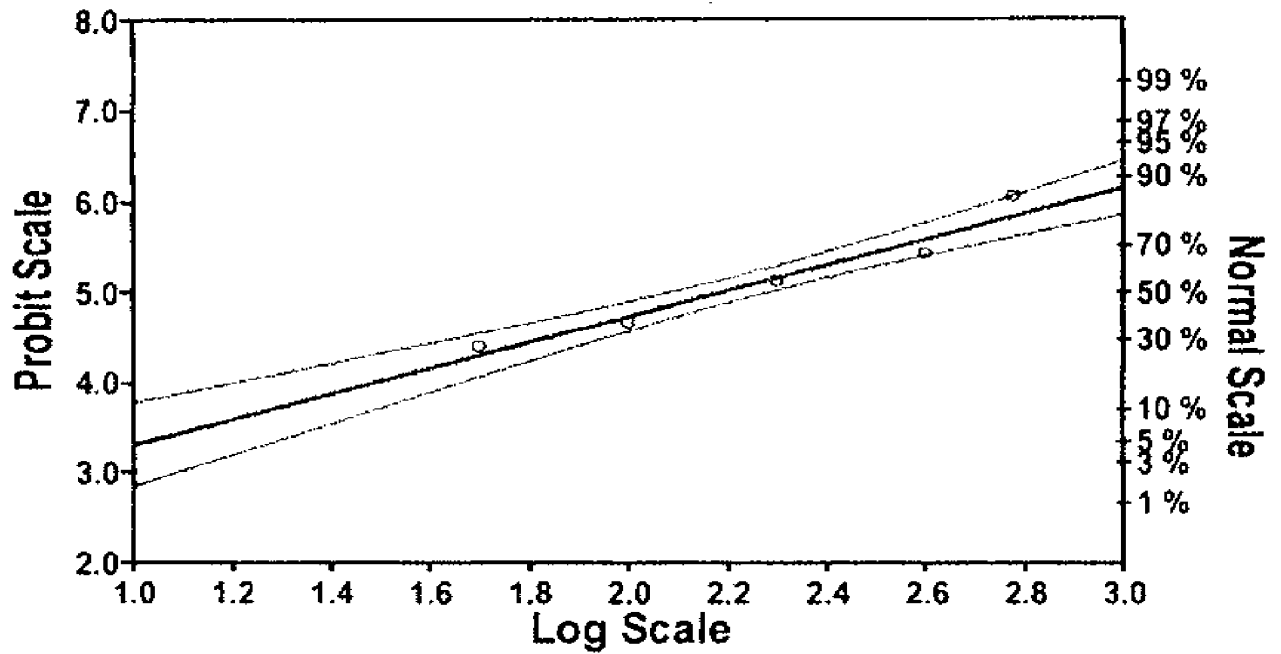


Fig. 17: Dose-mortality response of nymphs of *P. ulmi* to fenpropathrin

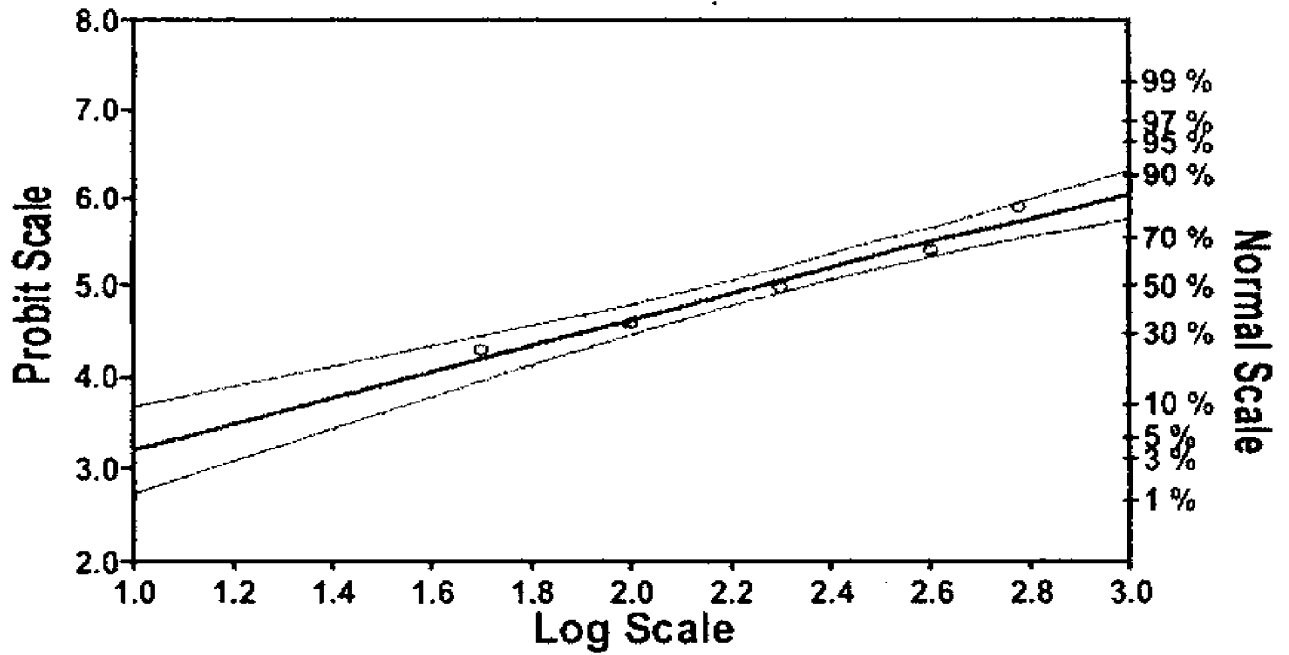


Fig. 18: Dose-mortality response of adults of *P. ulmi* to fenpropathrin

**Table 29: Dose-mortality response of nymphs of *P. ulmi*, 24 hours after leaf-dip treatment with fenpropathrin (Meothrin 30 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
600	2.778	75	86.00	84.78	6.059	6.041
400	2.602	75	69.33	66.66	5.430	5.421
200	2.301	75	58.66	55.06	5.127	5.127
100	2.000	75	42.00	36.95	4.667	4.667
50	1.699	75	33.00	27.17	4.404	4.406
0	0.000	75	8.00	-	-	-

Regression equation	Y	=	3.8987 + 1.4172 X
Heterogeneity	$\chi^2_{cal}$	=	3.315
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	154.253 ppm
Fiducial limits		=	123.418 and 192.793 ppm
LC <sub>90</sub>		=	1237.926 ppm
Fiducial limits		=	730.627 and 2097.459 ppm
Slope (b)		=	1.4172

#### 4.3.4.5 Adults

The mortality data of fenpropathrin are presented in Table 30 and regression line in Fig.18. From the data, it was observed that fenpropathrin when applied in the range of 50 to 600 ppm, gave mortality ranging from 24.55 to 81.05 per cent. The  $\chi^2$  test showed that the data were homogenous, since the calculated value of  $\chi^2$  (2.191) was lower than the tabulated value (7.815) at 5 per cent level of significance and 3 df. The data when subjected to probit analysis gave the LC<sub>50</sub> value of 183.311 ppm with fiducial limits of 147.481 and 227.845 ppm and LC<sub>90</sub> value of 1461.215 ppm with fiducial limits of 840.038 and 2541.728 ppm were obtained. The regression line had a slope of 1.4218.

**Table 30: Dose-mortality response of adults of *P. ulmi*, 24 hours after leaf-dip treatment with fenpropathrin (Meothrin 30 EC)**

Dose (ppm)	Log dose (X)	Number of mites treated (N)	Observed mortality (%)	Corrected mortality (%)	Empirical probit	Working probit (y)
600	2.778	75	82.00	81.05	5.904	5.894
400	2.602	75	66.33	64.55	5.379	5.376
200	2.301	75	52.33	49.82	4.982	4.982
100	2.000	75	37.00	33.68	4.583	4.582
50	1.699	75	28.33	24.55	4.292	4.295
0	0.000	75	5.00	-	-	-

Regression equation	Y	=	1.7820 + 1.4218 X
Heterogeneity	$\chi^2_{cal}$	=	2.191
	$\chi^2_{tab}$	=	7.815 (p = 0.05, 3 df)
LC <sub>50</sub>		=	183.311 ppm
Fiducial limits		=	147.481 and 227.845 ppm
LC <sub>90</sub>		=	1461.215 ppm
Fiducial limits		=	840.038 and 2541.728 ppm
Slope (b)		=	1.4218

The results obtained in the present study clearly showed that summer eggs were more susceptible than winter eggs to all the test acaricides. The intrinsic toxicity of different acaricides viz. milbemectin, hexythiazox, clofentezine and fenpropathrin against all the stages of *P. ulmi* revealed that milbemectin and fenpropathrin were effective against all stages of *P. ulmi*, whereas, both hexythiazox and clofentezine showed excellent activity against eggs, larvae and protonymphs but were ineffective against deutonymphs and adults. As an ovicide and larvicide, milbemectin was most toxic followed by hexythiazox, clofentezine and fenpropathrin. Nymphs and adults were highly susceptible to milbemectin followed by fenpropathrin.



Chapter-V .

## **DISCUSSION**



## Chapter-V

# DISCUSSION

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The salient findings of the present studies on the “**Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**” are discussed in the light of available relevant literature under the following heads:

### **5.1 Effect of European red mite feeding on yield and quality parameters of apple cv. Royal Delicious under field conditions**

The effect of different levels of mite feeding viz. 0, 250, 500, 750 and 1000 cumulative mite days (CMDs) of European red mite were determined on mean fruit weight, total soluble solids, fruit firmness, fruit colour, as well as return bloom, percentage of fruit set and fruit load in the following year.

#### **5.1.1 Effect of different feeding levels of European red mite on physico-chemical properties of fruits**

Studies on the effect of European red mite feeding at different levels on some physico-chemical characteristics of apple fruits cv. Red Delicious revealed that different levels of mite feeding (Table 3 and 4) exerted varying effects on mean fruit weight and total soluble solids of fruits, however, fruit firmness and anthocyanin content were not affected significantly during both the years of study.

In the present study, fruit weight decreased with increasing level of mite feeding. The maximum fruit weight was recorded in the control plants, which remained statistically at par with plants subjected to 250 cumulative mite days (CMDs) during both the years of study. These results are in partial agreement with those of Beers *et al.* (1990), who reported that fruit weight was not affected at mite feeding level of 250 and 500 CMDs. In the present study, significant reduction in fruit weight was observed at mite feeding level of 500 CMDs. These results are in conformity with those of Hull and

Greene (1983), who also observed significant reduction at mite feeding level of 500 CMDs. However, minimum fruit weight was recorded in plants stressed with 1000 CMDs and the reduction in fruit weight over control treatment was 14.38 and 17.54 per cent during the year 2005 and 2006, respectively. The present findings are in conformity with those of Beers *et al.* (1990), who reported that loss in fruit weight was 14.4 g per fruit or about 7.2 per cent per 1000 CMDs on 'Bisbee Delicious' apple infested with *P. ulmi*. Similarly, Beers and Hull (1990) reported reduced mean fruit weight at harvest with mite injury (1000 CMDs) occurring during mid season. Marini *et al.* (1994) in his studies on 'Delicious' apples also reported that fruit weight declined with increasing cumulative mite days.

The data on the effect of mite feeding on total soluble solids of fruit revealed that total soluble solids (TSS) declined with the increase in levels of mite feeding. The maximum total soluble solids were recorded in the fruits harvested from the control plants, closely followed by those infested with 250 CMDs during both the years, and both statistically at par with each other. However, significant reduction in total soluble solids was recorded at feeding level of 500 CMDs showing a reduction of 6.25 and 5.95 per cent during 2005 and 2006, respectively. These results are in partial conformity with the findings of Beers *et al.* (1990), who reported that total soluble solids were not affected at mite feeding level of 250 and 500 CMDs. In the present study, the minimum total soluble solids were recorded in fruits harvested from plants infested with 1000 CMDs and the reduction over control treatment was 13.28 and 15.47 per cent during 2005 and 2006, respectively. These results are in agreement with those of Ames *et al.* (1984) and Beers *et al.* (1990) who observed 12.9 and 3.8 per cent reduction in total soluble solids of 'Miller Sturdeespur' and 'Rome Beauty' apples, respectively, with the mite feeding level of 1000 CMDs. Similarly, Marini *et al.* (1994) reported that total soluble solids declined with increasing cumulative mite days at high, but not at low crop densities.

In the present studies the effect of mite feeding on reduction in mean fruit weight and total soluble solids of fruits may be attributed to the reduced photosynthetic activity of leaves leading to reduced production of carbohydrates.

The present study revealed that fruit firmness was not affected significantly by different levels of mite feeding. However, fruit firmness slightly increased with increasing levels of mite feeding. The results are in conformity with the findings of Hull and Beers (1990), who also reported that fruit firmness of 'Yorking' and 'Delicious' apples was not affected by different levels of mite injury (250, 750 and 1250 CMDs/leaf) during the current season and in the next season following mite injury. Similar conclusions were drawn by Chapman *et al.* (1952) who reported that mite injury did not affect fruit firmness of 'Cortland' and 'Red Delicious' apple at harvest or after storage. However, Beers *et al.* (1990) reported that fruit firmness was slightly increased (3.8 %) at mite injury level of 1000 CMDs on 'Bisbee Delicious' apples.

In the present study, fruit colour was not affected significantly by different levels of mite feeding. Ames *et al.* (1984) found that fruit load dominated colour consideration regardless of mite infestation level on 'Miller Sturdeespur' apple. Similar conclusion was drawn by Hull and Beers (1990), who reported that fruit colour was not consistently related to the amount of mite injury in 'Yorking' and 'Delicious' apples.

#### **5.1.2 Effect of different feeding levels of European red mite on yield attributes of apple**

The results obtained in the present investigation regarding the effect of different levels of mite feeding (250, 500, 750 and 1000 CMDs per leaf) revealed that return bloom, percentage fruit set and fruit load showed inverse relation with the increase in mite feeding (Table 5 and 6) during both the years of study.

In the present study, the maximum return bloom and fruit load was recorded in the control plants, which remained statistically at par with those stressed with 250 CMDs during both the years of study. These results are in partial agreement with those of Hull and Beers (1990), who reported that return bloom and fruit load was not affected at mite injury level of 250 and 500 CMDs on 'Yorking' and 'Delicious' apples. In the present study, significant reduction in return bloom and fruit load was observed at mite feeding level of 500 CMDs. However, the highest reduction in return bloom over control treatment was recorded in the plants stressed with 1000 CMDs (26.52 and 51.00 %

during the years 2006 and 2007, respectively), resulting in a fruit load that was 38.80 and 46.79 per cent lower than the control treatment during the respective years. The trend towards reduced flowering subsequent to mite damage has been reported by several workers in bearing plants, with magnitude of the reduction ranging between 40 to 80 per cent (Lienk *et al.*, 1956; Asquith, 1961; Lienk and Minns, 1980). The present findings are in conformity with the observations of Hull and Beers (1990), who reported that return bloom was significantly lower (59.00 %) in the 1250 CMD level than in the control, resulting in a fruit load that was 49.00 per cent lower than the control. Beers and Hull (1987) also reported significant reduction in the number of blossom clusters per plant on cultivar 'Golden Delicious' and 'Stayman' with European red mite infestation.

Studies on the effect of different feeding levels of European red mite (500, 750 and 1000 CMDs per leaf) revealed that mite feeding caused significant reduction in fruit set. In the present study, fruit set was not affected by mite feeding level of 250 CMDs during both the years of study. However, fruit set was affected significantly at mite feeding level of 500 CMDs and the reduction in fruit set over control treatment was 11.03 and 15.78 per cent, during 2006 and 2007, respectively. The highest reduction in fruit set over control was observed in the plants stressed with 1000 CMDs (38.81 and 46.80 % during the year 2006 and 2007, respectively). These results are in close proximity with the findings of Hull and Beers (1990) who reported that high mite injury (1250 CMDs) reduced percentage fruit set (37.50 %) relative to the control treatment on 'Yorking' and 'Delicious' apple plants. Reduced fruit set subsequent to mite damage has also been reported by Lienk *et al.* (1976) and Beers and Hull (1987). Similar conclusions were drawn by Chapman *et al.* (1952), who reported a substantial reduction in fruit set when high mite population occurred during early season (May-June).

The slight variation between the results obtained in the present study and other results concerning the effect of mite feeding on mean fruit weight, TSS, fruit firmness, fruit colour, return bloom, fruit set and fruit load may be attributed to orchard management practices including pruning and training, soil and pest management practices followed during the season and due to the interactions with other factors such as cultivars, rainfall and plant nutrition.

It is inferred from the present study that physico-chemical and yield parameters of apples were not affected significantly at mite feeding level of 250 CMDs, and a population upto 250 CMDs can be tolerated on the plants without any adverse effect on these parameters. However, a significant reduction in these parameters started at mite feeding level of 500 CMDs. Therefore, a tentative economic threshold level (ETL) of 250 CMDs can be established for *P. ulmi* on apple.

## **5.2 Evaluation of Horticultural mineral oils (HMOs) against European red mite, *P. ulmi* (Koch)**

### **5.2.1 Laboratory evaluation of HMOs**

#### **5.2.1.1 Overwintering eggs**

In present investigation, maximum hatching (69.02 %) of overwintering eggs of *P. ulmi* was recorded in the control after 30 days of treatment. Almost similar observations were made by Leski and Predki (1964) who observed that hatching of overwintering eggs extended over 18 days following hatching of the first egg. These findings are in conformity with the results obtained by Negi (2005) and Khujaria (2005), who reported maximum egg hatch of 71.00 and 82.80 per cent, respectively, in the control treatment after 30 days of treatment under laboratory conditions.

The effect of test horticultural mineral oil formulations observed 30 days after treatment indicated that MAK All Season HMO (1.5 %) was the most effective treatment with 0.39 per cent egg hatch, which was statistically at par with Orchol-13 at 1.5 per cent with 0.78 per cent egg hatch and remained superior to the remaining treatments recording egg hatch ranging from 2.28 to 8.97 per cent (Table 7). The above findings are in conformity with those of Lawson and Weires (1991), who documented 0.0 to 8.0 per cent hatch of overwintering *P. ulmi* eggs with 1 per cent petroleum oils and 67.00 per cent eggs hatch in control treatment under laboratory conditions. Bhardwaj (1998) also reported that 2 per cent IPOL orchard spray oil resulted in 85.00 per cent egg mortality of overwintering eggs of the European red mite under laboratory conditions. Similarly, Khajuria (2005) reported reduced hatching of winter eggs treated with Shelter 909®

summer oil and the mortality of eggs ranged from 51.4 to 88.8 per cent at concentration range of 0.5 to 2.0 per cent.

The studies established that HMO treatment at 1.5 per cent concentration is highly effective against winter eggs of *P. ulmi*. Thus, mite population can be managed successfully following HMO treatments on plants supporting ERM population in the previous season.

#### **5.2.1.2 Summer eggs**

The results obtained in the present studies regarding the susceptibility of summer eggs of European red mite against horticultural mineral oil formulations clearly showed that summer eggs were highly sensitive to all the treatments of test horticultural mineral oil formulations. Even at low concentration (0.25 %) of HMOs, least hatch of summer eggs ranging between 2.09 to 4.25 per cent (Table 8) was obtained in comparison to a high hatchability of 87.64 per cent in control treatment. The results of present study are in close conformity with those of Agnello *et al.* (1994), who observed 0.0, and 0.0 to 1.3 per cent hatch of 0–24 hour old summer eggs with 0.25 and 0.05 per cent Sunspray Ultra Fine Oil, respectively. In their experiment, egg hatch in control varied from 80.70 (0-24 hour old eggs) to 86.10 per cent (48–72 hour old eggs). Khujaria (2005) also reported 83.30 to 100.00 per cent mortality of eggs treated with summer oil (Shelter 909®) at concentration ranging from 0.1 to 1.00 per cent. A slight variation in egg hatch in different studies may be due to the eggs of mixed age groups taken for assay. Summer eggs were highly sensitive to all the treatments of test HMOs as compared to winter eggs.

#### **5.2.1.3 Efficacy of HMOs against motile stages of *P. ulmi***

The results on mortality of motile stages of *P. ulmi* following horticultural mineral oils application (Table 9) showed that larval stage was the most sensitive stage with 100.00 per cent mortality in all the HMO treatments even after 24 hours. Nymphs could not survive for more than 48 hours in any of the test HMO treatments at 1.0 and 1.5 per cent concentration, whereas, nymphal mortality was between 96.00 to

98.40 per cent at 0.5 per cent concentration. All the test HMO formulations at 1.0 and 1.5 per cent concentration caused adult mortality ranging from 98.40 to 100.00 per cent. The adult stage was more tolerant to the HMO treatments at 0.5 per cent with mortality ranging from 95.20 to 97.60 per cent. The decreasing order of susceptibility against horticultural mineral oils was larva, nymph and adult stage. The findings of the present study are in line with those of Agnello *et al.* (1994), who reported that newly emerged larvae and nymphs were unable to survive for more than 48 hours following application of petroleum oils (0.25 to 1.0 %). Similar results were reported by Khajuria (2005) who observed 98.6 to 100.00 per cent larval mortality with Shelter 909® summer spray oil at concentration ranging from 0.1 to 1.0 per cent.

In the present study, low concentration of HMOs caused complete mortality under laboratory conditions which may be due to the complete oil coverage achieved by immersing leaves in the oil mixtures or spraying them with an idealized spray, and very low degradation and volatilization of the residue.

## **5.2.2 Field evaluation of HMOs against European red mite, *P. ulmi* (Koch)**

### **5.2.2.1 Ovicidal effect of HMOs against overwintering eggs**

The results obtained in the present studies revealed that hatching of overwintering eggs of *P. ulmi* started one week after treatment at pink bud stage and maximum egg hatch of 3.23 per cent was obtained in the control treatment. Hatching of eggs continued for next three weeks and completion of egg hatching was observed during the last week of April and a maximum egg hatch of 74.27 per cent was recorded in the control treatment. These findings are in conformity with the observations of Kumar and Bhalla (1993) who reported appearance of first larvae from the overwintering eggs in early April on warming up of weather coinciding with pink bud stage of apple. The effectiveness of test horticultural mineral oil formulations when applied at pink bud stage against overwintering eggs of *P. ulmi* indicated that MAK All Season HMO (1.5 %) with 1.76 per cent egg hatch emerged as the most effective treatment, followed by Orchol-13, Arbofine and Servo Horticultural Mineral Oil each at 1.5 per cent with 2.08, 3.92 and 4.30 per cent egg hatch, respectively. HMOs at 1.0 per cent were significantly less

effective than those at 1.5 per cent concentration with egg hatch ranging between 3.84 to 6.37 per cent. All the test horticultural mineral oil formulations at 0.5 per cent concentration proved least effective with egg hatch ranging between 14.56 to 24.30 per cent.

The above findings are in agreement with the Chapman and Pearce (1949) who recorded 10.5, 1.9 and 1.5 per cent egg hatch with 'superior type' oils at 0.5, 1.0 and 2.0 per cent, respectively, applied 6 day prior to egg hatch (delayed dormant stage), as against 53.3 per cent egg hatch in the control treatment. Similar egg hatch of 10.1, 6.8 and 3.3 per cent following application of the 'superior type' oils at 0.5, 1.5 and 2.0 per cent were observed by Chapman and Lienk (1950). Chapman *et al.* (1962) and Chapman and Lienk (1966) observed less than 2 per cent egg hatch with 2 per cent petroleum oil applied at half inch green bud stage, however, delaying the treatment by few days (at pre-pink stage), similar results were obtained with a low concentration of 1.0 per cent. Lawson and Weires (1991) recorded 11.9, 19.0 and 22.0 per cent egg hatch with Volck Supreme (1 %), Sunspray 6E+ (1 %) and Sunspray 6E (1 %) petroleum oils, respectively. Bhardwaj (1998) reported 15 per cent egg hatch of European red mite with IPOL orchard spray oil at 2 per cent after 30 days of treatment, however, combination of IPOL with lindane (0.05 %) resulted in 10 per cent egg hatch. Similar results were obtained with Orchex 796 (1.5 %) by Bhardwaj and Bhardwaj (1999).

Comparison of data on egg hatch of overwintering eggs of *P. ulmi* when treated with HMOs (Table 7 and 10) revealed that relatively higher egg hatching was recorded under laboratory conditions than under field conditions. The difference in mortality caused by HMOs tested in the laboratory compared with those tested in the field can be attributed to differences in coverage achieved by oils and degradation or volatilization of the petroleum oils as influenced by weather. Coverage of eggs was certainly higher in the laboratory and relatively lower in the field as every plant part can not get complete coverage with HMOs, and also degradation and volatilization of the horticultural mineral oils was high under field conditions.

It is inferred from the present study that HMO treatment at 1.5 per cent concentration was highly effective against winter eggs of *P. ulmi* and the treatment close to egg hatching at pink bud stage seems to be the most appropriate stage. Similar conclusions were drawn by Chapman and Pearce (1949) who reported that winter eggs become more susceptible to petroleum oils as they approach hatching.

#### **5.2.2.2 Effectiveness of horticultural mineral oils as curative measure against motile stages of *P. ulmi***

The results pertaining to effectiveness of HMOs as curative measure against motile stages of *P. ulmi* under field conditions during 2005 and 2006 are presented in Table 11 and 12, respectively. The results of field trials on motile populations of mite clearly showed that all the test HMO treatments at 1.5 and 1.0 per cent remained effective upto 21 days (3 weeks) and motile population remained below economic threshold level (4 mites/leaf), while in control it had increased from 17.92 to 32.85 and 15.30 to 30.38 motile per leaf during 2005 and 2006, respectively. However, HMOs at 0.5 per cent concentration could not provide effective control of *P. ulmi* and recorded mite population ranging from 14.97 to 17.22 per leaf during 2005 and 10.20 to 12.88 per leaf during 2006 after 30 days of treatment.

The results of present study are in agreement with those of Nickel and Wong (1966), who documented fairly less 0.5 to 1.5 and 2.1 to 4.1 motiles per leaf obtained from plants treated with Humble 60 or Humble 70 or Volck Supreme (each at 1 %) after 7 and 22 days, respectively, as compared to 6.1 to 10.20 motiles per leaf at pre-treatment count. Beattie *et al.* (1997) reported reduction in mite population following 2 applications of DC-Tron NR or Caltex Lovis (0.5 and 1 %) or one application of conventional acaricides Sanmite® (pyridaben) 50 ml per 100 litres of water. They further reported that Caltex Lovis (1 %) reduced leaf occupancy of European red mite from 60 per cent to 15 per cent for three weeks. Similar results were obtained by Stanyard *et al.* (1998) reported adequate control of European red mite following application of Sunspray oil 6+(1 %), which was equally effective as the application of dicofol (0.025 %) and propargite (0.21 %). Similarly, Bhardwaj and Bhardwaj (2006) reported effective control of European red mite in apple orchards upto 30 days following application of

Orchol-13 (1 %), Orchex 796 (1 %), DC-Tron Plus (1 %) and Servo Horticultural Mineral Oil(1 %).

The present studies established that HMOs at 1.5 and 1.0 per cent concentration effectively control the mite population upto 21 days. Although HMOs at 1.5 per cent concentration were marginally superior over their concentration at 1.0 per cent, yet in view of cost of application it would be practicable to use these at 1.0 per cent concentration for effective management of mite population. Thus, ecofriendly HMO formulations can be substituted for dreadful acaricides to overcome the problem of mite resistance, protection of natural enemies and growing fruits free from pesticide residues.

### **5.2.3 Effect of horticultural mineral oils on apple**

Phytotoxicity of HMOs has remained a most important aspect of investigation since their use as insecticide. Foliage or fruit damage following application of HMOs during summer have been attributed to several factors like combination of oils with lime sulphur or wettable sulphur temperature, duration of oil action of protoplasm, low viscosity (Chapman and Pearce, 1949), low soil moisture level (Bogdarina, 1940; Agnello *et al.*, 1994), wide cut oil fractions (Chapman *et al.*, 1962), naphthenic constitution of oil (Lawson and Weires, 1991; Agnello, 2002), unsulfonated residue below 92 per cent (Davidson *et al.*, 1991; Agnello, 2002), varietal response (Agnello *et al.*, 1994; Williams *et al.*, 1996) and oil heaviness (Williams *et al.*, 1996; Agnello, 2002). In the present study, no fruit or foliage toxicity of HMOs was observed during both the years of investigation. The results were not unexpected as all the test HMOs meet the criterion of modern narrow range oils and were applied under complete precautions.

### **5.3 Intrinsic toxicity of some acaricides/insecticides against *P. ulmi***

The toxicity studies of different acaricides viz., clofentezine, hexythiazox, millbemectin and fenpropathrin was done for the first time against all stages of *P. ulmi* on apple under Indian conditions. The intrinsic toxicity of different acaricides was determined in terms of LC<sub>50</sub> values followed leaf-dip method.

### 5.3.1 Intrinsic toxicity of acaricides against eggs of *P. ulmi*

#### 5.3.1.1 Winter eggs

The intrinsic toxicity of different acaricides against winter eggs was evaluated by dip method. The LC<sub>50</sub> values were calculated through probit analysis and summarized in the Table 31. Based on the LC<sub>50</sub> values, milbemectin was found to be most toxic to the winter eggs of *P. ulmi* followed by hexythiazox, clofentezine and fenpropathrin. The LC<sub>50</sub> value for milbemectin was obtained as 5.726 and slope value as 1.2656.

The LC<sub>50</sub> value for hexythiazox against winter eggs of *P. ulmi* was estimated as 13.582 ppm and the probit slope was 1.5541. These results are in conformity with Rathman *et al.* (1990) who found LC<sub>50</sub> value of 7.6 ppm against winter eggs for hexythiazox. Similar results were reported by Baillod *et al.* (1986) who reported 66 to 94 per cent mortality of winter eggs of *P. ulmi* tested at 50 ppm hexythiazox.

Clofentezine had LC<sub>50</sub> value as 17.872 ppm when used against winter eggs and the probit slope was 1.3796. These results are similar to those of Welty *et al.* (1989) who estimated LC<sub>50</sub> for winter eggs as 11.1 ppm with the slope of the concentration-mortality regression line as 1.53. Aveyard *et al.* (1986) also reported that clofentezine at 100 ppm provided excellent mortality (99.6 %) of winter eggs when applied at pre-blossom stage. The LC<sub>50</sub> value of fenpropathrin against winter eggs of *P. ulmi* was estimated as 78.237 ppm and probit slope as 1.5695.

#### 5.3.1.2 Summer eggs

The intrinsic toxicity of acaricides against summer eggs of *P. ulmi* was determined in terms of LC<sub>50</sub> values following leaf-dip method. Based on the LC<sub>50</sub> values, the order of toxicity obtained was: milbemectin > hexythiazox > clofentezine > fenpropathrin (Table 32).

The LC<sub>50</sub> value of milbemectin was determined as 1.314 ppm and the probit slope was 1.444. The regression line estimated for hexythiazox by probit analysis had a slope of 1.3959 and the LC<sub>50</sub> value was 1.750 ppm. The results obtained in the present study

**Table 31: Toxicity of test acaricides against winter eggs of *P. ulmi* using dip method**

Acaricide	Heterogeneity ( $\chi^2$ )	Regression equation (Y)	LC <sub>50</sub> (ppm)	Fiducial limits (ppm)		Slope (b)
				Lower	Upper	
Clofentezine	1.7121	3.2725 + 1.3796 X	17.872	15.165	21.062	1.3796
Hexythiazox	0.924	3.2392 + 1.5541 X	13.582	11.741	15.711	1.5541
Milbemectin	3.654	4.0412 + 1.2651 X	5.726	4.743	6.911	1.2656
Fenpropathrin	4.317	2.0283 + 1.5695 X	78.237	67.762	90.332	1.5695

**Table 32: Toxicity of test acaricides against summer eggs of *P. ulmi* using leaf-dip method**

Acaricide	Heterogeneity ( $\chi^2$ )	Regression equation (Y)	LC <sub>50</sub> (ppm)	Fiducial limits (ppm)		Slope (b)
				Lower	Upper	
Clofentezine	4.000	4.0439 + 1.4268 X	4.678	3.920	5.582	1.4268
Hexythiazox	1.037	4.4606 + 1.3959 X	1.750	1.416	2.163	1.3959
Milbemectin	1.247	4.8285 + 1.4440 X	1.314	1.029	1.678	1.4440
Fenpropathrin	0.031	2.2380 + 1.6651 X	45.575	38.459	54.008	1.6651

for hexythiazox are in line with those reported by Welty *et al.* (1988), who estimated the LC<sub>50</sub> value of hexythiazox as 2.2 ppm with a probit slope of 1.8.

The LC<sub>50</sub> value of clofentezine was estimated as 4.678 ppm and the probit slope was 1.4268. In the present study, fenpropathrin was found to be least toxic to summer eggs with LC<sub>50</sub> value of 45.575 ppm. The results obtained in the present investigation are in agreement with those reported by Thakur (2002), who estimated LC<sub>50</sub> value of 56.42 ppm for fenpropathrin against summer eggs of *P. ulmi* using leaf-dip method.

The results obtained in the present studies regarding susceptibility of winter and summer eggs to acaricides has clearly established that summer eggs were more susceptible than winter eggs (Table 33 and 34) to all the test acaricides. The above findings are in conformity with those of Welty *et al.* (1988), who reported that summer eggs were 9 times more susceptible to hexythiazox than winter eggs (LC<sub>50</sub> values of 2.2 and 20 ppm, respectively). Similarly, Welty *et al.* (1989) reported that summer eggs (LC<sub>50</sub> = 1.01 ppm) were more susceptible than winter eggs (LC<sub>50</sub> = 11.1 ppm) to clofentezine using leaf-dip method.

### **5.3.2 Intrinsic toxicity of acaricides against motile stages of *P. ulmi***

The toxicity of milbemectin, clofentezine, hexythiazox and fenpropathrin was tested against all the motile stages of *P. ulmi* viz. larvae, protonymphs, deutonymph and adults using leaf-dip method. Out of the above mentioned acaricides only milbemectin and fenpropathrin were found effective against all the motile stages of *P. ulmi* (Table 33 and 34). The LC<sub>50</sub> values estimated for milbemectin against larvae, nymphs and adults were 3.163, 8.085, and 10.604 ppm, respectively, while for fenpropathrin LC<sub>50</sub> values calculated were 67.246, 154.253 and 183.311 ppm against larvae, nymphs and adults, respectively, which showed that milbemectin was highly toxic to all motile stages of *P. ulmi*. El-Khateeb *et al.* (2004) reported that milbemectin at 50 ml/100 litres of water was the most efficient treatment on motile stages of *Tetranychus urticae*, giving 89.45 per cent reduction in two years with respective mean of reduction of 89.71 and 89.22 per cent, respectively. McKee and Knowles (1984) estimated LC<sub>50</sub> value 241 ppm

**Table 33: Toxicity of test acaricides against larvae of *P. ulmi* using leaf-dip method**

Acaricide	Heterogeneity ( $\chi^2$ )	Regression equation (Y)	LC <sub>50</sub> (ppm)	Fiducial limits (ppm)		Slope (b)
				Lower	Upper	
Clofentezine	1.009	3.5525 + 1.3161 X	12.569	9.705	16.277	1.3161
Hexythiazox	0.083	3.6782 + 1.4916 X	7.694	5.811	10.187	1.4916
Milbemectin	0.833	4.4751 + 1.0494 X	3.163	2.324	4.304	1.0494
Fenpropathrin	1.700	2.1229 + 1.5741 X	67.246	54.513	82.954	1.5741

**Table 34: Toxicity of test acaricides against nymphs and adults of *P. ulmi* using leaf-dip method**

Acaricide	Stage of mite	Heterogeneity ( $\chi^2$ )	Regression equation (Y)	LC <sub>50</sub> (ppm)	Fiducial limits (ppm)		Slope (b)
					Lower	Upper	
Milbemectin	Nymph	3.931	4.0142 + 1.0859 X	8.085	5.970	10.950	1.0859
	Adult	1.809	3.9447 + 1.0290 X	10.604	7.788	14.438	1.0290
Fenpropathrin	Nymph	3.315	3.8987 + 1.4172 X	154.253	123.418	192.793	1.4172
	Adult	2.191	1.7820 + 1.4218 X	183.311	147.481	227.845	1.4218
Clofentezine	Protonymph	1.448	2.0176 + 1.5860 X	77.048	62.945	94.312	1.5806
Hexythiazox	Protonymph	0.270	2.9744 + 1.2676 X	39.617	30.921	50.759	1.2676

for fenpropathrin against the adults of *T. urticae* in the laboratory studies, which was little higher than that obtained in the present investigations. This variation in mortality may be attributed to the involvement of different species in the present investigations.

In preliminary tests, clofentezine and hexythiazox were not found to be effective against deutonymphs and adults of *P. ulmi*. Therefore, dose mortality relationship could not be obtained for clofentezine and hexythiazox against deutonymphs and adults of *P. ulmi* as sufficient mortality was not recorded at different concentrations. In the present studies, the LC<sub>50</sub> value for clofentezine against larvae and protonymphs were 12.569 and 77.048 ppm, respectively. Similar, results have been reported by Aveyard *et al.* (1986) who obtained the LC<sub>50</sub> value as 6.20 ppm against larvae using leaf-dip method.

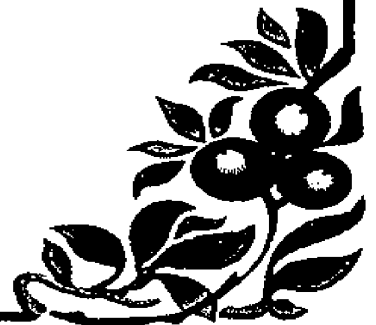
In the present study, the LC<sub>50</sub> value of 7.694 ppm and 39.617 ppm were calculated for hexythiazox against larvae and protonymphs of *P. ulmi*, respectively. These results are in accordance with those reported by Welty *et al.* (1988), who reported that mortality of larvae emerging from winter eggs was 94 to 100 per cent after exposure to leaves previously treated with 100 ppm hexythiazox and larvae that emerged from summer eggs were not able to survive foliage residues when leaves were dipped in  $\geq 6$  ppm hexythiazox. Similarly, Ressig and Hull (1991) observed 98.00 per cent mortality of larvae at 100 ppm concentration of hexythiazox under laboratory conditions.

In present laboratory studies using *P. ulmi*, clofentezine and hexythiazox showed excellent activity against eggs, larvae and protonymphs, but it proved ineffective against the later nymphal stage (deutonyhphs) and adults. These results are in line with those of Hoy and Ouyang (1986) who reported that hexythiazox and clofentezine selectively kills eggs and larvae of *P. ulmi*. Similar results were obtained by Aveyard *et al.* (1986), who reported that clofentezine showed good activity against eggs, larvae and protonymphs of *T. urticae*, but very little activity against deutonymphs and adults.



**Chapter-VI**

**SUMMARY AND CONCLUSIONS**



## Chapter-VI

# SUMMARY AND CONCLUSIONS

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The results of the present investigation on “**Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**” were carried out during 2005-2006 and 2006-2007 at the laboratory of the Entomology Section, Regional Horticultural Research Station, Dr. Y.S. Parmar University of Horticulture and Forestry, Mashobra, Shimla, Himachal Pradesh. Field trials were carried out at the experimental orchards of RHRS, Mashobra and two private orchards located at Theog and Kathasu (Jubbal) in district Shimla, Himachal Pradesh. The salient findings of the studies are summarized here under:

### **6.1 Effect of European red mite feeding on yield and quality parameters of apple cv. Royal Delicious under field conditions**

- Studies on the effect of different levels of European red mite feeding at 0, 250, 500, 750 and 1000 cumulative mite days (CMDs) on some physico-chemical characteristics of apple fruits cv. Royal Delicious showed that different levels of mite feeding exerted varying effects on mean fruit weight and total soluble solids of fruits, however, fruit firmness and anthocyanin content were not affected significantly during both the years of study.
- Mean fruit weight and total soluble solids (TSS) declined with the increase in levels of mite feeding. The maximum fruit weight and total soluble solids were recorded in the fruits harvested from the control plants, closely followed by those subjected to 250 CMDs, both statistically at par with each other. Significant reduction in fruit weight and total soluble solids were observed at mite feeding level of 500 CMDs.

However, minimum fruit weight and total soluble solids were recorded at feeding level of 1000 CMDs and reduction in fruit weight and TSS over control treatment was 6.16 and 6.25 per cent during 2005, and 7.51 and 5.95 per cent during 2006, respectively.

- Effect of mite feeding on fruit firmness and anthocyanin content showed that these parameters were not affected significantly by different levels of mite feeding. However, fruit firmness increased slightly with increasing levels of mite feeding and maximum fruit firmness was recorded in the fruits harvested from the plants infested with 1000 CMDs. A slight decrease in anthocyanin content was observed with the increase in mite feeding.
- Effect of different levels of mite feeding revealed that return bloom, percentage fruit set and fruit load showed inverse relationship with increase in mite feeding during both the years of study. The highest return bloom, fruit set and fruit load was recorded in the control plants, which remained statistically at par with the plants stressed with 250 CMDs. Minimum return bloom, fruit set and fruit load was observed in the plants stressed with 1000 CMDs and recorded a reduction of 26.52, 31.90 and 38.80 per cent during 2006, and 51.00, 40.15 and 46.79 per cent during 2007, respectively over the control treatment. However, significant reduction in these parameters was recorded at mite feeding level of 500 CMDs and the reduction in return bloom, fruit set and fruit load over control was 15.22, 11.03 and 18.05 per cent during 2006, and 25.50, 15.78 and 24.14 per cent during 2007, respectively.
- Physico-chemical and yield parameters of apples were not affected significantly at mite feeding level of 250 CMDs, while a significant reduction in these parameters started at mite feeding level of 500 CMDs. Therefore, a tentative economic threshold level (ETL) of 250 CMDs is established for *P. ulmi* on apple.

## **6.2 Evaluation of Horticultural mineral oils (HMOs) against European red mite, *P. ulmi* (Koch)**

### **6.2.1 Laboratory evaluation of HMOs against *P. ulmi***

- The studies on the effectiveness of recently introduced HMOs under laboratory conditions against winter and summer eggs of *P. ulmi* established that winter and summer eggs were highly susceptible to HMO treatments. However, summer eggs were comparatively more sensitive to HMO treatments as compared to winter eggs. Complete mortality of summer eggs was recorded even at a low concentration of 0.5 per cent. Among the test HMOs, MAK All Season HMO proved most effective against winter and summer eggs, followed by Orchol-13, Servo Horticultural Mineral Oil, and Arbofine. Thus mite population can be managed successfully following HMO treatments on plants supporting *P. ulmi* population.
- Effectiveness of HMOs under laboratory conditions against motile stages of *P. ulmi* showed that larval stage was the most sensitive stage with cent per cent mortality in all the HMO treatments even after 24 hours. Nymphs could not survive for more than 48 hours in any of the test HMOs at 1.0 and 1.5 per cent concentration. All the test HMO formulations at 1.0 and 1.5 per cent concentration proved effective against adult stage of *P. ulmi* and caused mortality ranging from 98.40 to 100.00 per cent. The decreasing order of susceptibility against horticultural mineral oils was larva, nymph and adult stage.

### **6.2.2 Field evaluation of HMOs against European red mite, *P. ulmi***

- Studies on the hatchability of overwintering eggs of *P. ulmi* under field conditions revealed that hatching of eggs started one week after treatment coinciding pink bud stage of apple. Hatching of eggs continued for next three weeks and was completed in last week of April.

- The effectiveness of test horticultural mineral oil formulations against overwintering eggs of *P. ulmi* when applied close to egg hatching at pink bud stage established that all the test horticultural mineral oil formulations at 1.5 and 1.0 per cent were highly effective under field conditions. However, MAK All Season HMO (1.5 %) with 1.76 per cent egg hatch emerged as the most effective treatment, followed by Orchol-13, Arbofine and Servo Horticultural Mineral Oil each at 1.5 per cent with 2.08, 3.92 and 4.30 per cent egg hatch, respectively. Therefore, treatment of HMOs at pink bud stage was found to be the most appropriate stage for the control of winter eggs of *P. ulmi*.
- Studies on the effectiveness of horticultural mineral oils as curative measure against motile stages of *P. ulmi* under field conditions showed that all the test horticultural mineral oil formulations at 1.5 and 1.0 per cent resulted in effective control of *P. ulmi* up to 21 days during both the years of study and recorded mite population ranging between 2.03 to 4.03 per leaf during 2005, and 2.73 to 3.96 per leaf during 2006. However, HMOs at 0.5 per cent could not provide effective control of *P. ulmi*. Among the test HMOs, MAK All Season HMO at 1.5 per cent concentration proved most effective, followed by Orchol-13, Servo Horticultural Mineral Oil and Arbofine, each at 1.5 per cent concentration. The mean mite population when recorded 30 days after spray ranged from 5.32 to 7.33 per leaf during 2005, and 5.03 to 6.52 per leaf during 2006 and were marginally superior over their concentration at 1.0 per cent with mite population ranging from 6.47 to 8.10 per leaf during 2005, and 6.01 to 8.21 per leaf during 2006. Yet in view of cost of application it would be practicable to use these at 1.0 per cent concentration for effective management of mite population.
- The studies on the effectiveness of horticultural mineral oils against all the stages of *P. ulmi* under laboratory and field conditions established that ecofriendly HMO formulations can be substituted for acaricides to manage the mite population effectively.
- None of the test concentration of HMOs caused phytotoxicity or any apparent adverse effect on the growth and development of plants during the course of study. Thus, all the test formulations of HMOs were found safe to the plants.

### 6.3 Intrinsic toxicity of acaricides against different stages of *P. ulmi* (Koch)

- The toxicity of acaricides to winter eggs of *P. ulmi* by dip method revealed that winter eggs showed maximum susceptibility to milbemectin ( $LC_{50} = 5.726$  ppm) and minimum to fenpropathrin ( $LC_{50} = 78.237$  ppm). The order of toxicity obtained was as: milbemectin ( $LC_{50} = 5.726$  ppm) > hexythiazox ( $LC_{50} = 13.582$  ppm) > clofentezine ( $LC_{50} = 17.872$  ppm) > fenpropathrin ( $LC_{50} = 78.237$  ppm).
- The intrinsic toxicity of acaricides against summer eggs was evaluated by leaf-dip method. Based on the  $LC_{50}$  values, milbemectin was found most toxic ( $LC_{50} = 1.314$  ppm), followed by hexythiazox ( $LC_{50} = 1.75$  ppm), clofentezine ( $LC_{50} = 4.678$  ppm) and fenpropathrin ( $LC_{50} = 45.575$  ppm).
- The toxicity studies of different acaricides based on  $LC_{50}$  values against winter and summer eggs of *P. ulmi* established that summer eggs were more susceptible than winter eggs to all the test acaricides.
- The toxicity studies of different acaricides against all motile stages of *P. ulmi* viz., larvae, protonymphs, deutonymphs and adults revealed that only milbemectin and fenpropathrin were effective against all motile stages of *P. ulmi* whereas, both clofentezine and hexythiazox exhibited excellent activity against eggs, larvae and protonymphs, but were ineffective against deutonymphs and adults.
- As a larvicide, milbemectin was most toxic ( $LC_{50} = 3.163$  ppm) followed by hexythiazox ( $LC_{50} = 7.694$  ppm), clofentezine ( $LC_{50} = 12.569$  ppm) and fenpropathrin ( $LC_{50} = 67.246$  ppm). Nymphs and adults were most susceptible to milbemectin with  $LC_{50}$  values of 8.085 and 10.604 ppm, followed by fenpropathrin with  $LC_{50}$  values of 154.253 and 183.311 ppm, respectively.
- Dose mortality relationship could not be established for clofentezine and hexythiazox against deutonymphs and adults of *P. ulmi* as sufficient mortality was not obtained at different concentrations of these acaricides in the preliminary tests.

## CONCLUSIONS

On the basis of the foregoing results, it is inferred that European red mite feeding leads to a variety of effects which were reflected in the current as well as following year. Yield and quality parameters of apples were not affected significantly at mite feeding of 250 CMDs and remain statistically at par with the control treatment. However, a significant reduction in mean fruit weight, total soluble solids, return bloom, fruit set, and fruit load started at feeding level of 500 CMDs, whereas fruit firmness and fruit colour were not affected significantly by any level of mite feeding. Therefore, a tentative economic threshold level of 250 CMDs was established for *P. ulmi* on apples. The studies on the effectiveness of HMOs under laboratory conditions established that HMOs at 1.5 per cent concentration were highly effective against all the stages of *P. ulmi*, and among the test HMOs, MAK All Season HMO proved most effective, followed by Orchol-13, Servo Horticultural Mineral Oil and Arbofine. The effectiveness of test HMOs against overwintering eggs of *P. ulmi* when applied at pink bud stage under field conditions showed that all the test HMOs at 1.5 per cent proved most effective. Studies on the efficacy of HMOs as curative measure against *P. ulmi* under field conditions during summer showed that all the HMO formulations at 1.5 and 1.0 per cent concentration kept the mite population below economic threshold level up to 21 days. Thus, mite management programmes in apples should include HMOs for effective management of *P. ulmi*. The toxicity studies of different acaricides against *P. ulmi* established that milbemectin and fenpropathrin were effective against all stages of *P. ulmi*, whereas, both clofentezine and hexythiazox exhibited excellent activity against eggs, larvae, and protonymphs but were ineffective against deutonymphs and adults. As an ovicide and larvicide, milbemectin was most toxic followed by hexythiazox, clofentezine and fenpropathrin. Nymphs and adults were highly susceptible to milbemectin followed by fenpropathrin.



**Chapter-VII**

**REFERENCES**



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# REFERENCES

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- Abbott W S. 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology* **18**: 265-267.
- \*Ackerman A J. 1923. Preliminary report on control of San Jose scale with lubricating oil emulsions. *United States Department of Agriculture Circular* **263**: 1-10.
- Agnello A M, Reissig W H and Harris T. 1994. Management of summer population of European red mite (Acari: Tetranychidae) on apple with horticultural oils. *Journal of Economic Entomology* **87**: 148-161.
- Agnello A M. 2002. Petroleum derived spray oils: chemistry, history, refining and formulation. In: *Spray oils Beyond 2000-sustainable pest and disease management*. G A C Beattie, D M Watson, M L Stevens, D J Rae and R N Spooner-Hart (eds.), University of Western Sydney, NSW, Australia, pp. 2-18.
- Ames G K, Johnson D T and Rom R C. 1984. The effect of European red mite feeding on fruit quality of Miller Sturdeespur apple. *Journal of the American Society for Horticultural Science* **109**: 834-837.
- Anonymous 1966. *1966-1967 treatment guide for California citrus crops*. California Agricultural Station and Extension Service, Berkeley, 53 p.
- Anonymous 2004. Spray schedule for 2004. Department of Horticulture, Himachal Pradesh Shimla-2 and Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, H.P.
- Asquith D and Hull L A. 1979. Integrated pest management systems in Pennsylvania apple orchards In: *Pest management programs for deciduous tree fruit and nuts*, D J Boethel and R D Eikenbary (eds.), Plenum, New York, pp. 203-222.
- Asquith D. 1961. Control of insect and mites: an investment for profit. *Pennsylvania Fruit News* **40** (1-2): 29-30.
- Aveyard C S, Peregrine D J and Bryan M G. 1986. Biological activity of clofentezine against egg and motile stages of tetranychid mites. *Experimental and Applied Acarology* **2**: 223-229.
- Awasthi R P and Kamal M Y. 2005. History, Challenges and future prospects. In: *The Apple: improvement production and post-harvest management*, K L Chadha and R P Awasthi (eds.), Malhotra Publishing House, New Delhi, India, pp. 1-15.
- \*Baillod M, Guignard E and Antonin P. 1986. A new generation of growth inhibiting specific acaricides. *Revue Suisse de Viticulture* **18**(4): 213-219.

- Baker R T. 1984. Effect of European red mite (*Panonychus ulmi*) on quality and yield of apples. *Proceedings of 10<sup>th</sup> International Congress of Plant Protection*, Brighton, England, p 108.
- Beattie G A C, Herron G A, Cliff A D, Tesoriero L, Stovold G, Barchia I, Rajakulendran V, Watson D M, Jiang L, Singh P, Kallinpur A S, Nicetic O, Parkes R, Thwaite W G, Gogala K, Eslick M, Nicol H and Fruness G O. 1997. Evaluation of petroleum spray oils. *Final report, Horticultural Research and Development Corporation Project*, HG/93/019. Canberra: HDRC.
- Beers E H and Hull L A. 1990. Timing of mite injury affects the bloom and fruit development of apple. *Journal of Economic Entomology* **83**(5): 547-551.
- Beers E H and Hull L A. 1987. Effect of European red mite (Acari: Tetranychidae) injury on vegetative growth and flowering of four cultivars of apple. *Environmental Entomology* **16**: 569-574.
- Beers E H, Hull L A and Greene G M. 1990. Effect of a foliar urea application and mite injury on yield and fruit quality of apple. *Journal of Economic Entomology* **83**(5): 552-556.
- Beers E H, Hull L A and Grimm J W. 1987. Relationships between leaf: fruit ratio and varying levels of European red mite stress on fruit size and return bloom of apple. *Journal of the American Society for Horticultural Science* **112**: 608-612.
- Bhardwaj S and Bhardwaj S P. 2004. Laboratory evaluation of some acaricides for the control of the European red mite, *Panonychus ulmi* (Koch) on apple. *Pest Management and Economic Zoology* **12**(1): 17-21.
- Bhardwaj S P and Bhardwaj S. 1999. Red mites on apple: present and future strategies for its control. *National Seminar on Himalayan Horticulture, Hortivision-2020, Abstract* p. 28.
- Bhardwaj S P and Bhardwaj S. 2000. European red mite- an emerging problem of apple. **In:** *Horticulture Technology Vision 2000 and Beyond* Vol. 2. *Protection and Preservation*, V K Sharma and K C Azad (eds.), Deep and Deep Publications, Delhi, pp. 428-432.
- Bhardwaj S P and Bhardwaj S. 2005. Insect and mite pests. **In:** *The Apple : improvement production and post-harvest management*, K L Chadha and R P Awasthi (eds.), Malhotra Publishing House, New Delhi, India, pp. 346-396.
- Bhardwaj S P and Bhardwaj S. 2006. Management of European red mite on apple with horticultural mineral oils in India- a new approach. **In:** *Abstract Book XII International Congress of Acarology*, 21-26 August, Amsterdam, The Netherland, p.30.

- Bhardwaj S P. 1998. Current status of temperate fruit pest and insecticide use in Himachal Pradesh. *Seminar on 50 years of Horticulture in Himachal Pradesh*. H. P. State Department of Horticulture, Shimla 16-20 November 1998, pp. 71-73.
- Bogdarina A A. 1940. The influence of water supply on the shedding of apple leaves during spraying with mineral oil emulsions. *Bulletin of Plant Protection* 1: 185-191.
- Botha J H, Plessis D du, Calitz F J and Du-Plessis D. 1995. Effect of Sunspray ultra-fine R summer oil on European red mite in apple orchards. *Journal of the Southern African Society for Horticultural Science* 5: 101-105.
- Bouron H. 1985. A new concept for the control of the fruit tree red spider mite. *Phytoma* 364: 10-11.
- Bower C C. 1990. Comparison of clofentezine and hexythiazox with cyhexatin for integrated control of European red mite, *Panonychus ulmi* (Koch). *Crop Protection* 9: 463-468.
- Briggs J B and Avery D J. 1968. Effect of infestation with fruit tree red spider mite, *Panonychus ulmi* (Koch), on the growth and cropping of young fruit trees. *Annals of Applied Biology* 61: 269-276.
- Bryan K M G , Geering A and Reid J. 1981. NC-21314, a novel compound for controlling phytophagous mites. In: *Proceedings of British crop protection conference on pests and diseases*. British Crop Protection Conference, London, pp. 67-74.
- Bryan K M G and Peregrine D J. 1983. Further developments of clofentezine for the control of mites in top fruits. In: *10<sup>th</sup> International Congress of Plant Protection*, Brighton, England, pp. 1001-1002.
- Buendia J and Roca M. 1983. A strategy for the control of *Panonychus ulmi* using clofentezine in apples and pear. In: *10<sup>th</sup> International Congress of Plant Protection*, Brighton, England, 1000 p.
- Bulgak V D. 1982. Harmfulness of spider mites on apple in the Crimea. In: *Proceedings of the All Union Research Institute of Plant Protection*, Leningrad, USSR, pp. 80-86.
- Chapman P J and Lienk S E. 1950. Orchard mite control experiment in western New York. *Journal of Economic Entomology* 43: 309-314.
- Chapman P J and Lienk S E. 1966. Effectiveness of oil sprays on European red mite control. *Proceedings of the New York State Horticultural Society* 111: 150-163.
- Chapman P J and Pearce G W. 1949. Susceptibility of winter eggs of European red mite to petroleum oils and Dinitro compounds. *Journal of Economic Entomology* 42: 44-47.

- Chapman P J, Lienk S E and Cuiertis O F. 1952. Responses of apple trees to mite infestations. *Journal of Economic Entomology* **45**: 815-821.
- Chapman P J, Lienk S E, Avens A W and White R W. 1962. Selection of plant spray oil with full pesticidal efficiency with minimum plant injury hazards. *Journal of Economic Entomology* **55**: 737-744.
- Chapman P J, Riehl L A and Pearce G W. 1952. Oil sprays for fruit trees. *United States Department of Agriculture Yearbook* 1952, pp. 229-239.
- Chapman P J. 1959. Pest status and control of orchard mites. *Proceeding of New York State Horticulture Society* **105**: 147-155.
- Chapman P J. 1967. Petroleum oils for the control of orchard pests. *New York State Agricultural Experiment Station Bulletin* **814**: 1-24.
- Chapman R B and Marris J W M . 1986. The sterilizing effect of clofentezine and hexythiazox on female two spotted mites. **In: Proceedings of 39<sup>th</sup> New Zealand weed and pest control conference**, Canterbury, New Zealand, pp. 237-240.
- Cox A J. 1938. Economic poisons decision No. 5 relative to spray oils. *California Department of Agriculture Special Publication* **163**: 10-11.
- Cranham J E, Helle W. 1985. Pesticide resistance in Tetranychidae. **In: Spider mites: their biology, natural enemies and control**, W Helle and M W Sakelin (eds.), Elsevier Science Publishing Co., New York, pp. 405-421.
- Cranshaw W S and Baxendale B. 1999. Insect control: Horticultural oils. *Colorado State University Cooperative Extension Insects*, Series No 5.569.
- Croft B A, Elfving D C and Flore J A. 1983. Integrated pest management and fruit tree physiology and growth. **In: Integrated Management of insect pests of pome and stone fruits**, B A Croft and S C Hoyt (eds.), Wiley Interscience, New York, pp 67-92.
- Croft B A, Hoyt S C and Westigard P H. 1987. Spidermite management on pome fruits: organotin and acaricide resistance management. *Journal of Economic Entomology* **80**: 304-311.
- Davidson N A, Dibble J E, Flint M L, Marer P J and Guye A. 1991. Managing insects and mites with spray oils. *University of California, Division of Agriculture and Natural Resources Publication* **334**: 47-48.
- Dennehy T J, Nyrop J P, Reissig W H and Weires R W. 1988. Characterization of resistance to dicofol in spider mite (Acari: Tetranychidae). *Journal of Economic Entomology* **81**: 1551-1561.
- deOng E R, Knight H and Chamberlin J C. 1927. A preliminary study of petroleum oils as an insecticide for citrus trees. *Hilgardia* **2**: 351-384.

- \*deOng E R. 1926. Technical aspects of petroleum oils and oil sprays. *Journal of Economic Entomology* **19**: 733-745.
- \*Dibble J E. 1971. All about mites and how to control them. *Western Fruit Grower* **22**: 25-26.
- Dokras A L, Gupta P R and Kumar R. 2002. Natural enemies complex of European red mite, *Panonychus ulmi* (Koch) in apple orchard of Himachal Pradesh. *Pest Management in Horticulture Ecosystems* **8**: 5-11.
- Ebeling W. 1950. *Subtropical Entomology*. Lithotype Process Co., San Francisco, pp. 165-215.
- El Khateeb, Habashy N H and Iskandar A K F. 2004. Field evaluation of some new acaricides against the two spotted spider mite. *Egyptian Journal of Agricultural Research* **82**(2): 619-629.
- Eslick M A, Thwaite W G and Nicol H I. 2002. Improved control of European red mite on apple using petroleum derived spray oils. In: *Spray Oils Beyond 2000-sustainable pest and disease management*. G A C Beattie, D M Watson, M L Stevens, D J Rae and R N Spooner-Hart (eds.), University of Western Sydney, NSW, Australia, pp. 292-296.
- Ewing H E. 1912. The occurrence of citrus red spider mite, *Tetranychus mystilaspides* Riley on stone and pomeaceous fruit trees in Oregon. *Journal of Economic Entomology* **5**: 414-415.
- Farrar M D and Kelley V W. 1935. The accumulative effect of oil sprays on apple trees. *Journal of Economic Entomology* **28**: 260-263.
- Finney D J. 1971. *Probit analysis*. Cambridge University Press, Cambridge, 318 p.
- Georghiou G P and Mellon R B. 1983. Pesticide resistance in time and space. In: *Pest resistance to pesticides*, GP Georghiou and T Saito (eds.), Plenum, New York, pp. 1-46.
- \*Goeze J A E. 1787. Geschichte einiger den Menschen, Thieren, Oekonomie and Gartneren Schadtichen Insekten. Lipzig: Weidmanns Erben and Reich.
- Gomez K A and Gomez A A. 1986. *Statistical procedures for agricultural research*. 2<sup>nd</sup> Edition. John Wiley and Sons, New York, pp. 99-107.
- \*Gray G P and deOng E R. 1926. California petroleum insecticides. *Industrial and Engineering Chemistry* **18**: 175-180.
- Gupta S K. 1991. Annual Report. All India Coordinated Research Project on Agricultural Acarology, ICAR, 256 p.

- Harbone J B. 1973. *Phytochemical methods*. Toppan Co. Ltd., Tokyo, Japan.
- Hardman J M, Franklin J L, Moreau D L and Bostanian N J. 2003. An index of selective toxicity of miticides to phytophagous mites and their predators based on orchard trials. *Pest Management Science* **59**(12): 1321-1332.
- Hardman J M, Herbert H J, Sanford K H and Hamilton D. 1985. Effect of populations of the European red mite, *Panonychus ulmi*, on the apple variety Red Delicious in Nova Scotia. *Canadian Entomologist* **117**: 1257-1265.
- Horwitz W. 1980. *Official methods of analysis*. Association of official analytical chemists. 13<sup>th</sup> Edition. Washington D C., USA.
- Hoy M A and Ouyang Y. 1986. Selectivity of the acaricides clofentezine and hexythiazox to the predator *Metaseiulus occidentalis* (Acari : Phytoseiidae). *Journal of Economic Entomology* **79**: 1377-1380.
- Hoyt S C and Tanigoshi L K. 1983. Economic injury levels for apple insect and mite pests. In: *Integrated Management of insect pests of pome and stone fruits*, B A croft and S C Hoyt (eds.), Wiley Interscience, New York, pp 203-218.
- Hoyt S C, Tanigoshi L K and Browne R W. 1979. Economic injury level studies in relation to mite on apple. *Recent Advances in Acarology* **1**: 3-12.
- Hull L A and Greene G M. 1983. Managing the European red mite using sampling, injury levels, *Stethorus punctum* and miticides. *Pennsylvania Fruit News* **63**(6): 12-22.
- Hull L A, Beers E H and Greene G M. 1985. How mite damage affects apple production. *Proceedings of the New York State Horticultural Society* **130**: 37-46.
- Hull L A, Beers E H and Grimm J W. 1986. Action thresholds for arthropod pests of apple. In: *Integrated pest management on major agricultural crops*, R E Frisbie and P L Adkisson (eds.), Texas Agricultural Experiment Station, Texas, pp. 66-86.
- Hull L A, Beers E H. 1990. Validation of injury thresholds for European red mite (Acari: Tetranychidae) on 'Yorking' and 'Delicious' apple. *Journal of Economic Entomology* **83**(5): 2026-2031.
- \*Ioriatti C, Angeli G, Delaiti M and Maines R. 1998. Susceptibility of population of *Panonychus ulmi* to the acaricide hexythiazox. *Informatore Agrario* **54**(20): 70-72.
- Jeppson L R, Keifer H H and Baker E W. 1975. *Mites injurious to economic plants*. University of California Press, Berkeley, Los Angeles, 614 p.
- Johnson W T. 1980. Spray oils as insecticides. *Journal of Arboriculture* **6**: 169-174.

- Khajuria D R and Sharma J P. 1996. Outbreak of phytophagous mites on apples in Kullu valley. *Indian Journal of Plant Protection* **24**: 124-138.
- Khajuria D R. 2005. Evaluation of shelter 909® summer spray oil for suppression of the European red mite, *Panonychus ulmi* (Koch) on apple in Himachal Pradesh. *Pest Management and Economic Zoology* **13**(2): 197-202.
- Khan I A and Zhu Y J. 2006. Toxicity of some pesticides to European red mite, *Panonychus ulmi* (Koch) (Acari : Tetranychidae), applied in apple orchards in the North Rhine Area, Germany. *Sarhad Journal of Agriculture* **22**(1): 125-129.
- Klopfenstein W G and Holdsworth R P. 1978. The effects of European red mite feeding on the growth and yield of Spurtype Red Delicious apple. *Research Circular of the Ohio Agricultural Research and Development Center* **239**: 35-37.
- Klopfenstein W G. 1977. Effect of European red mite feeding on growth and yield of 'Red Delicious' apple. Ph D dissertation, Ohio State University, Columbus.
- \*Kovaleski A and Salles L A B. 1984. Acaricide for the control of fruit tree red spider mite. *Anais do VII Congresso de Fruticultura* **3**: 725-730.
- Krawczyk G and Hull L A. 2005. Use of new generation of horticultural oils for mite management in fruit orchards. *Bulletin OILB/SROP* **28**(7): 233-237.
- Kumar R and Bhalla O P. 1993. An epidemic outbreak of *Panonychus ulmi* (Koch) (Acari: Tetranychidae) in apple orchards of Himachal Pradesh, India. *Current Science* **64**: 709.
- Lathrop F H. 1951. Sidelights on European red mite control. *Journal of Economic Entomology* **44**: 509-514.
- Lawson D S and Weires R W. 1991. Management of European red mite (Acari: Tetranychidae) and several aphid species on apple with petroleum oils and an insecticidal soap. *Journal of Economic Entomology* **84**: 1550-1557.
- \*Leski R and Predki S. 1964. Investigation on bionomics of *Panonychus ulmi*. *Polski Pismo Entomologiczne* **3**: 57-62.
- Lienk S E and Minns J C. 1980. Effect of early mite feeding on apple yield. *Proceedings of the New York State Horticultural Society* **125**: 93-96.
- Lienk S E, Chapman P J and Curtis O F. 1956. Response of apple trees to mite infestations, II. *Journal of Economic Entomology* **49**: 350-353.
- Lienk S E, Watve C and Minns J. 1976. Susceptibility of the European red mite and its predators to chemical treatments. *New York Food Life Science Bulletin* **62**: 1-10.

- Lienk S E. 1972. European red mite control on apple with early season sprays. *Journal of Economic Entomology* **75**: 1684-1686.
- Light W I St G and Ludlam F A B. 1972. The effects of fruit tree red spider mite (*Panonychus ulmi*) on yield of apple trees in Kent. *Plant Pathology* **21**: 175-181.
- Lodeman E G. 1896. *The spraying of plants*. MacMillan, New York, pp. 81-84.
- Lu C T and Wang C L. 2005. An investigation of spider mites on papaya and evaluation of some acaricides. *Plant Protection Bulletin of Taipei* **47**(3): 273-279.
- \*Mandersloot H J. 1987. Results with Apollo in Dutch apple growing. *Erwerbsobstbau* **24**(4): 125-126.
- Marini R P, Pfeiffer D G and Sowers D S. 1994. Influence of European red mite (Acari : Tetranychidae) and crop density on fruit size and quality and on crop value of 'Delicious' apples. *Environmental Entomology* **87**(5): 1302-1311.
- Marshall D B and Pree D J. 1986. Effects of pyrethroid insecticides on eggs and larvae of resistant and susceptible populations of spotted tentiform leaf miner. *Canadian Entomologist* **118**: 1123-1130.
- Marshall D B and Pree D J. 1991. Effects of miticides on the life stages of the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae). *Canadian Entomologist* **123**: 77-87.
- Marshall D B, Pree D J and McGarvey B C. 1988. Effect of benzylphenylurea insect growth regulators on eggs and larvae of the spotted tentiform leaf miner, *Phyllonorycter blancardella* (Fab.). *Canadian Entomologist* **120**: 49-62.
- Marshall J. 1948. Spray investigation in British Columbia. *Journal of Economic Entomology* **41**: 592-595.
- McKee M J and Knowles C O. 1984. Effects of pyrethroids on respiration in the two spotted spider mite (Acari: Tetranychidae). *Journal of Economic Entomology* **77**: 1376-1380.
- Meyer R H. 1972. Response of bloom and fruit set to plant spray oils on apple. *Journal of Economic Entomology* **65**: 1408-1410.
- Miller R L. 1983. Spray oil insecticides effectively control some insects and mites. *American Nurseryman* **158**: 37-43.
- Neal J W, McIntosh M S and Gott K M. 1986. Toxicity of clofentezine against two spotted and carmine spider mite (Acari: Tetranychidae). *Journal of Economic Entomology* **79**: 479-483.

- Negi M L. 2005. Evaluation of summer spray oils against Acarina, Pemphigid and Diaspidids infesting apple in HP. Thesis, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (HP), 115 p.
- \*Newcomer E J and Yother M A. 1927. Experiments for the control of the European red mite and other fruit-tree mites. *United States Department of Agriculture Technical Bulletin* 25: 33-34.
- \*Newcomer E J and Yothers M A. 1929. Biology of the European red mite in the Pacific North-West. *United States Department of Agriculture Technical Bulletin* 89: 1-69.
- Nickel J L and Wong T T Y. 1966. European red mite control on apple in California. *Journal of Economic Entomology* 59: 217-219.
- Nicolas J and Rykewaert P. 1986. Red spider mites of peach, *Panonychus ulmi* in Roussillon. *Arboriculturae Fruitiere* 33: 390-392.
- Nicotina M and Caprio E. 1996. Tests of selectivity on *Amblyseius andersoni* (Chant) and chemical control of *Panonychus ulmi* (Koch) and apple tree (*Malus pumila*) in the Caserta province. *Informatore Fitopatologica* 46(4): 48-53.
- \*Palevesky E, Oppenheim D, Reuveny H and Gerson U. 1994. The development of an action threshold for the control of the European red mite, *Panonychus ulmi* in the Upper Galilee of Israel. *Alon Hanotea* 48(6): 266-274.
- Palevesky E, Oppenheim D, Reuveny H and Gerson U. 1996. Impact of European red mite on Golden Delicious and Oregon Spur apples in Israel. *Experimental and Applied Acarology* 20(6): 343-354.
- \*Pap L, Hajimichael J and Bleicher E. 1996. Biological evaluation of SZI-121, a new miticide. *Journal of Environmental Science and Health Part B, Pesticides Food contaminants and Agricultural Wastes* 31(3): 521-526.
- \*Parrott P J, Hodgkiss H E and Serrine F A. 1906. Commercial miscible oils for treatment of the San Jose scale. *New York State Agricultural Experiment Station Bulletin* 281.
- Pearce G W and Chapman P J. 1947. Improved spray oils for fruit trees. *New York State Agriculture Experiment Station Farm Research* 13: 1-8.
- Pearce G W, Chapman P J and Avens W S. 1942. The efficacy of dormant type oils in relation to their composition. *Journal of Economic Entomology* 35: 211-220.
- Pickett A D, Patterson N A, Stultz H T and Lord F T. 1946. The influence of spray programs on the fauna of apple orchards in Nova Scotia: an appraisal of the prebloom and a method of approach. *Science and Agriculture* 26: 590-600.

- \*Pitre D and Bostanian N J. 1980. Preventive treatment against injurious mites on apple (*Panonychus ulmi* and *Aculus schlechtendali*). *Resume des Recherches Station de Recherches* 9: 25-26.
- Prasad V. 1974. *A Catalogue of Mites of India*. Indira Acarology Publishing House, Ludhiana, Punjab, 320 p.
- Pree D J and Wagner H W. 1987. Occurrence of cyhexatin and dicofol resistance in the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae) in Southern Ontario. *Canadian Entomologist* 119: 287-290.
- Pree D J, Marshall D B and McGarvey B D. 1992. Residual toxicity of dicofol, formetanate HCl, propargite, hexythiazox and clofentezine to European red mite on peach. *Canadian Entomologist* 124: 59-67.
- Pree D J. 1979. Toxicity of phosmet, azinphosmethyl and permethrin to the oriental fruit moth and its parasite, *Macrocentrus ancylivorus*. *Environmental Entomology* 8: 969-972.
- Pree D J. 1990. Resistance management in multiple pest apple orchards ecosystems in Eastern North America. In: *Pesticide Resistance in Arthropods*, R T Roush and B E Tabashnik (eds.), Chapman and Hall, New York, pp. 261-276.
- Pree D T, Bittner L A and Whitty K J 2002. Characterization of resistance to clofentezine in populations of European red mite from orchards in Ontario. *Experimental and Applied Acarology* 27(3): 181-193.
- Pritchard A E and Baker E W. 1955. A revision of spider mite family Tetranychidae, Memoirs Series Vol. 2. San Francisco Pacific coast, Entomological Society, 472 p.
- Rana V K and Bhardwaj S P. 2004. Bioefficacy of acaricides against European red mite, *Panonychus ulmi* on apple (*Malus domestica*). *Indian Journal of Agricultural Sciences* 74(11): 628-630.
- Rathman R J, Beers E H, Flexner J L, Riedl H, Hoyt S C, Westigord P H and Knight A C. 1990. Baseline bioassays with hexythiazox and clofentezine of three mite species (Acari: Tetranychidae) occurring on Washington and Oregon tree fruits. *Journal of Economic Entomology* 83(5): 1711-1714.
- \*Rauch F. 1985. Clofentezine: a new acaricide for fruit tree culture. *Defense des Vegetaux* 231: 13-17.
- Read A J. 1983. Bis clofentezine: novel compound for control of phytophagous mites. In: *Proceedings of 36<sup>th</sup> New Zealand weed and pest control conference*, Canterbury, New Zealand, pp. 261-264.

- Reissig W H and Hull L A. 1991. Hexythiazos resistance in a field population of European red mite (Acari : Tetranychidae) on apples. *Journal of Economic Entomology* 84(3): 727-735.
- \*Ross W A. 1926. Miscellaneous notes on lubricating oil spray with special reference to their use for pear psylla control. *Annual Report Entomological Society of Ontario* 56: 40-44.
- Schrader L and Kammereck R. 1996. Effect of horticultural mineral oils on apple and pear physiology. *Good fruit Growers* 47: 36-39.
- Shea W D. 1957. Efficiency of oils and other early season treatments for the control of European red mite. *Journal of Economic Entomology* 50: 518-519.
- Shepard H H. 1951. Petroleum, animal and vegetable oils, soaps, creosotes. **In:** *The chemistry and action of insecticides*. McGraw-Hill Book Co., pp. 191-232.
- \*Smith E H. 1952. Tree spray oils. *Advances in Chemistry* 7: 3-11.
- \*Smith J B. 1899. Crude petroleum as an insecticide. *New Jersey Agricultural Experiment Station Bulletin*, 138.
- \*Smith R H. 1932. The tank mixture method of using oil sprays. *California Agricultural Experiment Station Bulletin* 527.
- Smolarz S and Suski Z W. 1983. Fruit tree red spider control with flucythrinate and fenpropathrin. *Tenth International Congress of Plant Protection*. 1002.
- Spuler A, Overley F L and Green E L 1931. Oil sprays for summer use. *Washington Agriculture Experiment Station Bulletin* 252: 1-33 .
- Sridhar V and Rani B J. 2004. Bio-efficacy of milbemectin 1% EC on the two spotted spider mite, *Tetranychus urticae* (Koch) on rose grown under protected cultivation. *Journal of Ornamental Horticulture* 7(2): 210-212.
- Stamenkovic T, Stamenkovic S and Pantelic Z. 1984. The effect of the acaricide biscofentezin on *Panonychus ulmi* Koch (Acarina : Tetranychidae). *Zastita Bilja* 35(3): 271-276.
- Standyard M J, Foster R E and Gibb T J. 1998. Population dynamics of *Amblyseius fallacis* (Acari : Phytoseiidae) and European red mite (Acari : Tetranychidae) in apple trees treated with selected acaricides. *Journal of Economic Entomology* 91(1): 217-225.
- \*Sterk G, Peregrine D J. 1989. The influence of application timing on the activity of two ovolarvicidal acaricides against the fruit tree red spider mite, *Panonychus ulmi* (Koch). Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 54(3): 965-968.

- \*Swingle H S and Snapp O I. 1931. Petroleum oils and oil emulsions as insecticides, and their use against San Jose Scale on peach tree in south. *United States Department of Agricultural Technical Bulletin* 253: 1-48.
- Thakur Y. 2002. Studies on the biology and damage potential of European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of chemicals for its control. Ph.D. Thesis, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (HP), 133 p.
- Thwaite W G, Eslick M A and Nicol H I. 2002. Evaluation of petroleum derived spray oils for integrated pest and disease management in apple orchards. In: *Spray Oils Beyond 2000- sustainable pest and disease management*. G A C Beattie, D M Watson, M L Stevens, D J Rae and R N Spooner-Hart (eds.), University of Western Sydney, NSW, Australia, pp. 349-355.
- Tuovinen T. 1990. Chemical control of European red spider mite, *Panonychus ulmi* (Koch). *Annals Agriculturae Fenniae* 29(3): 195-204.
- Vigl J and Giuliani G. 1981. Bud burst spraying with mineral oils. *Obstbau Weinbau* 18(3): 90-92.
- Walter D E and Proctor H C. 1999. *Mites: Ecology, Evaluation and Behaviour*. University of New South Wales Press, Sydney. 529p.
- Welty C, Reissig W H, Dennehy T J and Weires R W. 1988. Susceptibility to hexythiazox of eggs and larvae of European red mite (Acari: Tetranychidae). *Journal of Economic Entomology* 81: 586-592.
- Welty C, Reissig W H, Dennehy T J and Weires R W. 1989. Activities of clofentezine against European red mite (Acari: Tetranychidae). *Journal of Economic Entomology* 82: 197-203.
- Welty C, Reissig W H, Dennehy T J and Weires R W. 1987. Cyhexatin resistance in New York population of European red mite (Acarina: Tetranychidae). *Journal of Economic Entomology* 81: 230-236.
- Westwood M N. 1978. Plant efficiency: growth and yield measurements. *Temperate zone pomology*. W H Freeman and Company San Francisco. pp. 119-120.
- Williams K, Brunner J and Drake S. 1996. Horticultural effects of summer oil applications. *Good Fruit Grower* 47: 50-52.
- \*Yother W W. 1918. Spraying for the control of insects and mites attacking citrus trees in Florida. *United States Department of Agriculture Farmers Bulletin* 933.

Zhou YuShu, Pu ChunShu, Chou GuiSheng, Zhang Ping and Mu LianXiao. 2005. Sensitiveness identification for three kinds of mites to acaricides. *China Fruits* 3:29-31.

Zwick R W, Fields G J and Mellenthin W M. 1976. Effect of mite population density on 'Newtown' and 'Golden Delicious' apple tree performance. *Journal of the American Society of Horticultural Science* 101(2): 123-125.

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***\*Original not seen***



# ABSTRACT



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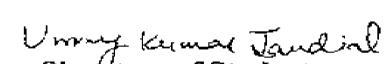
**Title of Thesis** : **Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some new acaricides for its control**

**Name of student** : Vinay Kumar Jandial  
**Admission No.** : H-2003-11-D  
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**Degree awarded** : Ph. D.  
**Year of award of degree** : 2007  
**No. of pages in thesis** : 117  
**No. of words in abstract** : 404

**ABSTRACT**

The present investigation on "Determination of economic threshold level for European red mite, *Panonychus ulmi* (Koch) on apple and evaluation of horticultural mineral oils and some acaricides for its control" were carried out during 2005-2006 and 2006-2007 at Regional Horticultural Research Station, Dr. Y.S. Parmar University of Horticulture and Forestry, Mashobra, Shimla, Himachal Pradesh and two private orchards located at Theog and Kathasu (Jubbal) in district Shimla, Himachal Pradesh. Studies on the effect of different levels of European red mite feeding at 0, 250, 500, 750 and 1000 cumulative mite days (CMDs) on yield and quality parameters of apple cv. Royal Delicious showed that yield and quality parameters of apples were not affected significantly at mite feeding of 250 CMDs and remained statistically at par with the control treatment. However, a significant reduction in mean fruit weight, total soluble solids, return bloom, fruit set, and crop load started at feeding level of 500 CMDs, whereas fruit firmness and fruit colour were not affected significantly at any level of mite feeding. Therefore, a tentative economic threshold level of 250 CMDs was established for *P. ulmi* on apples. The studies on the efficacy of Horticultural mineral oils (HMOs) against all stages of *P. ulmi* under laboratory conditions showed that HMOs at 1.5 per cent concentration were highly effective against all the stages of *P. ulmi*, and among the test HMOs, MAK All Season HMO proved most effective, followed by Orchol-13, Servo Horticultural Mineral Oil and Arbofine. All the test HMOs at 1.5 per cent concentration when applied at pink bud stage against overwintering eggs of *P. ulmi* proved highly effective under field conditions. Among the test HMOs, MAK All Season HMO at 1.5 per cent concentration proved most effective, followed by Orchol-13, Arbofine and Servo Horticultural Mineral Oil, each at 1.5 per cent concentration. Studies on the efficacy of HMOs as curative measure against *P. ulmi* under field conditions during summer showed that all the HMO formulations at 1.5 and 1.0 per cent concentration kept the mite population below economic threshold level up to 21 days. Among the test acaricides, milbemectin and fenpropathrin were effective against all stages of *P. ulmi*, whereas, both clofentezine and hexythiazox exhibited excellent activity against eggs, larvae, and protonymphs but were ineffective against deutonymphs and adults. As an ovicide and larvicide, milbemectin was most toxic followed by hexythiazox, clofentezine and fenpropathrin. Nymphs and adults were highly susceptible to milbemectin followed by fenpropathrin.

  
Signature of Major Advisor

  
Signature of Student

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# APPENDICES



**APPENDIX-I**

**Establishment of target cumulative mite days for *P. ulmi* on apple during 2005 at Kathasu (Jubbal), Shimla district**

Target threshold	Date of observation									
	6.4.05	13.4.05	20.4.05	27.4.05	4.5.05	11.5.05	18.5.05	25.5.05	1.6.05	
Mites/leaf	1.10	1.64	2.00	2.61	2.95	3.40	3.99	4.40	5.11	
Mite days	-	9.59	12.74	16.13	19.46	22.23	25.87	29.36	33.25	
CMDs	-	9.59	22.33	38.46	57.92	80.15	106.02	135.38	168.63	
Mites/leaf	0.90	1.20	1.60	2.25	2.70	3.48	4.20	4.70	5.25	
Mite days	-	7.35	9.8	13.47	17.33	21.63	26.88	31.15	34.82	
CMDs	-	7.35	17.15	30.62	47.95	69.58	96.46	127.61	162.43	
Mites/leaf	1.20	1.70	2.10	2.95	3.20	4.00	4.45	5.10	6.25	
Mite days	-	10.15	13.30	17.67	21.52	25.20	29.57	33.42	39.72	
CMDs	-	10.15	23.45	41.12	62.64	87.84	117.41	150.83	190.55	
Mites/leaf	1.26	1.54	1.98	2.71	2.90	3.22	3.81	4.15	4.95	
Mite days	-	9.80	12.32	16.41	19.64	21.42	24.61	27.86	31.85	
CMDs	-	9.80	22.12	38.53	58.17	79.59	104.20	132.06	163.91	

Each value a mean of five replications

Cont.....

Target threshold		Date of observation												
		8.6.05	15.6.05	22.6.05	29.6.05	6.7.05	13.7.05	20.7.05	27.7.05	31.7.05				
250 CMDs	Mites/leaf	5.90	7.10											
	Mite days	38.50	45.50											
	CMDs	207.13	252.63*											
500 CMDs	Mites/leaf	6.95	7.40	8.95	12.80	16.13								
	Mite days	42.70	50.22	57.22	76.12	101.26								
	CMDs	205.13	255.35	312.57	388.69	489.95								
750 CMDs	Mites/leaf	6.90	8.40	9.76	13.55	17.75	18.77	21.90**						
	Mite days	46.02	53.55	63.56	81.58	109.55	127.57	101.15						
	CMDs	236.00	290.12	353.63	435.26	544.81	672.38	773.53*						
1000 CMDs	Mites/leaf	5.60	6.92	9.10	13.11	16.40	18.21	22.10	27.40	31.10				
	Mite days	36.93	43.82	56.07	77.74	103.28	121.14	141.08	173.25	117.00				
	CMDs	200.84	244.68	300.75	378.49	481.77	602.91	743.99	917.24	1034.24*				

\*sprayed with recommended acaricides to check mite population

\*\*25<sup>th</sup> July

Each value a mean of five replications

Establishment of target cumulative mite days for *P. ulmi* on apple during 2006 at Kathasu (Jubbal), Shimla district

Target threshold	Date of observation																								
	8.4.06	15.4.06	22.4.06	29.4.06	6.5.06	13.5.06	20.5.06	27.5.06	3.6.06																
250 CMDs	Mites/leaf 1.40	Mite days -	CMDs -	Mites/leaf 1.33	Mite days -	CMDs -	Mites/leaf 1.70	Mite days -	CMDs -	Mites/leaf 0.81	Mite days -	CMDs -	Mites/leaf 1.40	Mite days -	CMDs -	Mites/leaf 1.70	Mite days -	CMDs -	Mites/leaf 1.11	Mite days -	CMDs -	Mites/leaf 1.40	Mite days -	CMDs -	
500 CMDs	1.80	11.20	14.18	18.02	23.10	27.65	32.02	37.70	40.78	43.40	49.15	56.87	64.59	72.31	80.03	87.75	95.47	103.19	110.91	118.63	126.35	134.07	141.79	149.51	157.23
750 CMDs	2.25	16.66	21.12	25.58	30.04	34.50	38.96	43.42	47.88	52.34	56.80	61.26	65.72	70.18	74.64	79.10	83.56	88.02	92.48	96.94	101.40	105.86	110.32	114.78	119.24
1000 CMDs	2.76	33.12	42.36	51.60	60.84	70.08	79.32	88.56	97.80	107.04	116.28	125.52	134.76	144.00	153.24	162.48	171.72	180.96	190.20	199.44	208.68	217.92	227.16	236.40	245.64

Each value a mean of five replications

Cont.....

Target threshold	Date of observation							
	10.6.06	17.6.06	24.6.06	1.7.06	8.7.06	15.7.06	22.7.06	29.7.06
250 CMDs	Mites/leaf	8.00						
	Mite days	50.40						
	CMDs	255.05*						
500 CMDs	Mites/leaf	7.33	8.40	12.16	17.21			
	Mite days	48.05	55.05	71.96	102.95			
	CMDs	243.23	298.08	370.04	472.99*			
750 CMDs	Mites/leaf	8.88	9.91	12.70	15.64	17.00		
	Mite days	56.63	65.76	79.14	99.19	114.24	130.38	
	CMDs	279.71	345.47	424.61	523.80	638.04	768.42*	
1000 CMDs	Mites/leaf	6.91	8.02	9.10	13.40	18.95	21.10	26.10
	Mite days	45.54	52.26	59.92	78.75	113.23	140.18	166.25
	CMDs	222.13	274.39	334.31	413.06	526.29	666.47	832.72
								1037.12*

Each value a mean of five replications

\*Sprayed with recommended acaricides to check mite population

**APPENDIX-II**

**Average temperature and relative humidity recorded in the Entomology Laboratory Regional Horticultural Research Station, Mashobra, Shimla during January, 2005 to December, 2006**

Period	Temperature (°C)			Relative humidity (%)
	Maximum	Minimum	Average	
<b>January 2005</b>				
1-8	17.60	09.50	13.55	68.70
9-16	16.00	06.20	11.10	69.40
17-24	17.10	07.10	12.10	62.70
25-31	15.40	09.60	12.50	86.10
<b>February 2005</b>				
1-8	17.50	09.60	13.55	57.60
9-16	15.75	07.85	11.8	68.00
17-24	15.90	09.00	12.45	66.85
25-28	16.30	09.80	13.05	71.30
<b>March 2005</b>				
1-8	17.70	09.35	13.53	72.83
9-16	19.15	11.00	15.08	70.17
17-24	18.00	11.93	14.97	78.60
25-31	19.50	12.25	15.88	74.50
<b>April 2005</b>				
1-8	22.30	16.40	19.35	72.83
9-16	24.00	17.00	20.50	70.00
17-24	24.83	19.17	22.00	60.83
25-30	26.50	20.75	23.63	58.00
<b>May 2005</b>				
1-8	26.37	21.25	23.81	69.25
9-16	23.67	18.00	20.84	78.33
17-24	24.10	18.92	18.92	78.16
25-31	24.70	18.40	21.55	78.00
<b>June 2005</b>				
1-8	22.70	15.90	19.30	72.60
9-16	26.25	15.25	20.75	82.75
17-24	24.00	18.50	21.25	83.20
25-30	24.80	20.40	22.60	83.75
<b>July 2005</b>				
1-8	22.64	19.43	21.04	87.86
9-16	23.83	19.33	21.58	84.67
17-24	21.58	19.17	20.38	92.33
25-31	21.83	19.08	20.46	92.50

Period	Temperature (°C)			Relative humidity (%)
	Maximum	Minimum	Average	
<b>August 2005</b>				
1-8	21.83	19.10	20.47	92.00
9-16	22.70	19.60	21.15	91.00
17-24	21.10	19.60	20.35	90.00
25-31	23.10	19.60	21.35	85.90
<b>September 2005</b>				
1-8	21.80	19.40	20.60	86.25
9-16	20.83	18.08	18.08	86.50
17-24	22.20	17.70	19.95	86.87
25-30	24.30	17.20	20.75	86.50
<b>October 2005</b>				
1-8	22.40	17.80	20.10	82.60
9-16	22.60	16.50	19.55	75.40
17-24	22.00	16.20	19.10	85.70
25-31	25.00	16.40	20.70	76.40
<b>November 2005</b>				
1-8	19.40	14.30	16.85	70.00
9-16	19.10	11.90	15.50	73.35
17-24	18.80	11.85	15.33	68.40
25-30	18.70	13.35	16.03	69.35
<b>December 2005</b>				
1-8	18.90	10.20	14.55	63.70
9-16	17.40	10.10	13.75	67.40
17-24	14.10	08.80	11.45	69.30
25-31	14.35	08.20	11.28	70.50
<b>January 2006</b>				
1-8	15.40	8.10	11.75	68.40
9-16	18.60	10.00	14.30	63.40
17-24	16.00	07.10	11.55	66.30
25-31	13.10	08.08	10.59	76.90
<b>February 2006</b>				
1-8	10.50	06.10	8.30	66.00
9-16	10.40	06.00	8.20	77.20
17-24	13.10	08.20	10.65	70.60
25-28	12.30	07.40	9.85	67.40
<b>March 2006</b>				
1-8	14.00	07.12	10.56	72.75
9-16	18.17	07.50	12.84	75.00
17-24	16.17	08.06	12.12	77.00
25-31	19.07	12.64	15.86	70.14

Period	Temperature (°C)			Relative humidity (%)
	Maximum	Minimum	Average	
<b>April 2006</b>				
1-8	22.00	15.50	18.75	72.70
9-16	22.60	18.36	20.48	63.86
17-24	23.50	18.33	20.92	70.17
25-30	21.40	18.30	19.85	68.25
<b>May 2006</b>				
1-8	25.40	19.33	22.37	67.70
9-16	21.88	16.90	19.39	86.10
17-24	25.20	19.58	22.39	76.00
25-31	24.50	18.75	21.63	74.00
<b>June 2006</b>				
1-8	24.30	18.50	21.40	81.00
9-16	24.40	21.67	23.04	86.04
17-24	21.10	17.17	19.14	84.00
25-30	24.20	19.60	21.90	82.60
<b>July 2006</b>				
1-8	22.33	20.08	21.21	85.83
9-16	23.70	20.70	22.20	82.00
17-24	20.64	19.00	19.82	89.85
25-31	20.30	18.30	19.30	85.85
<b>August 2006</b>				
1-8	22.10	18.70	20.40	85.00
9-16	22.90	19.40	21.15	84.40
17-24	22.29	19.21	20.75	87.43
25-31	21.58	19.00	20.29	89.33
<b>September 2006</b>				
1-8	23.36	19.43	21.40	84.71
9-16	23.17	18.67	20.92	79.50
17-24	23.92	18.08	21.00	82.33
25-30	27.20	17.10	22.15	77.60
<b>October 2006</b>				
1-8	28.10	17.50	22.80	70.00
9-16	29.75	17.20	23.48	62.10
17-24	27.10	18.38	22.74	65.40
25-31	21.70	15.40	18.55	74.20
<b>November 2006</b>				
1-8	19.00	40.40	29.70	78.40
9-16	18.70	13.80	16.25	75.10
17-24	18.00	12.00	15.00	77.35
25-30	17.80	11.50	14.65	76.40
<b>December 2006</b>				
1-8	16.50	10.40	13.45	74.40
9-16	19.20	09.40	14.30	70.00
17-24	19.55	09.95	14.75	67.70
25-31	20.25	10.40	15.33	66.95

**APPENDIX-III**

**Meteorological data recorded at Regional Horticultural Research Station, Mashobra, Shimla during January, 2005 to December, 2006**

Year & Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Snowfall (cm)
	Maximum	Minimum	Maximum	Minimum		
<b>2005</b>						
January	11.4	1.0	61.0	51.0	7.30	87.1
February	10.8	2.2	61.1	56.0	89.9	47.9
March	16.7	6.0	47.0	54.0	162.2	-
April	20.8	9.6	47.0	41.0	33.2	-
May	24.8	13.0	39.0	33.0	21.4	-
June	28.5	15.1	59.0	50.0	142.1	-
July	22.8	13.7	76.0	55.0	241.8	-
August	22.5	13.3	91.3	86.0	184.0	-
September	24.7	10.0	72.0	60.8	19.1	-
October	22.8	9.8	56.0	49.0	7.8	-
November	17.6	7.4	66.8	43.8	9.0	-
December	14.4	4.0	56.5	45.0	22.7	-
<b>2006</b>						
January	10.8	1.0	51.0	40.0	26.4	40.6
February	5.4	0.6	41.0	36.0	19.1	109.0
March	15.4	3.9	27.0	27.0	43.6	5.8
April	22.8	10.5	42.0	20.0	22.0	-
May	25.3	12.2	61.5	52.0	92.4	-
June	23.5	13.0	78.5	72.0	375.9	-
July	21.2	13.6	83.4	80.4	550.0	-
August	22.4	13.7	81.8	75.3	9.0	-
September	23.4	10.4	67.8	58.8	9.0	-
October	22.7	8.8	62.8	52.2	-	-
November	16.7	4.0	64.3	55.0	2.6	-
December	16.1	3.2	58.0	50.3	-	-

## Appendix –IV

### Mode of Action of Acaricides

1. **Milbemectin:** It acts a agonist of GABA (g-Amino butyric acid) in insect peripheral nervous system by enhancing binding of GABA, resulting in increased chloride ion flow. It has contact and stomach action with limited plant systemic activity but exhibits translaminar movement.
2. **Hexythiazox and Clofentezine:** They are mite growth inhibitors. The exact mode of action of these mite growth inhibitors is still not well understood. They kill the eggs before the mites hatch and also some immature stages. Adult mites are not killed, although adults exposed to residues may lay eggs that are not viable.
3. **Fenpropaphrin:** Inhibition of axonic transmission in the nervous system probably by blocking the  $\text{Na}^+$  gates in the open state.

**APPENDIX-V**

**Analysis of Variance for fruit weight (Table 3 and 4)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	42.60	10.65	120.23	32.92
Treatment	4	2035.80	508.94	3223.70	805.92
Error	16	166.24	10.39	389.89	24.37

**Analysis of Variance for total soluble solid (Table 3 and 4)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	0.531	0.132	1.455	0.638
Treatment	4	10.888	2.722	15.628	3.907
Error	16	1.100	0.069	2.496	0.156

**Analysis of Variance for fruit firmness (Table 3 and 4)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	9.309	2.327	9.066	2.266
Treatment	4	1.160	0.290	0.858	0.214
Error	16	16.626	1.039	28.366	1.774

**Analysis of Variance for Fruit colour (Table 3 and 4)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	0.0018	0.000445	0.0105	0.00264
Treatment	4	0.0001	0.000025	0.0013	0.00032
Error	16	0.0063	0.000395	0.0022	0.00014

**Analysis of Variance for Return bloom (Table 5 and 6)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	1.009	0.252	2.897	0.724
Treatment	4	20.094	5.023	47.469	11.867
Error	16	1.442	0.090	5.106	0.319

**Analysis of Variance for Fruit set (Table 5 and 6)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	31.521	7.880	13.825	3.456
Treatment	4	374.520	93.631	538.030	134.510
Error	16	51.594	3.225	107.180	6.698

**Analysis of Variance for Fruit load (Table 5 and 6)**

Source of variation	df	2005		2006	
		SS	MSS	SS	MSS
Replication	4	0.642	0.160	0.779	0.194
Treatment	4	11.922	2.980	16.797	4.199
Error	16	1.715	0.107	3.795	0.237



Analysis of Variance for winter egg hatch of *P. ulmi* under field conditions (Table 10)

Source of variation	df	Days after treatment											
		7			14			21			30		
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS		
Replication	3	0.093	0.030	9.247	3.082	6.618	2.206	51.233	17.078				
Treatment	12	7.520	0.627	4374.20	364.52	9537.40	794.78	9763.80	813.65				
Error	36	0.951	0.026	196.78	5.466	306.44	8.512	186.73	5.187				

Analysis of Variance for bio-efficacy of different HMOs against *P. ulmi* under field conditions during 2005 (Table 11)

Source of variation	df	Days after treatment														
		3			7			14			21			30		
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS			
Replication	3	0.098	0.033	0.050	0.017	0.114	0.038	0.331	0.105	0.093						
Treatment	12	36.643	3.053	41.138	3.428	54.524	4.543	62.968	5.247	4.344						
Error	36	1.990	0.055	1.888	0.052	1.129	0.031	2.428	0.067	0.048						

Analysis of Variance for bio-efficacy of different HMOs against *P. ulmi* under field conditions during 2006 (Table 12)

Source of variation	df	Days after treatment														
		3			7			14			21			30		
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS			
Replication	3	0.150	0.050	0.003	0.001	0.154	0.051	0.016	0.005	0.023						
Treatment	12	25.877	2.156	38.639	3.219	42.733	3.561	38.700	3.225	3.069						
Error	36	1.556	0.043	1.237	0.034	0.657	0.018	1.427	0.039	0.023						

# Curriculum vitae

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