BIOLOGY AND MANAGEMENT OF RICE LEAF MITE, *Oligonychus oryzae* (HIRST) (ACARI: TETRANYCHIDAE)

By

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(2013-11-172)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF HORTICULTURE

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DECLARATION

I, **Aswin T.** hereby declare that this thesis entitled **"Biology and management of the rice leaf mite, *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae)"**is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled"**Biology and management of the rice leaf mite, *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae)**" is a record of research work done independently by **Mr. Aswin T.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Aswin T.**, a candidate for the degree of Master of Science in Agriculture, agree that this thesis entitled **'Biology and management of the rice leaf mite, *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae)'** may be submitted by **Mr. Aswin T.**, in partial fulfillment of the requirement for the degree.

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THIS THESIS IS ONLY A BEGINNING OF MY JOURNEY...

DEDICATED TO MY INSPIRING PARENTS, BROTHER AND FRIENDS FOR BEING THE PILLOWS, ROLE MODELS, CATAPULTS, CHEERLEADING SQUAD AND SOUNDING BOARDS I HAVE NEEDED.

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. . . . Any omission does not mean lack of gratitude.

ASWIN T.

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20-08-2015 **(2013-11-172)**

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the World and forms staple food for more than 50 per cent of the global population. Nearly 90 per cent of the area, production and consumption of rice is confined to South East Asian countries. India is the second largest producer of rice in the World with an average production of 105.31 million tonnes (Food and Agricultural Organisation, 2013). The yield levels of paddy are greatly influenced by many factors, of which the role of insect and non insect pests is substantial, calling for frequent interventions.

In recent years, mites have emerged as serious pests of rice causing considerable damage, particularly in South India (Muthiah, 2007). The rice leaf mite *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae) and the sheath mite *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae) are considered as major pest of rice. Among these, the rice leaf mite *O. oryzae* is the predominant species. Hirst (1926) isolated paddy mite *Paratetranychus oryzae*, from Coimbatore and later renamed it as *Oligonychus oryzae* (Hirst).

Rice leaf mite becomes serious under field conditions particularly during summer months. Large number of different stages of the mite colonise the undersurface and desap the leaves causing white speckles on the upper surface which eventually turn yellow and dry up. A reduction of yield of upto 25 per cent has been estimated due to the severe infestation of this mite (Misra and Israel, 1968).

Sporadic incidence of the leaf mite has been reported recently from many rice growing tracts of Kerala where intensive cultivation is being practiced (Bhaskar and Thomas, 2011). At present, farmers depend mostly on conventional insecticides and acaricides for managing the mite. This can lead to problems like resurgence and adverse effects on native natural enemy fauna. Decreased efficacy of conventional pesticides as well as increased concerns over their use in rice ecosystems have emphasised on the need for identifying safer, more effective acaricide molecules for management of mite. However, no such study on the same has been conducted on *O. oryzae*, an emerging mite pest of rice in Kerala.

It is in this context that the present study entitled "Biology and management of the rice leaf mite, *O. oryzae* (Acari: Tetranychidae) on rice" was undertaken with the following objectives:

- To study the biology of *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae) on rice
- To evaluate the bioefficacy of new acaricide molecules and botanicals against the rice leaf mite

Review of Literature

2. REVIEW OF LITERATURE

Rice leaf mite *Oligonychus oryzae* (Hirst) is emerging as a major pest of rice in Kerala. The literature pertaining to the biology and management of *O. oryzae* and related species are discussed hereunder.

2.1 Incidence of leaf mite *Oligonychus oryzae* on rice

The occurence of *O. oryzae* on rice was first reported from South India by Cherian (1931). Misra and Israel (1968) reported that continuous feeding by all stages of the mite lead to yield reduction of 25 per cent. Later, several workers have reported incidence of the leaf mite from different parts of India, including Kerala, Tamil Nadu and Orissa (Lakshmi *et al.*, 2008).

(Rai *et al.,* 1977) reported a severe infestation of rice mite, *O. oryzae* at Mandya in Karnataka during 1976. Infested leaves became white between the veins and eventually shredded, while the veins themselves remained green. Eggs were found on the upper and lower leaf surface almost in equal numbers, but nymph and adult populations were much denser on the upper surface.

Similar attack of rice mite *O. oryzae* was also recorded from Vallanad, in Tamil Nadu, during September 1985. Nearly cent per cent infestation was recorded on rice variety IR56. Eggs, nymphs and adults were found on both sides of the leaf blade. Infested plants become yellowish-white with severe leaf mottling. High temperature of 35°C and dry weather for 30 days before the infestation was thought to have encouraged the population build up of the pest (Veluswamy *et al.,* 1987).

A severe incidence of *O. oryzae* was reported on 13 IR elite lines and six rice varieties in screenhouse trials in Tamil Nadu. Fifty days after planting, leaves showed yellowing symptoms (Karupuchamy *et al.,* 1987).

In a field trial conducted at Orissa to evaluate 16 rice varieties for resistance to *O. oryzae*, none of the test varieties was found to be free from mite infestation (Prakash and Rao, 1988).

Misra and Israel (1968), Rao and Kulshreshtha (1985), Swamiappan (1986), Veluswamy *et al.* (1987), Prakash and Rao (1988) and Lakshmi *et al.* (2008) studied the population dynamics of *O. oryzae* on different rice cultivars from India. Bright sunny weather followed by wet seasons was the most suitable condition for multiplication of the mites.

Severe incidence of *O. oryzae* was reported during 1997-98 from Jammu, India (Singh *et al.*, 2000). Later, the mite was reported from eastern Uttar Pradesh, at NDUAT-Crop research station, Masodha, Faizabhad (Singh, 2001).

Sporadic incidence of the mite in serious proportions has been reported from Palakkad district of Kerala during July, 2010 (Bhaskar and Thomas, 2011).

2.2 Biology of *Oligonychus* spp.

For the successful management of any pest, a thorough knowledge regarding its biology is necessary. The literature pertaining to the biology of *O. oryzae* and closely related species are reviewed below.

The life cycle of spider mite consist of an egg stage which on hatching passed through three primary stages – the larva, nymph (protonymph and deutonymph) and adult (Krantz, 1970). The immature stages *viz.*, larva and nymphs were followed by short quiescent stages (nymphochrysalis, deutochrysalis and teleiochrysalis), during which moulting took place (Patil, 2005).

2.2.1 Biology of *Oligonychus* spp on different crops

Das and Das (1967) studied the life history of *Oligonychus coffeae* Nietner at five constant temperatures. Pre ovipositional period ranged from 2 days at 20°C to 1 day at 32°C. Oviposition period ranged from 31 days at 20°C with a mean fecundity of 107 eggs per female to 6 days at 32°C with a mean fecundity of 12 eggs per female. Incubation period ranged from a mean of 11 days at 20°C to 4 days at 32 °C. The range for larval development time was 3 days at 20°C to 2 days at 30°C.

Haque *et al.,* (2007) conducted an experiment to study the duration of different developmental stages of *O. coffeae* in six generations during different seasons of the year on rose. The eggs of *O. coffeae* developed to adult within the shortest duration of 5.30 ± 0.16 days at 30.28°C and 76 % RH in June, but it took 12.91±0.21 days at 19.80°C and 75.41% RH in January.

The biology of *Oligonychus perseae* Tuttle, Baker and Abbatiello was studied at four different temperatures on avocado leaves *(Persea americana* Mill.). The time required for development from egg to adult was 34.89, 16.90, 13.87 and 9.81 days, at 15, 20, 25 and 30°C, respectively (Aponte and Mcmurtry, 2009).

Sridhar *et al.* (2010) studied the biology of *O. indicus* in 12 grain sorghum cultivars. Studies revealed that the effect of plant age was significant on the biology of the spider mite in all genotypes and duration of life cycle was longer at the flag leaf stage.

Das *et al.,* (2012) studied the effect of temperature and diet on growth and development of the red spider mite *O. coffeae*. The studies showed that the duration of life cycle was prolonged up to 18.79 days at 20°C, and reduced to 8.06 days at

35°C. The longevity of adult male and female were 12.7 and 28.3 days, respectively at 20°C.

A life table study was conducted on six host plants (date palm varieties Deglet Noor, Alig, Kentichi, Bessr, and Deglet Noor pinnae and sorghum leaves) showed that the life cycle of *Oligonychus afrasiaticus* McGregor differed among host plants with average values of 10.9 days on sorghum leaves. Relatively, fecundity and intrinsic rate of increase was higher, while average longevity was lower on sorghum leaves (Chaaban *et al*, 2012).

Under laboratory conditions, the duration of life cycle of *O. coffeae* was found to be 14.47 days. This included incubation period, duration of larva, protonymph, deutonymph, duration of life cycle, fecundity, pre-oviposition, oviposition and post oviposition periods (Mazid *et al.*, 2013).

The pre-oviposition, oviposition periods and fecundity of mated and unmated females of *Oligonychus biharensis* Hirst were studied on cowpea at 30 ± 2°C under laboratory conditions and it were recorded as 1.5 days, 11.5 ± 0.75 days and 50.9 ± 4.7 eggs for mated female and 40.2 ± 1.4 eggs for unmated females (Kaimal, 2013).

2.2.2. Biology of Rice leaf mite *O. oryzae*

The biology for *O. oryzae* had been studied by different authors. Misra and Israel (1968) developed techniques for rearing mites on rice leaves in the laboratory in Cuttack and also conducted studies on life-history of *O. oryzae*. The development period from egg to adult on an average was 10.75 days for males and 13.25 for females. Parthenogenetic females laid fewer eggs that developed into males only, whereas fertilized eggs gave rise to males and females in the ratio 1: 2.7. Similar observations were made by Susan (1976); Rao and Kulshreshtha (1985).

The life span of adult female *O. oryzae* could be further divided into a short pre-oviposition period, oviposition period lasting for few days and post oviposition period which is longer than the pre-oviposition period (Zhi-Qiang, 2003).

Nayak *et al.* (2008); Radhakrishna and Ramaraju (2009) studied the biology of *O. oryzae* on rice under laboratory conditions. The total developmental period required for the males was found to be greater than that observed for females. The development of egg, larva, protonymph and deutonymph of *O. oryzae* was completed in 5.9, 2.23, 2.27 and 2.42 days respectively. The total time for development of male and female were recorded as 10.58 and 12.64 days.

2.3 Management of mites

A brief review on use of acaricides for management of spider mites infesting crops is presented here under.

2.3.1 Conventional synthetic acaricides for management of spider mites

Conventional synthetic acaricides were in use for several years against mite pests on various crops.

Six pesticides, *viz.* dicofol, binapacryl, carbophenothion, lime-sulphur solution, dimethoate and phosalone, each at four different concentrations, were tested against the red spider mite *O. coffeae.* All, except lime-sulphur were found to be effective acaricides and also showed ovicidal action (Tripathi and Sriram, 1970).

Sprays containing 0.05% phosphamidon or 0.03% dimethoate were found to be effective in controlling the population of *O. oryzae* in Mandya district of Karnataka (Rai *et al.*, 1977).

Patel (1982) had shown that the use of carbaryl or endosulfan precipitated the outbreaks of *Tetranychus telarius* Linn. in eggplants grown in the field.

Field study to evaluate the efficacy of insecticide molecules against *Oligonychus* spp. in nine cultivars of rice indicated that dicofol and quinalphos were efficient in controlling the mite population (Mukerjee *et al*., 1989).

Sannaveerappanavar and Channa Basavanna (1989) indicated that dicofol is highly effective against all stages of mite when tested against *T. ludeni* in the laboratory.

Eight pesticides *viz*., tetradifon (0.05%), dicofol (0.05%), ethion (0.05%), decamethrin (0.0014%), cypermethrin (0.025%), fenpropathrin (0.01%), endosulfan (0.07%) and malathion (0.1%) were tested against *O. indicus* on sorghum at the farm of University of Agricultural Sciences, Bangalore. Among them, ethion, tetradifon and dicofol were found to be superior over other chemicals (Manjunatha and Puttuswamy, 1990).

James and Price (2002) reported that imidacloprid caused resurgence of *T. urticae* by causing an intrinsic increase in egg production in the exposed mites.

Endosulfan 35 EC, monocrotophos 36 EC, dichlorvos 76 EC, quinalphos 25 EC, nethrin (each @ 1.25 lit/ha) and lime sulphur wash (1:30) were tested against *Oligonychus sacchari* Mcgregor in sugarcane. The results revealed that spraying of plants with lime-sulphur (1:30) as well as nethrin @ 1.25 lit/ha gave significant reduction in the frequency of mite infestation as compared to rest of the treatments including control (Singh *et al*, 2003).

Nine acaricides were evaluated for efficacy against *T. urticae* infesting aubergine in Varanasi, Uttar Pradesh, and among them dicofol 18.5 EC was found to be most promising (Siddiqui and Singh, 2006).

Resistance to dicofol was observed on mite species of okra in parts of Gujarat, necessitating the use of newer acaricidal molecules with novel modes of action (AINPAA, 2009).

Use of synthetic pyrethroids has eliminated the natural enemies of mites and at sub-lethal concentrations, stimulated reproduction of mites leading to resurgence of mite pests on crops, mainly vegetables like okra and brinjal (Srinivasa *et al.*, 2010).

The bioefficacy of insecticides against rice leaf mite *O. oryzae* was studied under laboratory conditions at Karaikkal. The study revealed that methyl demeton 25 EC at 0.42 per cent concentration was superior against nymph and adult mites (Srimohanpriya *et al.*, 2010).To overcome these limitations, it is essential that eco-friendly approaches are exploited using botanicals and new synthetic acaricides molecules having different modes of action.

2.3.2 Botanicals for the management of spider mites

Umamaheshwari *et al.* (1999) noticed that among the different neem formulations and castor oil tested for their efficacy against red spider mite, following dip method in the laboratory, neem oil gave significantly higher mortality (79.60 %) compared to the other treatments tested.

Abhilash (2001) conducted field trial for managing *T. ludeni* on cowpea using botanicals. The results revealed that neem oil five per cent could be successfully used for suppressing the mite population. It was followed by neem garlic two per cent emulsion. But after five days, the mite population increased which showed the relevance of requirement for repeated application of botanicals.

Patil (2005) studied the effect of various botanicals against *T. macfarlanei.* Results revealed that neem oil showed maximum egg hatch inhibition of 55.18 per cent. Neem oil also caused significantly higher mortality of adults (21.67 %) at 24 hours which was on par with NSKE (18.33 %).

Neem oil two per cent was found to be effective in controlling the mite population on rose cultivated under polyhouse condition which brought out maximum reduction of mite population compared to other botanicals. NSKE five per cent was moderately effective in controlling the mite population on rose (Kumar, 2007).

Among the various botanicals studied for efficacy against red spider mite on brinjal in Karnataka, neem oil two per cent exhibited maximum acaricidal action (Patil and Nandihalli, 2009). At Varanasi, among the various botanicals tested against spider mites, NSKE five per cent proved to be the best, followed by azadirachtin and mahua oil respectively (AINPAA, 2009).

The studies on two spotted spider mites indicated that azadirachtin, in addition to being toxic to various development stages, acted as antifeedant, reduced the fecundity, fertility and shortened the life span of adult mites (Marcic *et al.*, 2011).

Krishna and Bhaskar (2013) tested the ovicidal activity of neem oil two percent against *T. urticae* on okra in the laboratory and recorded 67 per cent mortality.

2.3.3 New acaricide molecules for the management of spider mites

Acaricides such as kelthane 18.5 EC (20 ml/20 l of water), propargite 30 WP (30g/20 l), hexythiazox 20 EC (40 ml/20 l of water), amitraz 20 EC (30 ml/20 l of water) and bromopropylate 25 EC (30 ml/20 l of water) were identified as effective pesticides against *T. truncatus* in the field when mite population increased (Kongchuensin and Kulpiyawat, 1997).

Machini (2005) studied the effect of spiromesifen 240 SC on the red spider mites *T. evansi*. The chemical showed 100 per cent ovicidal activity and did not have acute toxicity on the motile stages of the mites, but completely deterred the adult females from laying eggs.

An experiment was conducted to evaluate the efficacy of spiromesifen against *O. coffeae*. Six different concentrations of spiromesifen (0.01, 0.005, 0.002, 0.001, 0.0006 and 0.0003%) and a standard dose of dicofol (0.05%) along with an untreated control (water spray) were tested under laboratory conditions. The results revealed that spiromesifen provided good mortality of mites at lower concentrations (Chakraborthy *et al.*, 2006).

In a laboratory bioassay conducted by Negi and Gupta (2007), no larva of *T. urticae* was found to survive for more than 48 hours in fenazaquin treated apple leaves. There was also no adult survival in fenazaquin treatment, proving it to be a promising candidate for mite management.

In a field trial conducted for the management of *T. urticae* on brinjal, spiromesifen 240 SC resulted in significant reduction in mite population seven days after treatment, which was on par with dicofol 18.5 EC. The next best treatment was fenazaquin 10 EC (Onkarappa *et al.*, 2007).

The efficacy of different acaricides was evaluated in Siruguppa, Karnataka against *O. oryzae* on rice. The acaricides significantly reduced mite population over the control in which abamectin 1.9 EC resulted in the lowest mean mite population (18.47/ cm^2 leaf area), and highest cumulative per cent mortality of active stages at 1, 3 and 7 DAT were 61.80, 80.51 and 86.10% respectively (Nayak *et al.*, 2008).

Radhakrishnan and Ramaraju (2009) found the fenazaquin 10 EC at the rate of 1mlL^{-1} to be effective against the eggs, while abamectin 1.8 EC at the rate of 0.5mlL^{-1} was effective acaricide the nymphs and adults of *O. oryzae*.

Studies on the bioefficacy of insecticides against *O. oryzae* revealed that methyl demeton 25 EC at 1000 ml ha^{-1} and novaluron 10 EC at 1000 ml ha^{-1} were effective in reducing the rice leaf mite population at 1, 3, 7 and 14 days after treatment under field condition (Srimohanapriya *et al.*, 2010).

Bioefficacy study was conducted against leaf (*O. oryzae*) and sheath (*Steneotarsonemus spinki*) mites in rice (cv. Vajram) under field condition with the treatments, profenofos 50 EC (500 g a.i./ha), ethion 50 EC (500 g a.i./ha), propargite 57 EC (570 g a.i./ha), spiromesifen 240 SC (72 g a.i./ha), fenpropathrin 30 EC (150 g a.i./ha), milbemectin 1.0% (2.5 or 4.5 g a.i./ha) and dicofol 18.5 EC (500 g a.i./ha). All the acaricides except milbemectin 1.0% at 2.5 g a.i. /ha were found to be effective in reducing mite population (Srimohanapriya *et al.*, 2010).

Misra (2011) conducted field trial at the Central Research Station Farm, Orissa University of Agriculture & Technology, Bhubaneswar to test the bio-efficacy of fenazaquin 10 EC against *T. urticae*. The results revealed that fenazaquin at 125 and 150 g a.i. ha^{-1} registered significantly lower mite population followed by dicofol at 250g a.i. ha^{-1}. Plots treated with fenazaquin at 125 and 150g a.i. ha^{-1} treatments recorded significantly higher fruit yield.

Field rates of newly introduced acaricides like fenazaquin, fenproparthrin, propargite and abamectin when compared with 95% lethal concentration (LC95 in ppm) value showed that the acaricides were effective at doses lower than the recommended dose against *O. coffeae* (Roy *et al.*, 2011).

An experiment was conducted at Banglore in farmer's field during summer, to evaluate fenazaquin and HMO, in comparison with the conventional acaricide molecule, dicofol against spider mites infesting tomato. Reduction in mite population to the tune of 52 to 81 per cent, 24 to 72 per cent and 46 to 85 per cent was recorded, respectively. Fenazaquin offered control over the mite to an extended period of two weeks compared to other treatments (AINPAA, 2011).

Saryazdi *et al* (2013) conducted leaf disc bioassay to study the effect of spiromesifen on eggs and gravid females of *T. urticae*. The results showed good ovicidal activity of spiromesifen, but the survival rate, total number of eggs laid per female and egg hatching rate were greatly reduced.

Sangeetha and Ramaraju (2013) tested the ovicidal activity of fenazaquin 10 EC at 125 g ai ha^{-1} against *T. urticae* on okra in the laboratory and recorded 81.25 per cent mortality with only 18.75 per cent egg hatchability.

Field trial conducted to study the efficacy of acaricides *viz.* propargite (0.057%), fenazaquin (0.0025%) and hexythiazox (0.005%) against two spotted spider mite *T. urticae* on strawberry revealed that maximum mortality of mite was observed in fenazaquin treated plants (0.2mites per leaf) followed by propargite (0.6 mites per leaf). Maximum population (9.4 mites per leaf) was recorded in hexythiazox treated plants. After seven days of spray, propargite and fenazaquin proved highly effective and recorded 0.6 and 1.4 mites per leaf respectively as against 27.4 and 26.7 mites per leaf in pre-count (AINPAA, 2013).

Fenazaquin 10 EC and spiromesifen 240 SC when tested along with the conventional acaricide, wettable sulphur for efficacy against *T. urticae*, fenazaquin recorded the minimum mite population at two, four and seven days after treatment which was on par with wettable sulphur. Though the population of mites two days after treatment was significantly high in spiromesifen compared to other treatments, it was found to be on par with them at four and seven days after treatment (AINPAA, 2013).

Polyhouse trial at Himachal Pradesh, to assess the efficacy of three acaricides *viz.* hexythiazox (0.005%), fenazaquin (0.0025%) and propargite (0.057%) and one Horticulture Mineral Oil, Servo 1 per cent against spider mites in beans recorded a maximum kill of mites on fenazaquin and propargite sprayed plants compared to all other treatments (AINPAA, 2013).

Krishna and Bhaskar (2013) tested the adulticidal activity of fenazaquin 10 EC against *T. urticae* on okra in the laboratory and recorded 100 per cent mortality 24 hrs after treatment.

Experiments conducted at Assam Agricultural University (AAU), for evaluating the bioefficacy of different acaricides *viz.*, etoxazole, bionol, spiromesifen and propargite against *O. coffeae* Nietner on tea revealed that spiromesifen 240 SC (100g.a.i/ha) was significantly superior over other acaricides at 1, 3, 7 and 10 days, after first spraying in reducing the mite population (Kachhawa *et al.*, 2014).

Material & Methods

3. MATERIAL AND METHODS

The present study was conducted in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara from February, 2014 to May, 2015. The objectives of the investigation were to study the biology of rice leaf mite, *Oligonychus oryzae* (Hirst) and to evaluate the efficacy of selected novel acaricide molecules and botanicals against *O. oryzae* on rice.

The methodology and techniques adopted for conducting various experiments based on the objectives set forth in the study are presented here under.

3.1 Biology of *Oligonychus oryzae* on Rice

The studies on the biology of rice leaf mite *O. oryzae* on rice was conducted in the Acarology laboratory of the Department of Agricultural Entomology during July-August, 2014 at 27 $\pm$ 3^0C and 70.2 $\pm$ 7 per cent relative humidity, using the rice variety Jyothi.

3.1.1 Field collection of *Oligonychus oryzae*

Twenty gravid females of *O. oryzae* collected from mite infested rice fields of Nenmara, Palakkad district were released separately on leaf bits of rice placed upside down in petriplates of 150 mm and lined with wet cotton pad. The mites were allowed to lay eggs and after ten days, one female and one male were selected randomly from each leaf bit for preparation of slides and further identification. The species identity of *O. oryzae* was confirmed by using standard taxonomic key (Gupta and Gupta, 1994). The characters such as thumb and claw process of pedipalp, tarsal claw and empodium, duplex setae on tarsi I and II and structure of aedeagus were considered for the same (Plate 1). This nucleus culture was used to mass culture *O. oryzae* in the laboratory for subsequent studies.

Plate 1. Taxonomic characters of *Oligonychus oryzae*

Plate 1a.Duplex setae leg I (40x)

Plate 1b.Thumb – claw process (40x)

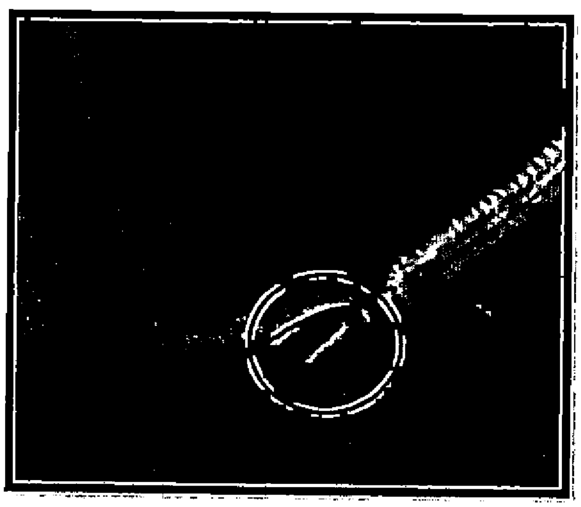


Plate 1c. Aedeagus (40 x)

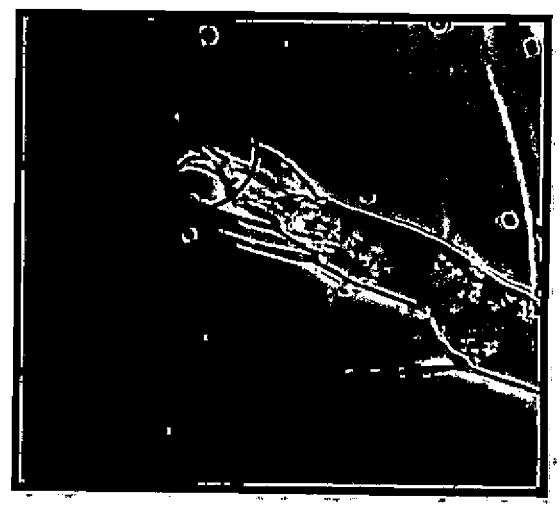


Plate 1d. Tarsal claw and empodium (40x

Plate 1. Taxonomic characters of *Oligonychus oryzae*

Plate 1a.Duplex setae leg I (40x)

Plate 1b.Thumb – claw process (40x)

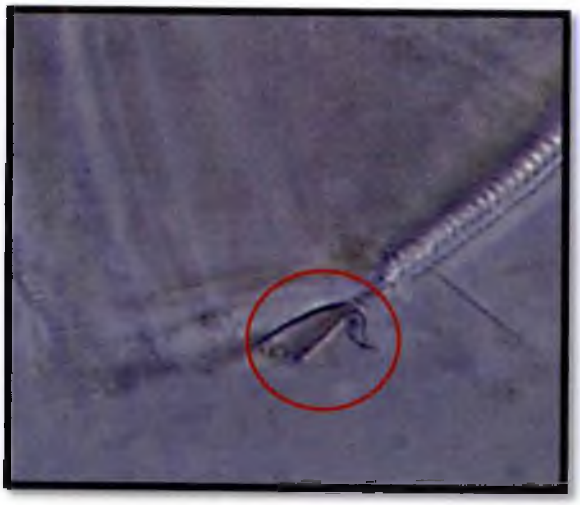


Plate 1c. Aedeagus (40 x)

Plate 1d. Tarsal claw and empodium (40x

3.1.2 Laboratory culturing of *Oligonychus oryzae*

Rice leaf mite *O. oryzae* was mass multiplied in the laboratory on rice seedling raised in plastic pots (Plate 2). For this three gravid females each collected from the culture maintained in Petri plates were released on each potted plant and allowed to multiply.

3.1.3 Life history of *Oligonychus oryzae*

The development and life history traits of *O. oryzae* were studied following the leaf bit method (Nayak *et al*, 2008). Leaf bits of $4\times1cm^2$ area were cut from rice leaves of healthy plants maintained in pots in poly house and placed upside down on wet cotton pad in Petri plates of 150 mm diameter (Plate 3) that were covered with lid after leaving a slight gap to prevent excessive moisture build up in Petri plate. In each Petriplate, five leaf bits were maintained. Sixty gravid females were collected from laboratory and transferred to individual leaf bits at the rate of two females per leaf bit for oviposition. Six replications were maintained. After 48 hours, the gravid females as well as the eggs were removed from the leaf retaining two 0-24 h old eggs on each leaf bit. Leaf bits were changed once every five days to ensure optimal nutrition for the mite.

3.1.3.1 Morphology and developmental duration of immature stages of *Oligonychus oryzae*

The development of immature stages of the mite was observed with the help of a Stereo Binocular Microscope (Leica EZ4 HD with 35 x magnification) at 2 h interval until they reached maturity.The morphology of different life stages of *O. oryzae* was studied. The duration of each stage namely, egg, larva, nymphs and quiescent stages were recorded till adult emergence. On emergence, the adult mites were sexed out to work out the developmental duration of different life stages separately for males and females.The values on developmental duration were expressed as mean days $\pm$ Standard Deviation (SD).

Plate 2. Stock culture of *O. oryzae* on plastic pots

Plate 3. Leaf bit method

Plate 3a. Release of gravid females on leaf bits ($4 \times 1\ cm^2$)

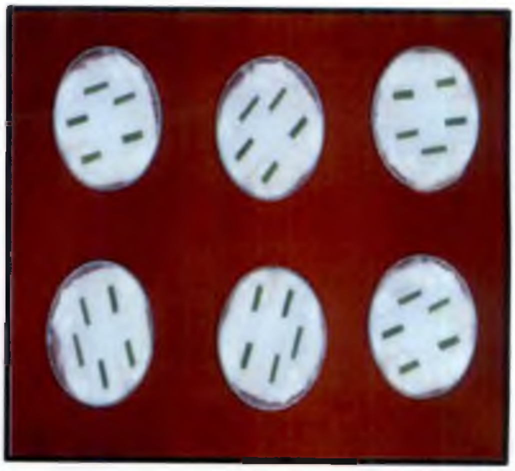


Plate 3b. Life history of *Oligonychus oryzae* - Experiment layout

3.1.3.2 Adult longevity

Newly emerged males and females were maintained on separate leaf bits to determine their longevity. Longevity of mated female was determined by placing a newly emerged female on a leaf bit onto which four males were released. The mites were allowed to mate and the males were removed 24 hours later. The mated female was maintained till death. Leaf bits were changed at every five days interval. Ten replications each were maintained for males, mated females and unmated females to work out the longevity which was expressed as mean days ± Standard Deviation (SD).

3.1.3.3 Reproductive biology of *Oligonychus oryzae*

To determine the duration of sexual development of mated female, one female teleiochrysalis was transferred to a leaf bit and four adult males were released onto the leaf bit and allowed to mate with the freshly emerged female. The males were removed 24 hours after the emergence of the female. The reproductive biology of unmated female was also studied by releasing only one teleiochrysalis on to leaf bit that moulted to female. Fifteen replications each were maintained for both mated and the unmated females. Observations on mating behaviour, pre-oviposition, oviposition and post-oviposition periods were recorded. The numbers of eggs laid by the mated as well as the unmated females were recorded till death of the female by replacing the leaf bits carrying eggs with fresh leaf bits at 24 h interval. The values were expressed as mean number of eggs per female ± Standard Deviation (SD).

3.1.3.4 Sex ratio and viability of eggs

Sex ratio and viability of eggs were studied following the method described by Gotch and Nagata (2001). The eggs laid by each mated as well as unmated female for the first five days were maintained and the viability was determined by counting the number of eggs that hatched out to larvae. From this, the per cent egg viability was worked out. The emerging mites were sexed out after reaching adulthood to determine the sex ratio. Ten replications each were maintained for both mated and unmated females.

3.1.3.5. Morphometric parameters of developmental stages of *Oligonychus oryzae*

Ten individuals each from different developmental stages from egg to adult were randomly selected and morphometric parameters were recorded. The diameter of egg and maximum body length and width of other developmental stages were recorded in micrometers (μm) using stereo binocular microscope (Leica EZ4 HD) equipped with image analyzer and expressed as mean ± Standard Deviation (SD).

3.2 Management of rice leaf mite *Oligonychus oryzae*

3.2.1 Laboratory bioassay

Bioassay studies were conducted in the laboratory to find out the efficacy of different treatments separately on eggs and gravid females using laboratory reared mite culture.

3.2.1.1 Ovicidal effect on eggs

Ovicidal bioassay was conducted on *O. oryzae* using topical application method with four new acaricide molecules, azadirachtin, neem oil and wettable sulphur with a standard check dicofol 18.5 EC and untreated control (Table 1).

Eggs of uniform age was obtained by transforming gravid females of *O. oryzae* from the mite culture individually on to 3 rice leaf bits (4×1 cm^2) placed in a Perti plate lined with moistened cotton pad with the help of a moistened zero size camel hair brush . The females were removed after 24 hours. Leaf bits containing *O. oryzae* eggs of uniform age were sprayed with the treatments to be tested using a hand atomizer (Plate 4). Untreated control was sprayed with water (Krishna and Bhaskar, 2013). The treated leaf bits with eggs were dried at room temperature for 30 minutes and placed in Petri plates. All treatments were replicated three times. Observations on mortality of eggs were recorded at 24, 48 and 72 h interval under the stereo binocular microscope.

3.2.1.2. Adulticidal on gravid females

The effect of different treatments (Table 1) on adult mites was studied by the leaf bit bioassay method (Plate 5). The required concentrations of the acaricides were prepared in water in beakers and leaf bits of 4×1 cm^2 were dipped in aqueous solution for ten seconds and then air dried for two hours. Ten gravid females of uniform age taken from the stock culture were released on to the treated leaf bits kept on wet cotton pad in Petri plate. Three replications were maintained for each treatment. Leaf discs dipped in water served as control, while those dipped in dicofol 18.5 EC served as standard check. Observations on mortality of adult mites were recorded at 24, 48 and 72 hours interval under the stereo binocular microscope and per cent mortality was calculated.

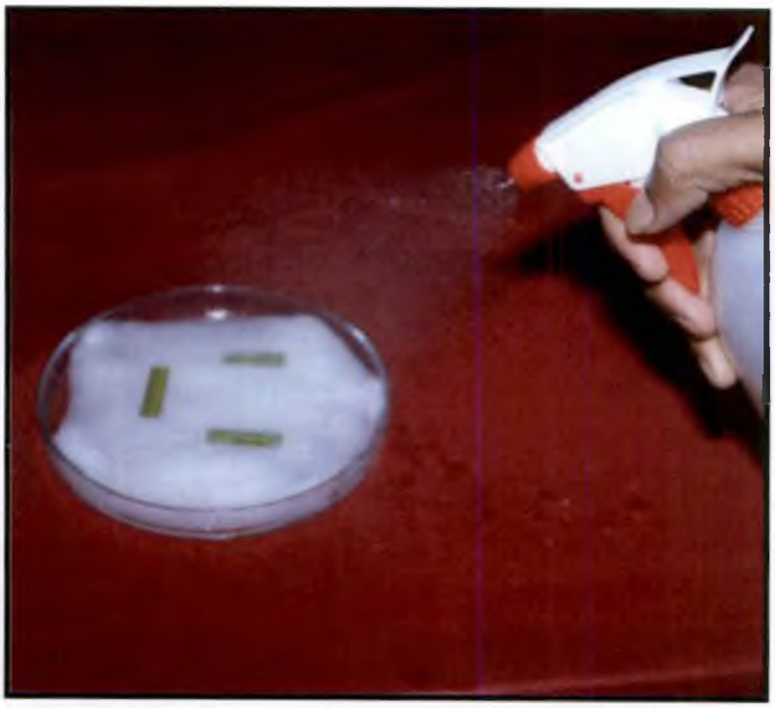


Plate 4. Topical application method

Plate 5. Leaf dip method

Table 1. Details of treatments against *Oligonychus oryzae* on rice under laboratory conditions

Sl.No	Treatments	Dosage (per 10 ml)
1	Fenazaquin 10 EC @ 125g ai/ha	25 μL
2	Spiromesifen 240 SC @ 100g ai/ha	8 μL
3	Fenpyroximate 5 SC @ 30g a.i. ha^{-1}	20 μL
4	Propargite 57 EC @ 600g a.i. ha^{-1}	20 μL
5	Neem oil 2%	200 μL
6	Azadirachtin 0.005%	50 μL
7	Wettable sulphur 80 WP @ 600g a.i. ha^{-1}	30 μL
8	Standard Check (Dicofol 18.5 EC @ 250g ai/ha)	25 μL
9	Untreated Control	Water spray

3.2.3. Data analysis

Data were transformed using square root transformation and subjected to one-way analysis of variance ($P < 0.05$). Means were compared by Duncan's Multiple Range Test (DMRT) to select the best treatments.

3.2.2. Evaluation of new acaricide molecules and selected botanicals against the rice leaf mite *Oligonychus oryzae* in pot culture

3.2.2.1 Mass culturing of *Oligonychus oryzae*

The mite culture was maintained on potted plants of rice (variety Jyothi) in the polyhouse of All India Network Project on Agricultural Acarology (AINPAA), Department of Agricultural Entomology (Plate 6). The culture was initiated by releasing laboratory reared *O. oryzae* on 45 days old potted plants. The pots were periodically replanted to reduce the effect of plant age on mite development and fecundity. Mite colonies were initiated by clipping a mite colonized rice leaf onto the leaf of a new plant.

3.2.2.2.Pot culture study

A pot culture experiment was conducted to evaluate the efficacy of four new acaricide molecules *viz*., spiromesifen 240 SC, fenazaquin 10 EC, fenpyroximate 5 SC and propargite 57 SC and two botanicals, neem oil 2 per cent and azadirachtin 0.005 per cent along with wettable sulphur 80 WP, a standard check, dicofol 18.5 EC and an untreated control, against *O. oryzae* on rice, using the variety Jyothi. The experiment was carried out in the polyhouse, of AINPAA, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during October–November, 2014. The crop was raised in pots and the experiment was laid out in Completely Randomized Block Design with six replications per treatment (Plate 7). Mites were released on 45 days old plants by stapling mite infested rice leaf bits of 4×1 cm^2 size with an average count of 30 mites per bit, at the rate of one bit per plant on the top leaf (Plate 8).

Treatments (Table 2) were imposed three weeks after the release of mites. Spray solutions was prepared by thorough mixing of measured quantity of the insecticide and required amount of water to form a uniform solution. The treatments

Plate 6. Mass culturing of *O. oryzae* on potted plants of rice in polyhouse

Plate 6. Layout of pot culture experiment

Plate 7. Leaf clip method of release

Plate 8. Leaf tray method

were applied using a hand operated high volume sprayer. Population counts of eggs and active stages of *O. oryzae* were recorded from $4\times1\text{cm}^2$ area each from three leaves per plant. For recording the observation, three leaf bits of $4\times1\text{cm}^2$ were cut at the rate of one leaf bit per pot. The bits were then placed on plastic trays lined with moistened cotton pad (Plate 9). The trays were brought to the laboratory and the mite populations were recorded using a Leica EZ4 HD stereo microscope. For observation of mite count under microscope. The leaf tray method of sampling was developed during the course of study as the leaf bits collected from rice plants rolled up immediately after incision, rendering counting being difficult. The population counts were recorded one day before spraying and 1st, 3rd, 7th, 10th and 14th day after spraying. The mean mite and egg counts were worked out and analyzed statistically.

3.2.2.3 Statistical analysis and interpretation of data

Data on mean population of mites were transformed using square root transformation. Population difference on one, three, seven,ten and fourteen days after treatment were tested by one way ANOVA. The result obtained was subjected to DMRT (Duncan's Multiple Range Test). The mean per cent reduction in population of mites over untreated control was also worked fourteen days after treatment application.

Table 2. Treatments evaluated against rice leaf mite, *Oligonychus oryzae* on rice in pot culture

Sl. No.	Treatments	Dosage	Trade name
1	T1: Fenazaquin 10 EC	125g a.i. ha^{-1}	Magister
2	T2: Spiromesifen 240 SC	100g a.i. ha^{-1}	Oberon
3	T3: Fenpyroximate 5 SC	30g a.i. ha^{-1}	Sedna
4	T4: Propargite 57 EC	600g a.i. ha^{-1}	Omite
5	T5: Azadirachtin 0.005%	5ml/l	Econeem plus
6	T6: Neem oil 2%	20ml/l	Neem oil
7	T7: Wettable sulphur 80WP	600g a.i. ha^{-1}	Accor
8	T8: Dicofol 18.5 EC	250g a.i. ha^{-1}	Hilfol
9	T9: Untreated Control	-	-

Experimental Results

4. EXPERIMENTAL RESULTS

The results of the experiments on biology and management of the rice leaf mite, *Oligonychus oryzae* are presented in this chapter.

4.1. Biology of *Oligonychus oryzae* on rice

The studies on the biology of rice leaf mite were conducted at AINPAA, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during the period from July-August 2014 at 27 $\pm$ 3^0C and 70.2 $\pm$ 7 % relative humidity, using the rice variety Jyothi.

4.1.1. Life history of *Oligonychus oryzae* on rice

The life cycle of rice leaf mite consisted of five different stages such as the egg, larva, protonymph, deutonymph and the adult. In between the stages from larva to adult, short quiescent intervals called nymphochrysalis, deutochrysalis and teleiochrysalis were also observed (Plate 10).

4.1.1.1. Morphology and developmental duration of immature stages of *O. oryzae*

The morphological characters and the duration of development of various life stages of *O. oryzae* presented in Table 3.

4.1.1.1.1. Egg

Eggs were laid singly or in small groups of 10-12 on the upper surface of leaf bits by gravid females. The eggs were spherical in shape and transparent. They were like tiny drops of water when freshly laid. Two dark reddish coloured eye spots, which resembled the simple eye of larvae, were clearly visible on the eggs. But the eggs turned dull white in colour and gradually turned to brown prior to hatching. The mean incubation period was 3.80 days for both males and females.

Table 3. Duration of development of *Oligonychus oryzae* on rice

Stage	Development period (Mean days ± SD)*	
	Male	Female
Egg	3.80±0.70	3.80± 0.70
Larva	1.37± 0.68	1.40± 0.31
Nymphochrysalis	0.73± 0.40	1.03± 0.90
Protonymph	0.91± 0.35	1.04±0.40
Deutochrysalis	0.69± 0.30	1.12± 0.57
Deutonymph	0.98± 0.28	1.30± 0.37
Teleiochrysalis	1.15± 0.38	1.20± 0.47
Total developmental period	9.87 ±0.72	10.47±0.51

***mean of 50 observations*

4.1.1.1.2. Larva

The eggs hatched out to larvae with 3 pairs of legs. Newly hatched larva was white coloured. They were spherical and small in size and crawled around for sometime. The body colour changed to pale green upon feeding. The simple eyes on the dorsum of propodosoma were clearly distinguishable. The mean larval period recorded was 1.37 days for males and 1.40 days for females.

4.1.1.1.3. Nymphochrysalis

Nymphochrysalis is the intermediate quiescent stage between larva and protonymph. During this stage, larva stopped feeding, remained attached to leaf surface and entered into quiescence, with the anterior two pairs of legs kept forward and close towards the body and the posterior legs were extended backwards and held close to the sides of opisthosoma. This stage was immediately followed by moulting. Average duration of nymphochrysalis stage was 0.73 days for male and 1.03 days for female.

4.1.1.1.4. Protonymph

Protonymph stage was the first nymphal stage that came out by splitting open the larval skin. Protonymph was oval shaped, deep amber coloured and larger in size compared to that of larva, with four pairs of legs. The mean protonymph period lasted for 0.91 days for males and 1.04 days for females.

4.1.1.1.5. Deutochrysalis

Protonymph entered into deutochrysalis which was the second quiescent stage.The protonymph remained attached to the leaf surface, as in case of nymphochrsalis. Deutochrysalis stage, on an average, lasted for 0.69 days in the case of males and 1.12 days in the case of females.

4.1.1.1.6. Deutonymph

Deutonymph was the second nymphal stage and emerged from deutochrysalis after moulting. They were actively moving and feeding. Deutonymph was greyish green in colour when emerged and became dark green later on. During the stage, sexes could be differentiated apparently by body size. Female deutonymphs were larger and broader than their male counterparts while male deutonymphs were elongate. The mean deutonymph period was 0.98 days for males and 1.30 days for females.

4.1.1.7. Teleiochrysalis

Teleiochrysalis was the third quiescent stage immediately after deutonymph. This period on an average lasted for 1.15 days for males and 1.20 days for females.

4.1.1.8. Adult

Adult mites emerged after the final moult from teleiochrysalis. The mites exhibited sexual dimorphism in the adult stage. Males were smaller in size with body tapering posteriorly to a blunt point. Female mites were whitish, larger and plumper with longer setae all over the body and legs and turned darker after mating. Both males and females possessed bright red eye spots on the dorso-lateral propodosoma.

4.1.1.1.9. Total developmental period

The total developmental period from egg to adult emergence recorded a mean value of 9.87 days for males and 10.47 days for females.

4.1.1.2. Adult longevity

Adult males recorded a mean longevity of 8.00 days while the corresponding figures for mated and unmated females were 10.34 and 12.10 days respectively (Table 4).

Table 4. Adult longevity of *O. oryzae*

Sex		Duration (Days $\pm$ SD)*
Male		8.00 ± 1.00
Female	Mated	10.34 ± 0.04
	Unmated	12.10 ± 0.14

**Mean of ten observations*

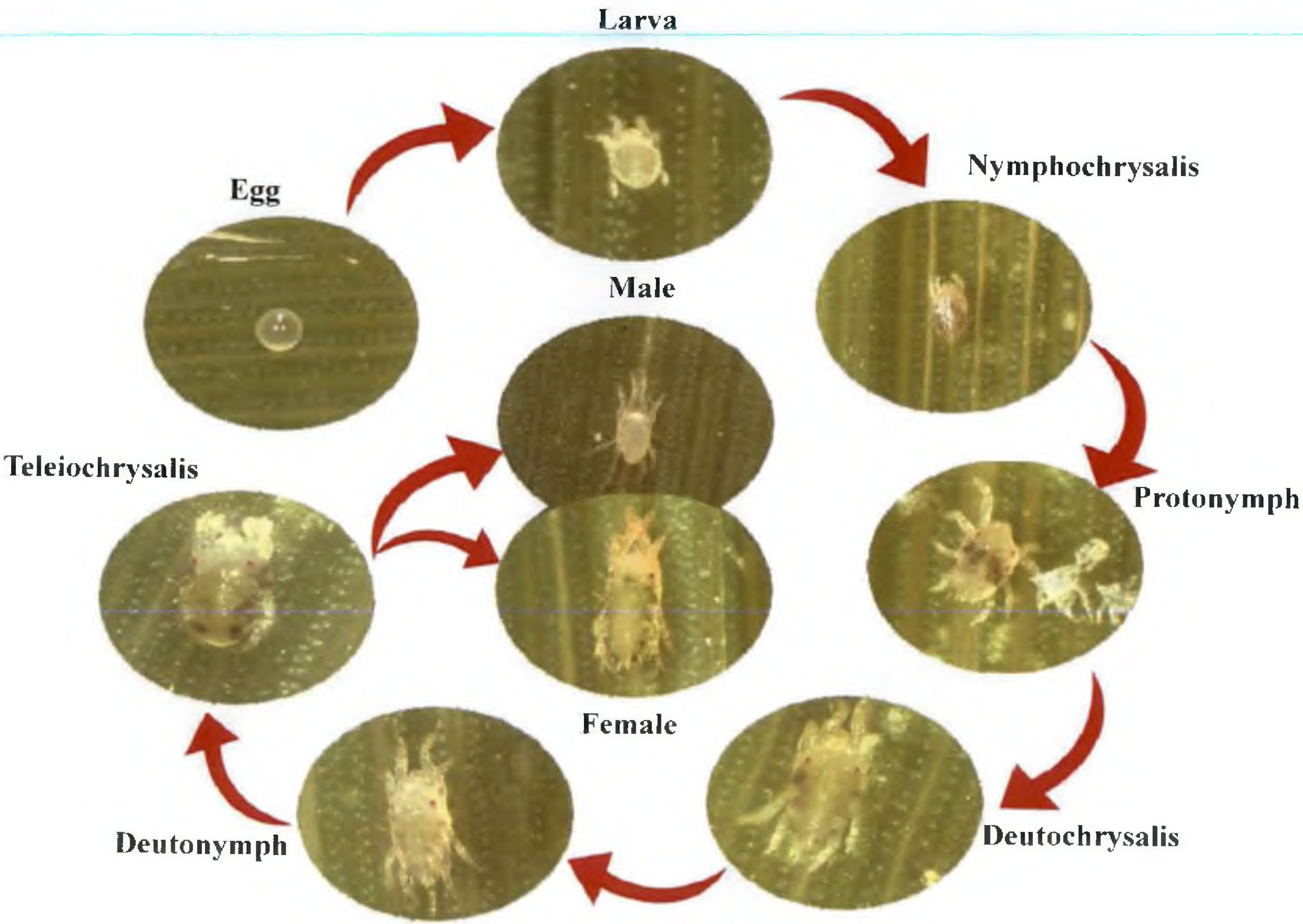


Plate 9. Life cycle of *Oligonychus oryzae* on rice (35x)

Plate 10. Male resting over female teliochrysalis (35x)

4.1.1.3. Reproductive biology of *Oligonychus oryzae*

4.1.1.3.1. Mating behaviour

Newly emerged males were found to be moving actively in search of females to mate.They rested near or over the quiescent female deutonymphs that they came across, guarding (Plate 11) them and even fighting with the rival males for the yet to emerge females. Mating took place immediately after the emergence of the female. Male pushed and raised the posterior abdominal region of the female and slide underneath with its hysterosoma upturned. Mating lasted for a mean period of one minute (Table 5). Male was observed to mate with several females, though a female usually mated only once.

4.1.1.3.2. Pre-oviposition, oviposition and post-oviposition period of females of *Oligonychus oryzae*

The life span of adult female mites consisted of pre-oviposition period, oviposition period and post-oviposition period and the duration of life span was found to be longer in unmated females. The mean pre-oviposition period in mated and unmated females lasted for 0.89 and 1.02 days respectively. Oviposition and post-oviposition periods lasted for 6.27 days and 2.08 days in case of mated females and 7.31 days and 2.12 days in case of unmated females respectively as represented in Table 5.

Table 5. Pre-oviposition, oviposition and post-oviposition period of females of *Oligonychus oryzae*

Parameters		Duration (Mean ± SD)*
Mating period		1.00 ± 0.36 minutes
Pre-oviposition period	Mated female	0.89 ± 0.03 days
	Unmated female	1.02 ± 0.05 days
Oviposition period	Mated female	6.27 ± 0.06 days
	Unmated female	7.31 ± 0.26 days
Post-oviposition period	Mated female	2.08 ± 0.03 days
	Unmated female	2.12 ± 0.06 days

**Mean of ten observations*

Table 6. Fecundity, sex ratio and egg viability of *Oligonychus oryzae*

	Fecundity (No. of eggs)	Male : Female ratio	Egg viability (%)
Mated female	21.27 ± 4.54*	1 : 3	89.67
Unmated female	17.18 ± 3.54*	1 : 0	81.69

**Mean of ten observations*

4.1.1.3.3. Fecundity, sex ratio and egg viability of *Oligonychus oryzae*

Mated females on an average laid 21.27 eggs whereas unmated females laid only 17.18 eggs. Mated female produced a progeny consisting of both males and females in the ratio 1:3, whereas unmated females produced only males. The eggs of *O. oryzae* recorded a viability of 89.67 per cent for mated females and 81.69 for unmated females (Table 6).

4.1.2. Morphometric parameters of development stages of *Oligonychus oryzae*

The morphometry of different life stages of *O. oryzae* is presented in Table 7. A gradual increase in size was recorded from egg to adult stage, except in the case of teleiochrysalis, which was smaller than the deutonymph. As sexes could be distinguished only from deutonymph stage, the measurements were recorded in common upto deutochrysalis stage. From deutonymph stage onwards, measurements were recorded separately for male and female. Eggs on an average measured 120.10 µm in diameter. A total mean body length of 170 µm and mean body width of 130 µm were recorded for larva. Nymphochrysalis measured a mean length of 202 µm and a mean width of 140 µm. The length of the protonymph was 237 µm while the average width was recorded as 152 µm. Deutochrysalis measured 256 µm in length and 170.02 µm in breadth. Male deutonymphs had a length of 265.02 µm and a width of 163.51 µm, where as female deutonymphs on an average measured 310.20 µm in length and 206.24 µm in width. Length and width of teleiochrysalis were 286.59 µm and 171.32 µm for males and 305.14 µm and 198.63 µm for females respectively. The maximum length and width recorded during the adult stage were 262.30 and 169.18 µm, and 337.12 and 175.04 µm for both males and females respectively (Table 7).

Table 7. Morphometric parameters of development stages of *Oligonychus oryzae*

Stage	Mean ± SD (µm)			
	Length (µm) *		Width (µm) *	
Egg (Diameter)	120.10 ± 6.21			
Larva	170.20 ± 02.54		130.21 ± 01.08	
Nymphochrysalis	202.12 ± 02.57		140.12 ± 01.56	
Protonymph	237.10 ± 10.11		152.01 ± 04.32	
Deutochrysalis	256.14 ± 05.39		170.02 ± 02.51	
	Male		Female	
	Length (µm)	Width (µm)	Length (µm)	Width (µm)
Deutonymph	265.02 ± 10.32	163.51 ± 04.96	310.20 ± 15.71	206.24 ± 02.74
Teleiochrysalis	286.59 ± 02.44	171.32 ± 01.90	305.14 ± 06.22	198.63 ± 01.12
Adults	262.3 ± 04.47	169.18 ± 04.37	337.12 ± 12.02	175.04 ± 0.02

**Mean of ten observations*

4.2 Management of rice leaf mite *Oligonychus oryzae*

4.2.1 Laboratory bioassay

4.2.1.1. Ovicidal effects on eggs

Mortality of eggs was observed in all the treatments except control and ranged from 66.60 per cent in case of neem oil to a maximum of 86.60 per cent in fenazaquin at 72 h after treatment. There was in increase in mortality with increase in time as well. The bioassay studies revealed that ovicidal activity of all the treatments increased from 24 h to 72 h. At 24 h, fenazaquin showed the highest egg mortality recording a mean of 30.0 percent, however was on par with spiromesifen (23.30%), propargite (16.66%), wettable sulphur (16.66%) and fenpyroximate (13.33 recorded mortality values that were on par with the standard check dicofol (13.33 %). Both the botanicals recorded identical but significantly lower mortality values of 6.66 per cent. The mortality was found to have increased from 24 to 48 h in all the treatments except in case of neem oil. At 48 h, fenazaquin continued to be the best treatment causing 40.00 per cent egg mortality. Both spiromesifen and fenpyroximate recorded mean mortality values of 33.30 per cent and were statistically on par with fenazaquin. neem oil showed the lowest mortality percent of 6.66 per cent. At 72 h, fenazaquin showed highest ovicidal activity (86.60%) followed by propargite (83.30%) and spiromesifen (80.00%) and were on par with one another. Both fenpyroximate and wettable sulphur resulted in a mortality of 70 per cent and were statistically on par with dicofol (76.6%). Lowest mortality was recorded by neem oil (66.60%), but it was on par with azadirachtin (60.60%) (Table 8). All treatments were significantly superior to untreated control which recorded till 72 h after treatment.

Table 8.Ovicidal effect of different treatments on eggs of *Oligonychus oryzae*

Sl.No	Treatments	Mortality (%)		
		24h	48h	72h
1	T1- Fenazaquin 10 EC	30.00 (5.52)[a]	40.00 (6.36)[a]	86.6 (9.33)[a]
2	T2-Spiromesifen 240 SC	23.30 (4.43)[ab]	33.30 (6.08)[a]	80.00 (8.98)[abc]
3	T3-Fenpyroximate 5SC	13.33 (3.67)[bc]	33.3 (5.52)[ab]	70.00 (8.57)[cde]
4	T4- Propargite 57 EC	16.66 (4.00)[abc]	26.60 (5.19)[ab]	83.3 (9.15)[ab]
5	T5-Azadiractin 0.005%	6.66 (2.40)[cd]	6.66 (2.40)[c]	60.6 (7.78)[f]
6	T6- Neem oil 2%	6.66 (2.40)[cd]	23.33 (4.76)[b]	66.6 (8.19)[ef]
7	T7-Wettable sulphur 80 WP	16.66 (4.00)[abc]	26.66 (5.19)[ab]	70.00 (8.39)[de]
8	T8- Standard check (Dicofol 18.5 EC)	13.33 (3.67)[bc]	26.66 (5.19)[ab]	76.60 (8.78)[bcd]
9	Untreated control	0.00 (0.70)[d]	0.00 (0.70)[d]	0.00 (0.70)[g]
CD value (p = 0.05)		1.73	1.30	0.54

Values in the parenthesis are square root transformed values. Means followed by same letters do not differ significantly by DMRT (p = 0.05)

4.2.2.2. Effect on gravid female

The acaricide molecule, fenazaquin showed 100 per cent mortality of gravid females within 24 h of treatment and was the best treatment observed. Spiromesifen (73.30 %), fenpyroximate (70.00 %), propargite (70.00 %), wettable sulphur (70.00 %) and dicofol (63.3 %) were statistically on par. Neem oil and azadirachtin recorded significantly lower mortality of 30.00 and 23.30 per cent respectively. At 48 h, fenazaquin continued to be the best treatment (83.30 %). Spiromesifen and propargite (83.30%) recorded increase in mortality and were 100 %, found to be superior to standard check, dicofol 18.5 (70.00%). Fenpyroximate (76.6%) and wettable sulphur (73.3%) were found to be on par with dicofol. The botanicals, neem oil (53.30 %) and azadirachtin (40.00 %) showed an increase in mortality, after 48 h and were found to be significantly inferior to other treatments except untreated control. After 72 h spiromesifen also recorded 100 per cent mortality. Propargite was the next best candidate with a mortality value of 90.00 per cent. Both fenpyroximate and wettable sulphur recorded mortality of 80 percent and were significantly superior over the standard check, dicofol (73.3%). The botanicals were found to be inferior to the standard check, dicofol. Among the botanicals, neem oil 2 % recorded a higher mortality of 63.30 per cent compared to azadirachtin (53.30%). Effects of various treatments under investigation on the gravid females of *O. oryzae* are presented in Table 8.

4.3.3. Efficacy of treatments against *Oligonychus oryzae* on rice after first spray application

The results of the experiment to evaluate the efficacy of different treatments against mite after the first spray are presented in Table 10. The mean mite counts before the application of treatments per 4 cm^2 leaf area ranged from 15.88 to 20.02.

Table 9. Effect of different treatments on gravid females of *Oligonychus oryzae*

Sl.No	TREATMENTS	Mortality (%)		
		24h	48h	72h
1	T1- Fenazaquin 10 EC	100 (10.02)[a]	100 (10.02)[a]	100 (10.02)[a]
2	T2-Spiromesifen 240 SC	73.30 (8.59)[b]	83.30 (9.15)[b]	100 (10.02)[a]
3	T3-Fenpyroximate 5SC	70.00 (8.40)[b]	76.60 (8.78)[bc]	80.0 (8.97)[c]
4	T4- Propargite 57 EC	70.00 (8.40)[b]	83.30 (9.14)[b]	90.0 (9.51)[b]
5	T5-Azadiractin 0.005%	23.30 (4.71)[c]	40.00 (6.33)[e]	53.30 (7.53)[f]
6	T6- Neem oil 2%	30.0 (5.52)[c]	53.30 (7.33)[d]	63.30 (7.98)[e]
7	T7-Wettable sulphur 80 WP	60.0 (7.78)[b]	73.30 (8.58)[bc]	80.0 (8.97)[c]
8	T8- Standard check (Dicofol 18.5 EC)	63.30 (7.98)[b]	70.00 (8.40)[c]	73.30 (8.59)[d]
9	Untreated Control	0.00 (0.70)[d]	0.00 (0.70)[f]	0.00 (0.70)[g]
CD value (p = 0.05)		0.94	0.70	0.35

Values in the parenthesis are square root transformed values. Means followed by same letters do not differ significantly by DMRT (p = 0.05)

One day after spraying , the lowest mite count was recorded in wettable sulphur (1.14 / 4 cm^2 leaf area) and standard check, dicofol (2.13 /4cm^2 leaf area) which were on par with fenazaquin (2.23 / 4cm^2 leaf area), fenpyroximate (3.74) , propargite (3.77) and spiromesifen (4.53). The botanicals *viz.,* neem oil and azadirachtin recorded 4.91 and 3.40 mites respectively per 4 cm^2 leaf area.

At three days after application, all the treatments significantly reduced the mite population compared to untreated control. The lowest mite population of 0.33 mites per 4cm^2 leaf area was recorded in the treatment fenazaquin. The treatment spiromesifen and propargite recorded a mite population of 0.56 and 0.61 per 4 cm^2 leaf area and were on par with each other . Fenpyroximate recorded an average of 0.78 mites per 4 cm^2 leaf area and was on par with standard check, dicofol (0.83 per 4 cm^2 leaf area) and wettable sulphur 80 WP (0.94 per 4 cm^2 leaf area). Azadirachtin and neem oil recorded a population of 1.00 and 1.03 mites per 4 cm^2 leaf area respectively. All were superior over untreated control which recorded a mean population of 28.2 mites per 4 cm^2 area.

At seven days after spraying, The lowest mite population of 0.33 per 4 cm^2 leaf area was recorded by fenazaquin. This was followed by spiromesifen (0.79), fenpyroximate (0.99) and propargite (1.53) which were on par with each other as well as standard check, dicofol (1.14 per 4 cm^2 leaf area). All the above treatments were significantly superior to botanicals and wettable sulphur. Wettable sulphur (1.70 per 4 cm^2 leaf area) was on par with the botanical, azadirachtin (1.75 per 4 cm^2 leaf area) but was superior to neem oil (1.93 per 4 cm^2 leaf area) and untreated control which recorded 31.00 mites per 4 cm^2 leaf area.

Similar trend was observed at ten days after spraying where the chemical molecules continued to record lower mite populations. Fenazaquin recorded the lowest count of 0.68 per 4 cm^2 leaf area followed by spiromesifen (0.74). Both fenazaquin and spiromesifen were found to be superior over standard check dicofol.

Fenpyroximate (0.87/ 4 cm^2/leaf area) and propargite (1.10 / 4 cm^2 leaf area) were found to be on par with standard check dicofol (1.29 / 4 cm^2 leaf area). Wettable sulphur (1.56/ 4 cm^2 leaf area) was also statistically on par with standard check dicofol. The botanicals azadirachtin (2.23) and neem oil (2.70) were found to be on par with each other and superior over untreated control (29.20).

At fourteen days after spraying, all the new molecules recorded lower mite population. The lowest mean mite population was recorded by fenazaquin 10 EC (0.36) which was on par with spiromesifen (0.46), fenpyroximate (0.58) and propargite (0.65).Wettable sulphur (0.64) and standard check dicofol (0.75) were also on par with new molecules. Among the botanicals,azadirachtin recorded lower mite population (1.77) as compared to neem oil (2.02). All the treatments recorded significant reduction in mite population as compared to untreated control.

Fenazaquin recorded the highest reduction in mite counts of 97.10 per cent followed by spiromesifen (96.60), propargite (96.03), fenpyroximate (95.07), wettable sulphur (95.46) and standard check, dicofol (94.64). Among botanicals, highest reduction in mite population was recorded by azadirachtin (87.32 %) in comparison to neem oil (85.53%).

4.3.3.2 Efficacy of treatments against *Oligonychus oryzae* on rice after second spray application

The mean count of mites before the second spray application of the treatments per 4 cm^2 leaf area ranged from 14.35 to 20.78. The results of the pot culture experiment to evaluate the efficacy of different treatments against mite after the second spray are presented in Table 11.

Table 10. Effect of various treatments on population of *Oligonychus oryzae* on rice after first spray application

Sl No	TREATMENTS	Mean no. of mites / 4 cm^2 leaf area						Mean (%) reduction over control
		1DBT	1DAS	3DAS	7DAS	10DAS	14DAS	
1	T1- Fenazaquin 10 EC	15.88 $(4.04)^{b}$	2.23 $(1.64)^{cd}$	0.33 $(0.91)^{e}$	0.33 $(0.90)^{e}$	0.68 $(1.08)^{e}$	0.36 $(0.91)^{c}$	97.1
2	T2-Spiromesifen 240 SC	16.77 $(4.16)^{b}$	4.53 $(2.21)^{b}$	0.56 $(1.03)^{de}$	0.79 $(1.14)^{d}$	0.74 $(1.09)^{e}$	0.46 $(0.97)^{c}$	96.6
3	T3-Fenpyroximate 5SC	15.55 $(4.00)^{b}$	3.74 $(2.04)^{b}$	0.78 $(1.12)^{bcd}$	0.99 $(1.22)^{d}$	0.87 $(1.17)^{de}$	0.58 $(1.01)^{c}$	95.07
4	T4- Propargite 57 EC	16.84 $(4.16)^{b}$	3.77 $(2.05)^{b}$	0.61 $(1.05)^{cde}$	1.53 $(1.14)^{d}$	1.10 $(1.25)^{cde}$	0.65 $(1.06)^{c}$	96.03
5	T5-Azadiractin 0.005%	15.82 $(4.03)^{b}$	3.40 $(1.96)^{bc}$	1.00 $(1.22)^{bc}$	1.75 $(1.48)^{bc}$	2.23 $(1.65)^{b}$	1.77 $(1.50)^{b}$	87.32
6	T6- Neem oil 2%	15.63 $(4.01)^{b}$	4.91 $(2.28)^{b}$	1.03 $(1.23)^{b}$	1.93 $(1.55)^{b}$	2.70 $(1.77)^{b}$	2.02 $(1.60)^{b}$	85.53
7	T7-Wettable sulphur 80 WP	15.67 $(4.01)^{b}$	1.14 $(1.28)^{e}$	0.94 $(1.19)^{bcd}$	1.70 $(1.44)^{bc}$	1.56 $(1.43)^{c}$	0.64 $(1.06)^{c}$	95.46
8	T8- Standard check (Dicofol 18.5 EC)	15.92 $(4.04)^{b}$	2.13 $(1.58)^{de}$	0.83 $(1.15)^{bcd}$	1.14 $(1.27)^{cd}$	1.29 $(1.33)^{cd}$	0.75 $(1.10)^{c}$	94.64
9	Control	20.02 $(5.00)^{a}$	27.90 $(5.33)^{a}$	28.20 $(5.35)^{a}$	31.00 $(5.60)^{a}$	29.20 $(5.45)^{a}$	28.00 $(5.33)^{a}$	
	CD value (p = 0.05)	NS	0.37	0.15	0.22	0.20	0.21	

DBT = Day Before Treatment; DAT = Days After Treatment ; Means followed by same letters do not differ significantly by DMRT (p = 0.05) ; Mean reduction- Mean reduction over untreated control; †- Values in the parenthesis are square root transformed values.

At three days after spraying, all the treatments significantly reduced the mite population as compared to untreated control. The lowest mite population of 0.17 per 4 cm^2 leaf area was recorded in fenazaquin, which was on par with the treatments, fenpyroximate (0.25), spiromesifen (0.41) and propargite (0.47/ 4 cm^2 leaf area). Wettable sulphur (1.22/ 4 cm^2 leaf area) was statistically on par with the standard check, dicofol (0.88/ 4 cm^2 leaf area). Azadirachtin and neem oil recorded mite populations of 1.45 and 1.65 mites /4 cm^2 leaf area respectively and continued to be inferior to standard check dicofol. However, both the botanicals were superior over untreated control which recorded a mean population of 29.12 mites / 4 cm^2 leaf area.

At seven days after spraying, the lowest mite population of 0.31 per 4 cm^2 leaf area was recorded by fenazaquin followed by spiromesifen (0.70/ 4 cm^2 leaf area), both being on par with each other. These treatments were significantly superior to with fenpyroximate (0.64) and propargite (0.72 per 4 cm^2 leaf area) which were statistically on par with each other. Wettable sulphur (1.75/ 4 cm^2 leaf area) and azadirachtin (1.76) were on par with standard check, dicofol (1.71 per 4 cm^2 leaf area). Neem oil showed a mean mite population of 3.11 per 4 cm^2 leaf area and was superior over untreated control which recorded 33.6 mites per 4 cm^2 leaf area.

Similar trend was observed at ten days after spraying where the chemical molecules continued to record lower mite populations with fenazaquin recording the lowest count of 0.33 per 4 cm^2 leaf area. It was found to be on par with spiromesifen (0.52 / 4 cm^2 leaf area) and propargite (0.72 / 4 cm^2 leaf area). The treatments fenpyroximate (1.03/ 4 cm^2 leaf area), wettable sulphur (1.15/ 4 cm^2 leaf area), neem oil 2 per cent (1.25/ 4 cm^2 leaf area) and standard check, dicofol (1.19 / 4 cm^2 leaf area) were on par with each other. The botanical azadirachtin recorded a mite population of 1.52 per 4 cm^2 leaf area and was superior over untreated control (29.44 per 4 cm^2 leaf area).

At fourteen days after spraying, the lowest mean mite population was recorded by fenazaquin (0.31) which was on par with spiromesifen (0.30), fenpyroximate (0.54), propargite (0.56), wettable sulphur (0.48) and standard check dicofol (0.73). Among the botanicals, azadirachtin recorded lower mite population (1.24) as compared to neem oil (1.51). All the treatments recorded significant reduction in mite population as compared to untreated control.

After the second spray application, fenazaquin recorded the highest reduction in mite count of 96.34 per cent followed by spiromesifen (93.43) propargite 57 EC (93.75), fenpyroximate (93.44), standard check dicofol (92.16) and wettable sulphur (89.51). In case of botanicals, highest reduction in mite population was recorded in azadirachtin with 87.96 percent in comparison to neem oil with 85.43 percent.

Table 11. Efficacy of various treatments on population of *Oligonychus oryzae* on rice after second spray application

Sl No	TREATMENTS		Mean no. of mites / cm^2 leaf area					Mean reduction (%)
		1DBS	1DAS	3DAS	7DAS	10DAS	14DAS	
1	T1- Fenazaquin 10 EC	15.41 (3.98)^{bc}	1.80 (1.46)^{c}	0.17 (0.80)^{d}	0.31 (0.89)^{c}	0.33 (0.90)^{e}	0.31 (0.90)^{c}	96.34
2	T2-Spiromesifen 240 SC	16.13 (4.06)^{bc}	3.41 (1.90)^{bc}	0.41 (0.93)^{d}	0.70 (1.05)^{de}	0.52 (0.99)^{de}	0.30 (0.91)^{c}	93.43
3	T3-Fenpyroximate 5SC	14.35 (3.85)^{bc}	2.84 (1.86)^{bc}	0.25 (0.87)^{d}	0.64 (1.06)^{d}	1.03 (1.10)^{bcd}	0.54 (0.97)^{c}	93.44
4	T4- Propargite 57 EC	14.43 (3.85)^{bc}	2.33 (1.68)^{bc}	0.47 (0.98)^{d}	0.72 (1.10)^{d}	0.72 (1.09)^{cde}	0.56 (1.00)^{c}	93.75
5	T5-Azadiractin 0.005%	15.65 (4.01)^{bc}	3.79 (2.00)^{b}	1.45 (1.39)^{b}	1.76 (1.49)^{c}	1.52 (1.41)^{b}	1.24 (1.32)^{b}	87.96
6	T6- Neem oil 2%	14.88 (3.91)^{bc}	4.03 (2.07)^{b}	1.65 (1.45)^{b}	3.11 (1.89)^{b}	1.25 (1.31)^{bc}	1.51 (1.40)^{b}	85.43
7	T7-Wettable sulphur 80 WP	16.35 (4.1)^{b}	3.70 (1.94)^{bc}	1.22 (1.31)^{bc}	1.75 (1.5)^{c}	1.15 (1.28)^{bc}	0.48 (1.02)^{c}	89.51
8	T8- Standard check (Dicofol 18.5 EC)	13.91 (3.79)^{c}	1.40 (1.44)^{c}	0.88 (1.16)^{c}	1.71 (1.48)^{c}	1.19 (1.29)^{bc}	0.73 (1.06)^{c}	92.16
9	T9- Control	20.78 (5.84)^{a}	27.19 (5.26)^{a}	29.12 (5.44)^{a}	33.6 (5.83)^{a}	29.44 (5.67)^{a}	31.65 (5:60)^{a}	
	CD value (p = 0.05)	NS	0.5	0.19	0.17	0.24	0.22	

DBT = Day Before Treatment; DAT = Days After Treatment; Means followed by same letters do not differ significantly by DMRT (p = 0.05); Mean reduction- Mean reduction over untreated control; †- Values in the parenthesis are square root transformed values.

Discussion

5. DISCUSSION

The present study was undertaken to investigate the biology of rice leaf mite, *Oligonychus oryzae* (Hirst) and to evaluate the efficacy of new acaricide molecules and botanicals against *O. oryzae* on rice. The observations and inferences based on the study are discussed below in the light of available literature.

5. 1. Biology of *Oligonychus oryzae* Hirst on rice

The studies on the biology of *O. oryzae* were conducted in the Acarology laboratory at 27 $\pm$ 3^{0}C and 70 $\pm$ 2 per cent relative humidity on leaf bits of rice. Developmental stages consisted of egg, larva, protonymph, deutonymph and adult stage. These stages are common in the life history of spider mites belonging to the family Tetranychidae. These stages have also been reported in the life history of *O. oryzae* on paddy by Nayak *et al.*, (2008) and Radhakrishnan and Ramaraju (2009) under laboratory conditions. The developmental stages of *T. urticae* on okra consisted of egg, larva, protonymph, deutonymph and adult stage as reported by Rajkumar (2003) in jasmine and Silva *et al.*, (2009) in gerbera indicating the uniformity in pattern of development for the family Tetranychidae.

The development duration of development of various life stages of *O. oryzae* recorded in the present study was found to be shorter'compared to that reported by Nayak *et al* (2008) (Fig. 1). A total developmental period of 9.87 $\pm$ 0.72 and 10.47 $\pm$ 0.51 were recorded respectively for male and female in the study, while Nayak *et al* (2008) reported a longer development period of 10.58 $\pm$ 1.50 days in males and 12.64 $\pm$ 1.57 days in females. Laboratory studies on biology of *O. oryzae* at five different temperatures namely 20, 25, 28, 30 and 35^{0}C carried out at Tamil Nadu Agricultural University revealed that the duration of development of various stages as well as total duration of *O. oryzae* decreased with increase in temperature (Radhakrishnan and Ramaraju 2009). At 20^{0}C, the mite took on an average, 16.10 days for development from egg to adult. The total development period was 13.65, 8.88, 8.35, 8.33 days at temperatures 25, 28, 30 and 35^0C respectively. The present study was carried out at a temperature of 27 ± 3^0C in the laboratory and hence the development duration (9.87 days for male and 10.47 days for female), which falls between 13.65 and 8.88 days corresponding to 25^0C and 28^0C respectively, is in agreement with earlier findings. This results also clearly brings out the influence of temperature on the biology of *O. oryzae*. Temperature was also found to have a profound impact on the duration of development stages of the red spider mite *O. coffeae* on tea, as the mite completed its development in a shorter duration of 6.85 days at 32^0C, while the same duration was prolonged to 14.47 days at 22.5^0C (Mazid *et al.*, 2013). Similar trend was reported by Haque *et al* (2007) in *O. coffeae* on rose. In Kerala, the rice leaf mite, *O. oryzae* usually occurs in serious proportions in rice fields of Palakkad district during July-August when the region experiences temperatures between 30 and 35^0C (Bhaskar and Thomas, 2011; AINPAA, 2013). At this temperature range, a shorter developmental duration ranging between 8.35 and 8.33 days was reported in *O. oryzae* by Radhakrishna and Ramaraju (2009). Hence it is expected that in the rice fields of Palakkad, rice leaf mite completes its development in a period shorter than that recorded in the present study in the laboratory at 27^0C enabling fast multiplication and completion of several generations during the infestation period. This might be the reason for sudden flare up and outbreak like situation of the mite in the paddy fields of Palakkad district during July-August 2010 as reported by Bhaskar and Thomas (2011).

The study showed that male *O. oryzae* completed development from egg to adult faster than female (Fig. 2). This trend was also reported by Nayak *et al* (2008) in *O. oryzae* where, males on an average took only 10.58 days in comparison to 12.64 days in females. Longer developmental duration in females was also reported in different species of tetranychid mites by several workers. Nazeh *et al.*, (2012) reported that males of *T. urticae* completed their life cycle in 6.3 days and females in 6.5 days on pear, while Rajkumar (2003) observed a duration of 10.70 days for male and 12.36 days for female to complete their life cycle in jasmine. Laboratory studies on biology of *O. persae* on avocado leaves at four different temperatures recorded longer duration of immature stages as well as total development period in females compared to males. Similarly, the males of two spotted spider mite *T. urticae* recorded a shorter development period of 6.73 days compared to 7.52 days in females on okra (Krishna and Bhaskar, 2014). The early emergence of male ensures sexual reproduction and sustenance of population as against parthenogenesis which is commonly observed in tetranychid mites in the absence of males and which results in all male population.

In the present study, the longevity of females was found to be more compared to that of males. Also, unmated females lived longer compared to mated females.These findings are also consistant with that of Nayak *et al* (2008) who reported that females of *O. oryzae* lived longer (12.10 days) compared to males (7.90 days). Simillarly the shorter duration of unmated females in the present study is also in line with previous studies. For instance, the negative influence of mating on the life expectancy of females in tetranychid mites was reported earlier by several workers (Krishna and Bhaskar 2014; Manujunatha and Puttuswamy 1989).

Figure 1. Duration of development stages of *Oligonychus oryzae*

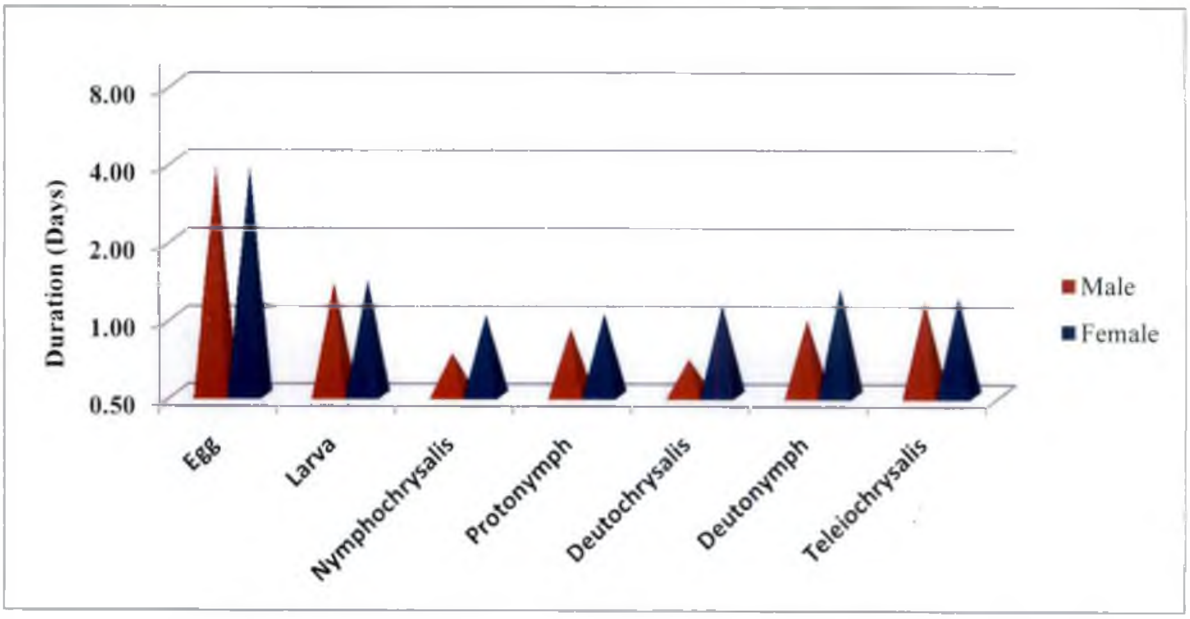
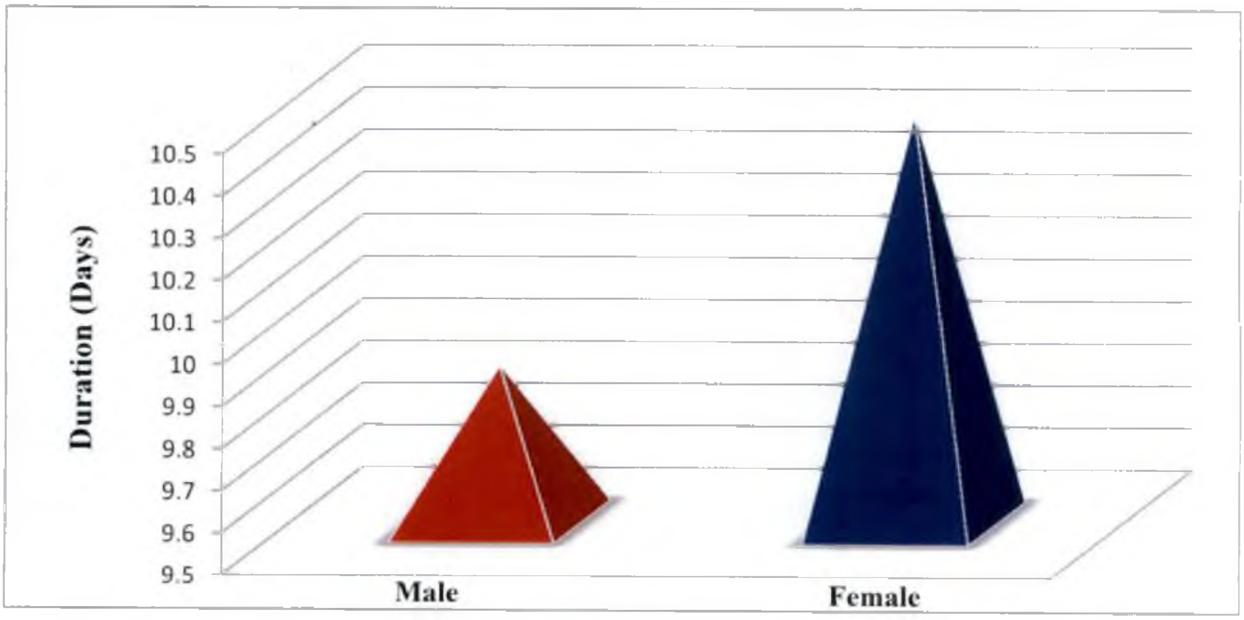


Figure 2. Total development period of *Oligonychus oryzae*



Parthenogenetic reproduction took place where unmated females produced only males. Arrhenotokous reproduction was earlier reported in *O. oryzae* on rice which produced only male progenies (Nayak *et al* 2008). Under natural conditions, this behaviour may help the mite in bringing about natural control in population in situations when food source is scarce or space is limited. Mated females showed higher fecundity (21.27) compared to unmated females (17.18). Higher fecundity of mated female was also reported on *O. indicus* in sorghum (Chundawat *et al* 2009) where the mated females on an average laid 32.20 and unmated 25.92 eggs. In general, the fecundity of Oligonychus spp. was found to be lower compared to Tetranychus spp. Nayak et al (2008) reported an average fecundity of 30.70 eggs in *O. oryzae* on rice. Mated females of T. urticae recorded a fecundity of 108 eggs, while unmated females laid 77 eggs .The viability of eggs of *O. oryzae* was (88.35%) also lower compared to that of *T. urticae* on bhindi (92.10%) (Krishna and Bhaskar, 2014).

In the present study, mated females produced the progeny consisting of both female and male in the sex ratio 1:3. Nayak *et al* (2008) also reported a female biased sex ratio of 1:2.7 for the fertilised eggs of *O. oryzae.* On bhindi, the fertilized eggs of *T. urticae* produced progenies of males and females in the ratio 1:5.8 (Krishna and Bhaskar, 2014). Kaimal and Ramani (2011) also reported a similar sex ratio of 1:5 in *T. ludeni* on velvet bean. However, such a wider ratio is not expected to affect fertilization of females in a generation, as male tetranychid mites are known to be polygamous (Kaimal and Ramani, 2011; Patil, 2005)

5.2 Management of rice leaf mite *Oligonychus oryzae*

5.2.1 Laboratory bioassay

In the laboratory bioassay, the novel acaricide molecule fenazaquin recorded the highest mortality of eggs and gravid female mites (Fig 3 and 4). It was reported to have high efficacy against eggs and motile stages of tetranychid mites (Marcic *et al.*, 2011). In separate laboratory bioassays conducted, fenazaquin recorded egg mortality of *T. urticae* of 100 per cent at 24 h after treatment (Reddy *et al.*, 2014) and 94.21 per cent at 72 h after treatment (Krishna and Bhaskar, 2013).

Spiromesifen recorded 80.00 per cent mortality of eggs at 72 h after treatment. It also recorded significantly higher mortality of gravid females. In the separate laboratory bioassay studies 72 h after treatment, spiromesifen was reported to cause 90.00 percent mortality on eggs and 100 percent mortality of gravid females (Reddy *et al* 2014) and 90.0 percent mortality of eggs.

Propargite also showed good mortality of eggs and gravid females 72 h after treatment. It was also earlier reported to cause a very high mortality of 97.17 per cent on adult females of *T. urticae* in a laboratory bioassay (Reddy *et al* 2014).

In the laboratory bioassay, fenpyroximate recorded 70 per cent egg mortality and 80 per cent mortality of gravid females 72 h after treatment which is significantly superior over control. Fenpyroximate is a mitochondrial electron transport inhibitor with similar mode of action as fenazaquin. (Kodandaram *et al* 2010).

In the present study, though wettable sulphur recorded significantly lower mortality at 24 and 48h, the mortality was found to have increased to 70 and 80 per cent of eggs and gravid females respectively at 72 h after treatment. In a field trial conducted to evaluate the efficacy of acaricide molecules against *T. urticae*, the efficacy of wettable sulphur was found to be on par with fenazaquin and spiromesifen four and seven days after treatments (AINPAA 2013).

In the present study the botanicals showed significantly lower mortality of eggs as well as gravid females, though were superior over untreated control.

Figure 3. Effect of different treatments on eggs of *Oligonychus oryzae*

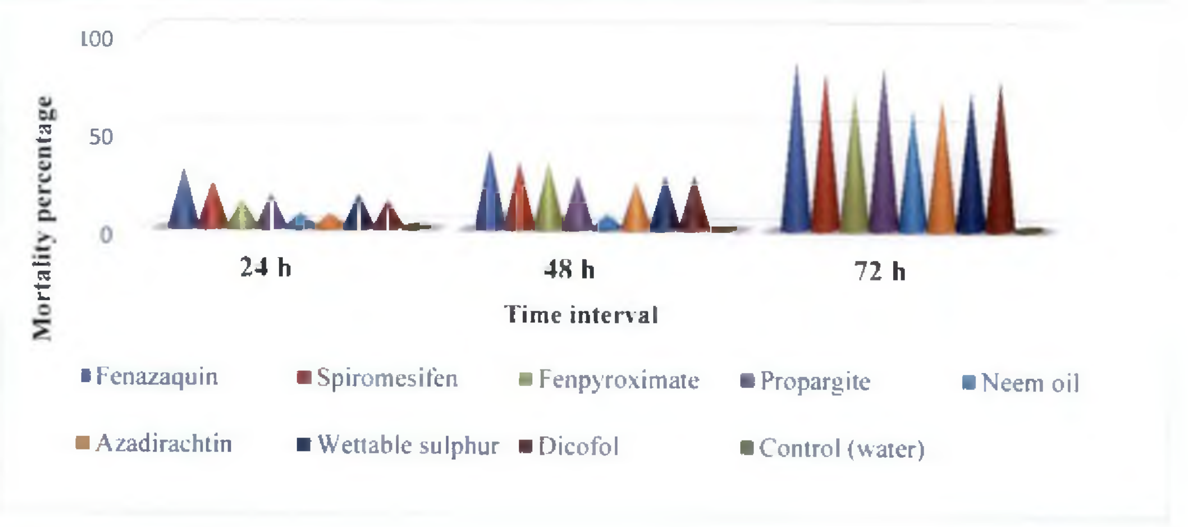
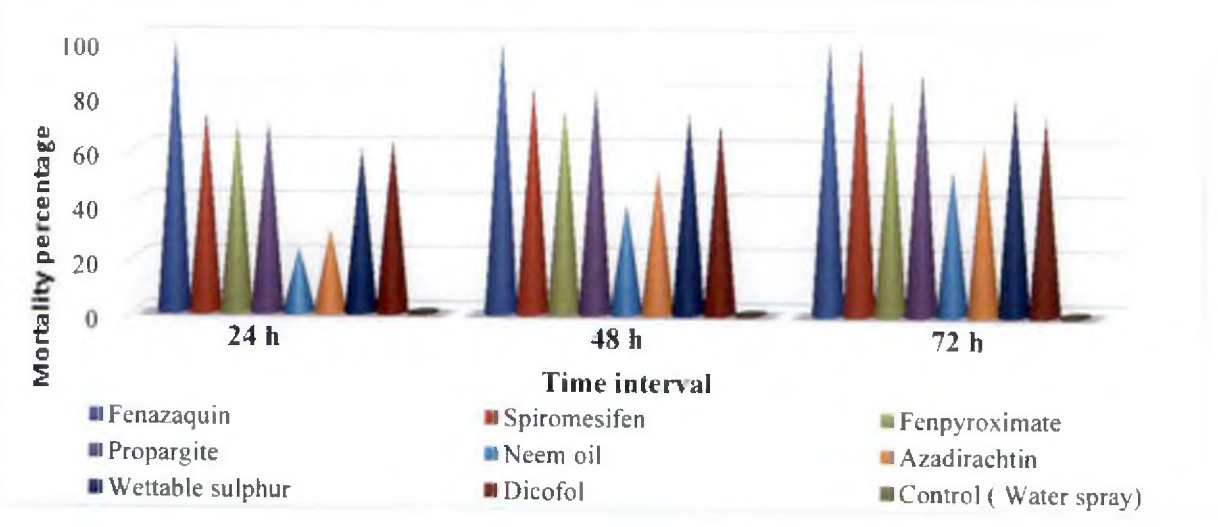


Figure 4. Effect of different treatments on gravid females of *Oligonychus oryzae*



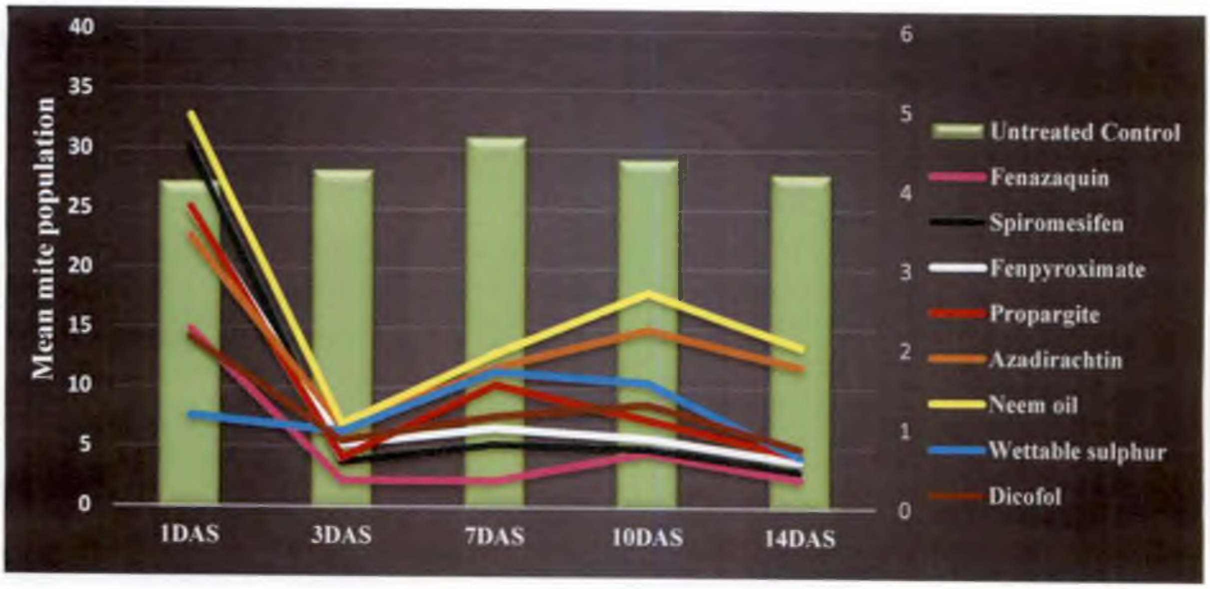
5.2. Evaluation of the efficacy of new acaricide molecules and botanicals against the Rice leaf mite *Oligonychus oryzae* on rice.

Pot culture study was conducted to evaluate the efficacy of four new acaricide molecules, two botanicals and wettable sulphur, along with standard check and an untreated control against the rice leaf mite on rice in the poly house at College of Horticulture, Vellanikkara during December – March, 2015.

The results of the experiment showed that all the four novel acaricide molecules tested namely fenazaquin, spiromesifen, fenpyroximate and propargite were effective in reducing the population of *O. oryzae* after first and second spray applications (Fig 5 and 6). Efficacy of these molecules in reducing the mite population was pronounced from 3rd day after spray application onwards. In the study, wettable sulphur also showed good efficacy against *O. oryzae* and by 14 days after treatment application its efficacy was on par with novel acaricide molecules. However the botanicals tested were found to be inferior to all other treatments though significantly reduced mite population over untreated control.

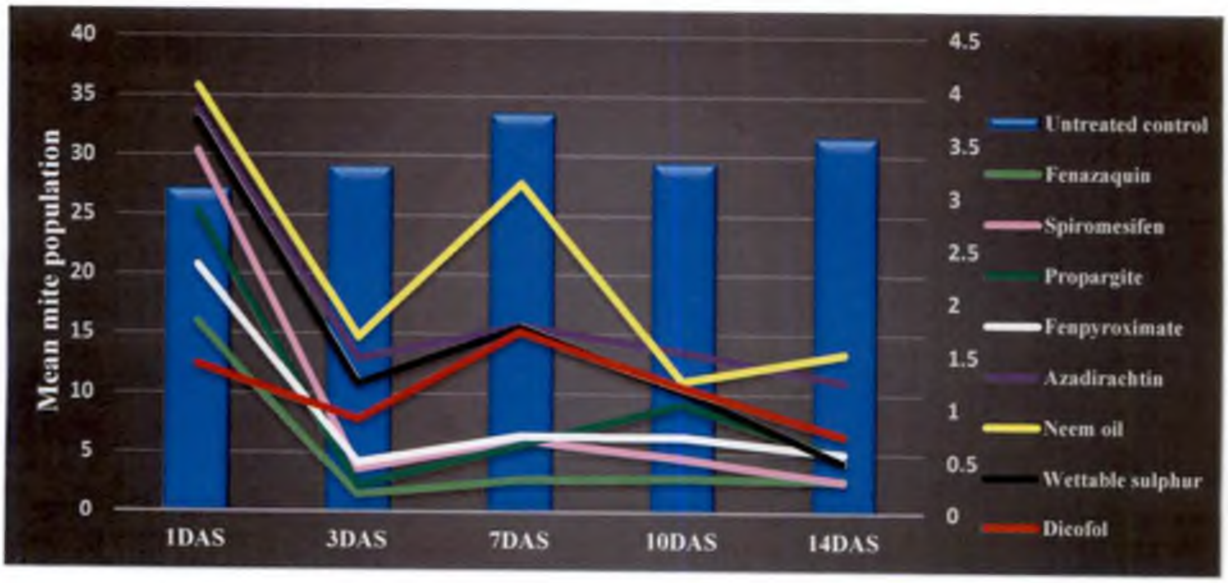
Fenazaquin constantly recorded lower mite count up to fourteen days. At 14 DAS, it recorded the highest reduction in mite population over untreated control after each spray. Fenazaquin is an acaricide which belongs to quinazoline class of chemicals which inhibits mitochondrial electron transport (MET) at complex 1. It has high efficacy against eggs and motile stages of tetranychid mites (Marcic *et al*, 2011). In the field experiment conducted in the rice fields of Tamil Nadu during 2005 and 2006, to evaluate the efficacy of pesticides against *O. oryzae*, fenazaquin was found to be the most effective treatment against mite eggs (Radhakrishnan and Ramaraju, 2009). A significant reduction in the mite population of motile stages was also reported in the study. Fenazaquin 10 EC was also reported to cause 90.52 percent mortality of adult mites of *T. macfarlanei* (Patil, 2005). Study conducted to determine the relative toxicity of different acaricides against *O. coffeae* on tea revealed that fenazaquin was the most toxic compound against the eggs of *O. coffeae* (Roy *et al*, 2011).

Figure 4. Efficacy of various treatments on population of *Oligonychus oryzae* on rice after first spray



Days after treatment

Figure 5. Efficacy of various treatments on population of *Oligonychus oryzae* on rice after second spray



Days after treatment

Spiromesifen, a tetraonic acid derivative acts as inhibitor of acetyl coA carboxylase, a key enzyme in fatty acid biosynthesis. It is highly toxic to eggs and immature stages of spider mites, while it acts more slowly against adult females causing reduction in fertility and fecundity (Marcic *et al*, 2011). A complete suppression of population of *T. urticae* could be achieved in ten days time using spiromesifen under field condition (Sato *et al.* 2011). Spiromesifen significantly reduced mite population from one day after spray application and was found to be on par with fenazaquin recording a higher reduction in mite count over untreated control. In a field experiment at Tamil Nadu, spiromesifen was reported to bring down *O. oryzae* population by 87.3 per cent. Spiromesifen has been reported to show better efficacy than dicofol against phytophagous mites (Kavitha *et al.* 2006).

Fenpyroximate is a mitochondrial electron transport inhibitor with similar mode of action as fenazaquin. It causes rapid knockdown effect against larva, nymph and adult, mainly by contact and ingestion. In the present study, fenpyroximate significantly reduced mite population from 1 DAS till 14 DAS. Its efficacy was on par with other acaricidal molecules fenazaquin and spiromesifen with significant reduction in mite population over untreated control. When fenpyroximate was evaluated against *O. oryzae* in rice field of Tamil Nadu, 87.2 per cent reduction in mite population was recorded (AINPAA, 2013). Fenpyroximate recorded 99.89 per cent reduction in the mite population of *T. urticae* on chrysanthemum in polyhouse (Reddy *et al.* 2014). In the present study fenpyroximate recorded a very high reduction of 95.07 per cent after first spray and 93.44 per cent after the second spray. This substantial reduction in population may be because the experiment was carried out in controlled condition in polyhouse.

Propargite is a sulphate ester compound which is a potent inhibitor of mitochondrial ATPase effective against synthesis of energy molecules. It is effective against all stages of mite. In the present study its efficacy was on par with other novel molecules namely fenazaquin, spiromesifen and fenpyroximate showing 96.03 per cent and 93.15 per cent reduction in mite population over untreated control. However in the rice field of Tamil Nadu only 79.53 per cent reduction in the mite population was recorded by propargite (AINPAA, 2013). As the present study was carried out in the polyhouse where controlled condition prevails the molecule might have shown better performance than expected in the open field.

Wettable sulphur though recorded lowest mite population at 1DAS during first spray, its efficacy was significantly inferior to novel acaricide molecule at 3 and 7 DAS. However at 14 DAS its efficacy was found to be on par with novel molecules. When Fenazaquin and spiromesifen was tested along with the conventional acaricides, wettable sulphur for efficacy against *T. urticae*, fenazaquin recorded the minimum mite population at two, four and seven days after treatment which was on par with sulphur. Though the population of mites two days after treatment was significantly high in spiromesifen compared to other treatments, it was found to be on par with them at four and seven days after treatment (AINPAA, 2013).

In the pot culture study, considerable reduction in mite population was found in the botanicals azadirachtin (87.32 % and 87.96 %) and neem oil (85.53 % and 85.43 %) after the first and second spray application respectively. Patil and Nandihalli (2009) reported that neem oil 2 per cent exhibited maximum acaricidal action against red spider mite in brinjal. When different botanicals were tested in the poly house against *T. urticae* on rose, neem oil 2 per cent was found to be the most effective treatment (Kumar, 2007). However the efficacy of both the botanicals was found to be inferior to novel molecules, wettable sulphur as well as standard check, dicofol. Field trials conducted in Tamil Nadu to study the efficacy of different acaricides against *O. oryzae* also showed that novel molecules were superior to azadirachtin (Radhakrishnan and Ramaraju, 2009).

Summary

6. SUMMARY

The study entitled "Biology and management of the rice leaf mite, *Oligonychus oryzae* Hirst (Acari: Tetranychidae)" on rice, was carried out at the Acarology laboratory, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during February, 2014 – May, 2015 to investigate the biology of rice leaf mite, *Oligonychus oryzae* Hirst (Acari: Tetranychidae) and to evaluate selected new acaricide molecules *viz.*, spiromesifen 240 SC, fenazaquin 10 EC, fenpyroximate 5 SC, propargite 57 SC and botanicals *viz.*, neem oil 2 per cent and azadirachtin 0.005 per cent, along with wettable sulphur 80 WP and standard check, dicofol 18.5 EC against *O. oryzae* on rice.

The salient findings of the study are summarized here under.

- The biology of *O. oryzae* was studied under laboratory conditions during July- August 2015 at 27 $\pm$ 3^{0}C and 70.2 $\pm$ 7 % relative humidity, using rice variety Jyothi. The life cycle of *O. oryzae* composed of egg, larva, protonymph, deutonymph and adult. The immature stages *viz.*, larval and nymphal stages were followed by short quiescent intervals called nymphochrysalis, deutochrysalis and teleiochrysalis respectively.

- Incubation period of 3.80 days, larval period of 1.37 and 1.40 days, protonymphal period of 0.73 and 0.40 days and deutonymphal period of 0.98 and 1.30 days were observed, in male and female of *O. oryzae,* respectively.

- The total developmental period from egg to adult emergence was shorter for male (9.87 days) compared to female (10.47 days). Male was whitish green, smaller in size with body tapering posteriorly to a blunt point. Female was whitish green in colour, larger and plumper with longer setae over the body and legs.

- The adult mite recorded longevity of 8, 10.34 and 12.1 days for male, mated female and unmated female, respectively.

- *O. oryzae* exhibited both sexual and parthenogenetic reproduction. Mated female's progeny consisted of both males and females in the ratio 1:3, whereas unmated female produced 100 per cent males.

- Pre-oviposition, oviposition and post-oviposition periods lasted for 0.89, 6.27 and2.08 days and 1.02, 7.31 and 2.12 days, respectively in mated and unmated female. Mated and unmated females on an average produced 21 and 17 eggs respectively.

- Laboratory bioassay carried out to evaluate four new acaricide molecules (Spiromesifen 240 SC, fenazaquin 10 EC, fenpyroximate 5 SC, propargite 57 SC) two botanicals (neem oil 2 per cent and azadirachtin 0.005 per cent) and wettable sulphur 80 WP along with a standard check (Dicofol 18.5 EC) and an untreated control against *O. oryzae* revealed that the new acaricide molecules exhibited high efficacy against various stages of *O. oryzae* and showed a significant reduction in egg and mite population after 72 h of treatment application.

- Pot culture experiment was carried out to evaluate the efficacy of four new acaricide molecules (spiromesifen 240 SC, fenazaquin 10 EC, fenpyroximate 5SC, propargite 57 SC), two botanicals (neem oil 2 per cent and azadirachtin 0.005 per cent) and wettable sulphur 80 WP along with a standard check (Dicofol 18.5 EC) and an untreated control against *O. oryzae* during October 2014 to Febraury, 2015 with two spray applications. The new acaricide molecules, exhibited high efficacy against *O. oryzae* and showed significant reduction in mite population fourteen days after two spray applications.

- Fourteen days after spray application the efficacy of wettable sulphur was on par with novel acaricide molecules and standard check, dicofol.

- Among the botanicals evaluated, azadirachtin 0.005 percent was found to be superior to neem oil 2 per cent though they were on par with each other.

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BIOLOGY AND MANAGEMENT OF RICE LEAF MITE, *Oligonychus oryzae* (HIRST) (ACARI: TETRANYCHIDAE)

By

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THESIS

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ABSTRACT

Mites have emerged as serious pest of rice, particularly in South India in the recent years. The rice leaf mite, *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae) is reported to cause a reduction in yield of 25 per cent in rice. Sporadic incidence of the leaf mite has been reported recently from many rice growing tracts of Kerala as well. Yet, hardly any study has been conducted either on biology or management of this important pest.

The present study entitled "Biology and management of the rice leaf mite, *Oligonychus oryzae* (Hirst) (Acari: Tetranychidae) was undertaken at Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014-15. The objectives of the study were to elucidate the biology of *O. oryzae* on rice and to evaluate four new acaricide molecules namely, spiromesifen 240 SC, fenazaquin 10 EC, fenpyroximate 5 SC, propargite 57 SC, two botanicals (neem oil 2 per cent and azadirachtin 0.005 per cent) and wettable sulphur 80 WP against *O. oryzae* on rice.

The study on the biology of *O. oryzae* was conducted in the Acarology laboratory during July-August, 2014 at 27 ± 3^0C and 70.2 ± 7 per cent RH, following leaf bit method. The life cycle of *O. oryzae* consisted of egg, larva, protonymph, deutonymph and adult. The immature stages were followed by short quiescent intervals called nymhochrysalis, deutochrysalis and teleiochrysalis. The mite recorded an incubation period of 3.80 days. Larval period of 1.37 and 1.40 days, protonymphal period of 0.91 and 1.04 days and deutonymphal period of 0.98 and 1.30 days were recorded in males and females of *O. oryzae* respectively. The total development period from egg to adult was shorter for male (9.87 days) as compared to female (10.47 days). *O. oryzae* exhibited both sexual and parthenogenetic reproduction. Mated female's progeny consisted of both males and females in the ratio 1: 3, whereas, unmated female produced only males. Pre-oviposition, oviposition and post-oviposition periods lasted for 0.89, 6.27 and 2.08 days in case of mated female, and 1.02, 7.31 and 2.12 days in unmated female respectively. Mated and unmated females on an average produced 21 and 17 eggs respectively. The adult mite recorded longevity of 8.00, 10.34 and 12.1 days for male, mated female and unmated female, respectively.

The new acaricide molecules namely, fenazaquin 10 EC, spiromesifen 240 SC and propargite 57 SC evaluated in the laboratory resulted in significantly higher mortality of eggs and gravid females, 72 h after treatment application.

In the pot culture experiment, all the four novel acaricide molecules tested, namely fenazaquin, spiromesifen, fenpyroximate and propargite succeeded in reducing the population of *O. oryzae* significantly. Efficacy of these molecules in reducing the mite population was pronounced from 3rd day after spray application. Wettable sulphur also showed high efficacy against *O. oryzae* and 14 days after treatment application, its efficacy was on par with novel acaricide molecules. The botanicals tested significantly reduced mite population over untreated control, though were found to be inferior to all other treatments.

The study has for the first time, documented the biology of *O. oryzae* in Kerala, which could form the basis for future investigation into ecological and management aspects of the mite. It has also succeeded in identifying a number of novel molecules for further, field level evaluation.