POPULATION DYNAMICS, DAMAGE ASSESSMENT AND MANAGEMENT OF COCONUT MITE, *ACERIA GUERRERONIS* KEIFER IN SOUTHERN REGION OF BANGLADESH

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JUNE, 2019

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REGISTRATION NO. 14-06369

A dissertation
Submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN ENTOMOLOGY

SEMESTER: JANUARY- JUNE, 2019

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CERTIFICATE

This is to certify that dissertation entitled ***"POPULATION DYNAMICS, DAMAGE ASSESSMENT AND MANAGEMENT OF COCONUT MITE, ACERIA GUERRERONIS KEIFER IN SOUTHERN REGION OF BANGLADESH"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***DOCTOR OF PHILOSOPHY IN ENTOMOLOGY****, embodies the result of a piece of bona fide research work carried out by* ***MD. ISHAQUL ISLAM, Registration no. 14-06369*** *under my supervision and guidance. No part of the dissertation has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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TO

MY BELOVED

PARENTS

LIST OF ABBREVIATIONS AND ACRONYMS

Sl. No.	Abbreviation	Full meaning
1.	AAEO	Assistant Agriculture Extension Officer
2.	AEO	Agriculture Extension Officer
3.	BADC	Bangladesh Agriculture Development Corporation
4.	BARI	Bangladesh Agricultural Research Institute
5.	BARC	Bangladesh Agricultural Research Council
6.	BBS	Bangladesh Bureau of Statistics
7.	BRAC	Bangladesh Rural Advance Committee
8.	DAE	Department of Agricultural Extension
9.	DD	Deputy Director
10.	EU	European Commission
11.	FAO	Food and Agriculture Organization
12.	FGD	Focus Group Discussion
13.	IPPC	International Plant Protection Convention
14.	ISPM	International Standard for phytosanitary Measures
15.	NGO	Non-Government Organization
16.	PRA	Pest Risk Analysis
17.	PPW	Plant Protection Wing
18.	UAO	Upazila Agriculture Officer
19.	USA	United States of America
20.	USDA	United States Department of Agriculture

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, the Cherisher and Sustainer of the World. His blessings have enabled the author to complete his dissertation leading to Doctor of Philosophy degree.

The author expresses his heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to his adorable teacher, venerable Research Supervisor and Chairman of the Advisory Committee Dr. Md. Razzab Ali, Professor, Department of Entomology, Sher-e-Bangla Agricultural University for his planning, painstaking and scholastic guidance, support, extraordinary kind concern, everlasting encouragement, inestimable cooperation and intellectual encircling the till final preparation of the dissertation.

He express his profuse gratitude, cordial appreciation and gratefulness to his thoughtful, creative members of the advisory committee Professor Dr. Md. Abdul Latif, Department of Entomology, Sher-e-Bangla Agricultural University, for his valuable suggestions, guidance constant encouragement and inestimable during the entire period of study.

Cordial thank giving due to the scholar members of the advisory committee, Dr. Mohammed Ali, Professor, Department of Entomology, and Dr. F. M. Aminuzzaman, Professor, Department of Plant Pathology, Sher-e-Bangla Agricultural University, for their valuable suggestions, comments and advice during the entire period of study.

The author acknowledges his sincere gratitude to the BARC (Bangladesh Agricultural Research Council) authority for providing a fellowship for PhD study.

With due regards, he thanks the Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. He also acknowledges with deep regards the help and cooperation received from his respected teachers and stuff of the Department of Entomology, Sher-e-Bangla Agricultural University while carrying out this work.

Cordial thank giving due to the Dr. Nazirul Islam, Director General, BARI (Bangladesh Agricultural Research Institute) for his valuable suggestions, comments and advice during the entire period of study work.

He expresses his heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to his late parents for their sincere and affectionate support and love, extraordinary kind concern, everlasting encouragement and inestimable cooperation during the entire period of study.

Last but not the least his dearest thanks goes to his beloved wife Laila Nahar for her interest in his work, her encouragement and love, which immensely contributed to his success.

Finally the author is deeply indebted to his loving daughter 'Anika Islam' and son 'Ashray Mobasar' who must have missed his warm company and total attention during the whole study period. Their big sacrifice, patience and cooperation made it possible to complete his degree successfully.

Dated: June, 2019 ***The Author***

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MD. ISHAQUL ISLAM

ABSTRACT

The study was made in the southern region of Bangladesh *viz*, Jashore, Satkhira, Barishal and Bagerhat as well as in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during June 2015 to May 2017 to evaluate the population dynamics, damage assessment and management of coconut mite, *Aceria guerreronis* Keifer in southern region of Bangladesh. In the southern districts of Bangladesh, coconut growers' were aware about the coconut mite as a major pest of coconut and also took some management practices against this mite. The study revealed significant variations in the average population of coconut mite on different aged coconut nuts. The highest population of coconut mite was observed in April, 2017 in Jashore region (18.44 coconut mites/ 4 sq mm), followed by in Satkhira region (14.81), in Barishal region (9.97) and in Bagerhat region (4.02 coconut mites/ 4 sq mm). On the other hand, the lowest population of coconut mite was observed in August, 2017 in Jashore region (0.85 coconut mites/ 4 sq mm), followed by in Satkhira region (0.51), in Barishal region (0.34) and in Bagerhat region (0.34 coconut mites/ 4 sq mm). There was distinct effect of weather factors on the population of coconut mite specially decline of population with high rainfalls. All coconut trees were infested by the coconut mite from September, 2016 to June, 2017 of Jashore, Satkhira, Barishal and Bagerhat districts of Bangladesh. On the basis of damage extent to coconuts the mean grading index in the month of June, 2017, Jashore region showed the highest value 4.40 following Satkhira region (4.11), Barisal region (3.89), Bagerhat region (3.61) and the South-West region of Bangladesh (4.00). The size of infested coconuts was affected the length, breadth and weight of coconut nut being 26.82 cm, 50.4 cm and 1.51 kg respectively for Grade-1 infested coconut nut, 24.32cm, 47.84 cm and 1.25 kg for Grade-2, 23.83 cm, 47.39 cm and 1.24 kg for Grade-3, 23.32 cm, 44.32 cm and 1.17 kg for Grade-4 and 22.23 cm, 42.99 cm and 1.01 kg, respectively for Grade-5 infested coconut nut. In the study of efficacy of chemical treatments against coconut mite, T_3 (Intrepid 10SC @ 4ml/L of water) showed the best performance with 100.00 % mortality while T_0 (untreated control) showed the lowest performance with 0.00 % at 12, 24 and 36 hours after treatment application. The treatment application as IPM in coconut orchard in Jashore region was effecti9ve in 12 months in IPM package P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) that reduced the mite infestation at 1.67% over untreated plants.

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CHAPTER I

INTRODUCTION

Coconut is a splendid creation of the planet. Coconut palm (*Cocos nucifera* Beccari) is regarded as “Tree of heaven”, because, besides providing food, shelter and employment, it also supplies raw materials for a variety of traditional rural industries. The word derived from the Spanish and Portuguese word, “coco”, which means “monkey/grotesque face”, but the plant is known in many countries by local names. For example, it has been known as “*naryal*” in India for millennia and as “nut of India” by Cosmos, the Egyptian traveler, in AD 545. The tree itself has been described as, “man's most useful tree”, “king of the tropical forest”, “tree of life” and “lazyman's crop” (Woodroof 1970). It is one of the most perennial sources of edible oil. Every part of this plant is useful and commercially important. The coconut belongs to the family Palmae, included under the lower group of flowering plants known as the monocotyledons (Bose and Mitra 1980), which consists of 200 genera and over 2,000 described species (Child 1974). Coconut is the main source of cash income for farmers in the coastal belt/southern region in Bangladesh. Coconut varieties fall under two broad groups, tall or *typica* and dwarf or *nana*. Tall and dwarf coconut types may hybridize to produce intermediate forms. The traditional commercial coconuts were the tall varieties which were preferred to the dwarf varieties because of the quality and quantity of copra they produce. They normally live for over 60 years, adaptable to a wide range of soil conditions, fairly resistant to diseases, insects and water stress, and start to bear within six to ten years. The dwarf varieties come into within three to four years, attain full production by the ninth year and have a life span of about 30 to 40 years (Child 1974).

The coconut palm and its fruit are regarded as the most important plant to humans around the world (Child 1974). Among its most important uses coconut is a food source, provides supplement for body fluids and minerals and acts as an anti-helminthic. The liquid endosperm is also a media for *in-vitro* storage of semen and a growth regulator of plants (Woodroof 1970). Copra, a major product of the coconut industry, is the white kernel, or coconut "meat" after it is dried. In many tropical countries, coconut water is a principal product. Coconut water is the clear liquid in the coconut and is sometimes erroneously called coconut milk which is actually the paste made by grinding the kernel. Copra, the dehydrated endosperm of the nut, is next to soybean as a source of oil for food. Coconut oil is also used in cosmetics and pharmaceuticals. The material that remains after the oil is expressed from copra is called oilcake and is used as animal feed (Woodroof 1970). Coconut shell is used directly as fuel, filler, extender in the synthesis of plastic, to make activated charcoal, household articles, and to produce various distillation products, such as tar, wood spirit and pitch. Coir, a course fiber from the husk of the nut, has various domestic and industrial uses. Coconut root is brewed and used in folk medicine, for example, as a cure for dysentery (Woodroof 1970). Coconut accounts for a large part of the national earnings of the Asian and Pacific Coconut Communities (APCC 2010).

In Bangladesh, the total area of land under coconut cultivation is 32 thousand acres hectares and the total production of coconut is 30,790 metric tons (Anon 2019). Coconut grows well in the coastal region of Bangladesh like Khulna, Bagerhat, Jassore, Satkhira, Barisal, Bhola, Chittagong, Feni, and Noakhali (Islam 2002). Bangladesh grows a variety of crops and rice is the predominant one that accounts for about 75% of the cropped areas. On the other hand at present different fruit crops occupy only 1.5% of the total cultivated land of the country, where about 70 different fruits are grown including coconut. Coconut occupies only 0.63% of total cultivated lands for fruit crops in Bangladesh (Anon 2019). However, in Bangladesh, coconut is considered as a crop of high economic value due to its diversified uses. The crop is commonly grown in homesteads with efficient utilization of land. Many small holder households generally depend on the coconut for their livelihood as it provides regular incomes (Eyzaguirre and Batugal 1999). It has also been estimated that around 44% of total production of coconut is consumed as tender nut and 40% as mature nut for fresh consumption. Only 9% is processed in industries while 7% is used for seedling purpose (Islam 2002).

In the coastal region of Bangladesh, air always contains more moisture and breezes gentle, which is very useful for pollination and fruit set of coconut. Moisture preservation ability of coconut is very low. In coastal region water table is light deep and temperature variation is low. There is a huge scope of coconut production in the coastal region including Satkhira, Khulna and Bagerhat district. Soil and climate of this region is favorable for coconut production. But the production of coconut is not satisfactory in the region due to infestation of coconut mite (Islam 2002).

Coconut wood is more and more being used for building houses and other uses such as furniture or tool handles. Recently, coconut palms are found to suffer from reduction in size, followed by immature bud dropping. This problem has taken an epidemic turn in major coconut growing areas of the world. More than 900 species of pests are associated with cultivated and wild coconut palm. This number includes both invertebrates and vertebrates. Of these, red palm weevil, (*Rhynchophorus ferrugineus* Olivier), rhinoceros beetle (*Oryctes rhinoceros* L.) and eriophid mite (*Aceria guerreronis*) (Keifer) (Prostignata: Eriophyidae) are the most important devastating pests of coconut growing areas of the world. These three arthropod pests are distributed wherever coconut palm occurs. Yield losses may be more than 25% as reported from India (Gopal and Gupta 2001) due to attact of these pests. Recently coconut mites are causing severe problem in the sub-continent.

Coconut eriophyid mite, *Aceria guerreronis* Keifer is a potential and invasive pest of coconut causing heavy economic loss to the coconut Industry (Keifer 1965). The coconut mite is considered as the most important pest of coconuts in the America, Africa and most recently in South-East Asia. Although its exact origin is debatable, it is likely to be native to South America and introduced to Africa and Asia, where it is an invasive species (Navia *et al.* 2005). In India, coconut eriophyid mite was first reported from Amballur, Panchayat in Ernakulam district of Kerala during 1998 (Sathiamma *et al.* 1998). Within a short span of time the mite had spread rapidly to all major coconut growing regions of the country and currently its incidence is reported from the entire coconut growing states of West and East Coast and North-East part of India including Lakshadweep and Andaman and Nicobar Islands (Rabha *et al.* 2013 Nair *et al.* 2005, Sujatha and Rao 2004, Singh and Rethinam 2004, Mullakoya 2003, Mallik *et al.* 2003, Khan *et al.* 2003, Nair 2002, Ramaraju *et al.* 2000). The host range of *A. guerreronis* is very narrow. Apart from coconut, *A. guerreronis* was also recorded from palmyrah palm (*Borassus flabellifer*) in India (Ramaraju and Rabindra 2001).

Occurrence of this mite was also noticed in Bangladesh, Nepal, Maldives and other South East Asian countries. In Bangladesh, the incidence of this mite was first noticed during 2004 (Islam *et al.* 2008). However, later on the real cause of this bud damage was identified by the scientists. Infestation of coconut mite is noticed all over Bangladesh but severe infestation of this pest was recorded from the southern part of the country especially in the coastal districts (Islam *et al.* 2008). Coconut mites probably disperse from one palm to another by air current or by phoresy e.g., carried on insects or birds that visit palm flowers. Wind-aided migration is thought to be responsible for *A. guerreronis* dispersal (Julia and Mariau 1979; Griffith 1984; Ramarethinam and Marimuthu 1998; Ramarethinam *et al.* 2000), though mites also cross over touching inflorescences, with a tendency to move from older to younger inflorescences (Moore and Alexander 1987). Where coconut palms are dense, they can crawl from palm to palm. Their inefficient host-finding capabilities seem to be compensated by a high reproductive rate (Haq 2001 and Mohanasundaram *et al.* 1999).

The coconut mite pest occurs in both tropical and sub-tropical climates and infestation is more severe in relatively dry climates, or during the dry season of wetter climates (Howard *et al.* 1990, Griffith 1984, Zuluaga and Sanchez 1971). However, no clear relationship has been observed between mite densities and weather, or as such a relationship existed, it was obscured by other factors (Ramaraju *et al.* 2000, Howard *et al.* 1990, Mariau 1969 & 1977, Doreste 1968).

Mite density tended to decline immediately after heavy rain, while egg density was unpredictable after rainfall. In the absence of substantial rainfall, active mites were subjected to high temperatures. The wind velocity was positively correlated with the active mite density (Varadarajan and David 2002). Generally, mites are able to tolerate extreme temperatures. The phytoptid *Nalepella hearloui* Boczek which infests the needles of *Picae abies* overwinters exclusively at the egg stage (Loyttyniemi, 1971). Diapaused eggs of *P. abies*, when taken to the laboratory hatched after 17 days at 10°C, after 10 days at 15°C and after 7 days at 20, 25 or 30°C (Manson and Oldfield 1996). Fertilized eggs of the citrus bud mite, *Aceria sheldoni* (Ewing) produced offspring at 24-30°C (Sternlicht and Goldenberg 1971). The way in which *A. guerreronis* tolerates temperatures needs to be examined further.

The pest complex of coconut is widening in recent years. Lepesme (1947) listed 751 species of insects infesting palms, of which nearly 22 percent are specific to the coconut palm. Nirula (1955) and Kurien *et al.* (1979) listed 106 and 547 insect and mite species respectively. Mohanasundaram and Kuppusamy (1989) presented a review on the coconut mites and listed twenty mite species including the occurrence of six new species from Tamil Nadu, South India (Sathiamma 1995). Among them, coconut eriophyid mite *Aceria guerreronis* (Keifer) is considered to be one of the very serious pest and found to cause serious damage resulting in heavy loss in production of nuts. Yield loss to various levels has been reported worldwide as a result of infestation by the pest. In general, pest incidence and extent of loss are comparatively high during the initial few years of pest occurrence in a particular locality due to the invasive nature of the pest. Yield loss depends on the cultivar, health and general maintenance of the crop as well as intensity of infestation. Increased difficulty in dehusking (leading to greater labour requirements for this job) also contributes to economic loss. Feeding by few mites causes only cosmetic damage to the husk without affecting the quality and quantity of copra and coconut water (Mohan *et al.* 2014).

However, the management practices against coconut mite taken by coconut growers are nutrition management, sanitation management, cultural management, miticide spraying and IPM. In these practices, coconut growers are willing to spray acaricide frequently and at indiscriminate rate against coconut mite. Acaricides have been tested for control of the coconut mite and some have been shown to kill the mites. However, most chemicals applied topically had to be applied frequently and indefinitely to maintain control. Systemic acaricides might persist longer in the plant, but such chemicals could result in residues in the fruits as coconuts are harvested throughout the year. Their indiscriminate use has created several problems in agroecosystem such as direct toxicity to beneficial organisms (predators, parasitoids, pollinators, etc.), fishes and man (Goodland *et al.* 1985), increased resistance, phytoxicity of pesticides, outbreak of secondary pests, susceptibility of crop plants to insect pests, increased environmental and social costs, health hazards and environmental pollution. Chemical control is perhaps the least viable option for control of coconut mite. Botanicals are comparatively less toxic, naturally available materials, less expensive, less hazardous, bio-degradable and also safe for beneficial organisms.

Objectives of the study

Considering the above view in mind, the present study has been undertaken with the following objectives.

1. To assess the present status of coconut mite (*Aceria guerreronis*) problem in major regions of Bangladesh;
2. To study on the population dynamics of coconut mite in those areas;
3. To assess the damage severity caused by coconut mite in the garden; and
4. To find out the effective management practices against coconut mite on coconut plants.

CHAPTER II

REVIEW OF LITERATURE

Coconut mite, *Aceria guerreronis*, is one of the most important and major pest of coconut. In Bangladesh, the southern region is most favourable for coconut cultivation and coconut mite causes main problem there. To evaluate the bioecology and management practices in Bangladesh, this study was made. For the purpose of the study, the most relevant information is given bellow under the following subheadings:

2.0. Coconut mite

2.1. Taxonomic Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Arachnida

Order: Prostigmata

Family: Eriophyidae

Genus: *Aceria*

Species: *A. guerreronis*

Other scientific name: *Eriophyes guerreronis*

2.2. Morphology and biology of coconut mite

Coconut mite is an elongate wormlike, yellowish white eriophyid. Adult females are 205–255 µm long and 36–52 µm wide (Keifer 1965). Eggs are small, white, round to oval. Except for sizes and for the presence of genital openings in adults, all developmental stages are quite similar. Information about the morphometric variation among populations from the Americas, Africa and Asia was presented by Navia *et al.* (2006, 2009).

On coconut, coconut mite populations develop on the meristematic zone of the fruits covered by the perianth (bracts). Feeding in this zone causes physical damage that leads to necrosis (Moore and Howard 1996). Mites can be found on coconut inflorescences during the dispersion process.

Earlier studies on coconut mite biology were conducted by Mariau (1977) in Benin, Suarez (1991a) in Cuba, and Haq (2001) and Sobha and Haq (2011) in India. The authors determined that immature development on coconut can be completed in 8–10.5 days, and that each female may lay up to 66 eggs. Similar to other eriophyids, the immature phase of coconut mite includes the egg, larval and one nymphal stage (Manson and Oldfield 1996).

A more detailed biological study was conducted by Ansaloni and Perring (2004) on pieces of meristematic tissue of young *S. romanzoffiana* leaves, at different temperatures. Development from egg to adult was observed to require 30.5, 16.0, 11.5, 8.1 and 6.8 days at 15, 20, 25, 30 and 35^{o}C, respectively, and the maximum temperature to allow development was estimated to be close to 40^{o}C. Lower threshold and optimal development temperatures were calculated to be 9.3 and 33.6^{o}C, respectively. Although coconut mite is found mainly in tropical and subtropical climates, it can survive for at least 5 h of frost and for more than a week below 5^{o}C (Howard *et al.* 1990). Ansaloni and Perring (2004) determined that fertilized females were able to lay a maximum of 51 eggs over a maximum of 43 days. Eggs laid by non-fertilized females produced only male offspring, indicating this species to be arrhenotokous.

2.3. Colonization process

Varadarajan and David (2002) observed no significant difference between the numbers of mobile coconut mite on the fruit surface covered by the bracts and on the bracts, but found more eggs on the bracts. Conversely, Thirumalai Thevan *et al.* (2004) observed more coconut mite on the fruit surface than on the bracts. Recent surveys of the acarine fauna on different parts of coconut palms revealed that the area under the perianth is occupied mostly by coconut mite, harboring a lower diversity of phytophagous and predatory mites than the leaves (Lawson-Balagbo *et al.* 2008 a). Varadarajan and David (2002) evaluated the pattern of coconut mite distribution among the bracts, observing more eggs and post-embryonic stages on the inner bracts. Similar results were obtained by Lawson-Balagbo *et al.* (2007 a) in relation to coconut mite post-embryonic stages.

Very young fruits are almost entirely covered by the perianth, which is tightly adherent to the fruit surface, giving maximal protection against coconut mite. However, as the fruits grow, the space underneath the bracts increases, in many cases allowing coconut mite to first have access to the protected tissues when fruits are about a month old (Moore and Howard 1996, Howard and Abreu Rodrı´guez 1991, Mariau 1977, Mariau and Julia 1970, Moore and Alexander 1987). The tightness of the bracts to the fruit surface depends on variety, fruit age, water stress and infestation by other phytophagous organisms (Aratchige 2007, Moore 1986, Mariau 1977).

Information on the process of coconut mite colonization of coconut trees and phonological periods when fruits are susceptible to coconut mite infestation is important for the development of management strategies. Mariau and Julia (1970) observed a high rate of abortion of young coconut fruits, independent of mite attack. At the same time, they noticed that coconut mite could be found on a small proportion of fruits that had been fecundated just a few days earlier and that the level of infestation increased progressively afterwards. Thus, it seems that infested young fruits could also be aborted, reducing the number of infested young fruits on the plants to low levels, possibly turning their detection difficult.

Considerable variation in population levels are observed between infested fruits of a bunch. A study conducted in Sri Lanka indicated that variations seem to be lower on 6-month old fruits, suggesting that the sample from this bunch would be more reliable in population assessments of coconut mite (Fernando *et al.* 2003). In Brazil, Galva˜o *et al.* (2011) observed no significant differences between coconut mite densities on fruits of basal, median and apical thirds of a bunch, when all fruits of 2- to 6-month-old bunches were considered together. However, the authors observed that on younger bunches fruits of the apical third tended to have lower coconut mite densities than those of the basal third. Fruit age at which lesser variability is observed is expected to vary according to variety and prevailing edaphoclimatic conditions. In Brazil, smaller variations for Green Dwarf variety was also observed to occur on 6-month-old fruits, but that was associated with a reduced coconut mite population level (Galva˜o *et al.* 2011).

As with most mites, coconut mite is not evenly distributed among the coconut bunches in a palm. Highest coconut mite population densities have been reported on fruits ranging from 3 to 7 month after fertilization (Negloh *et al.* 2011, Galva˜o *et al.* 2011, Thirumalai Thevan *et al.* 2004, Fernando *et al.* 2003, Mallik *et al.* 2003, Varadarajan and David 2002, Moore and Alexander 1987). Soon after reaching the maximum level, coconut mite population usually declines quickly. Galva˜o *et al.* (2011) suggested that coconut mite population decline on bunches older than 4 months could be due to an effect of the predator, reduction of the proportion of undamaged tissue amenable to attack and/or less favorable characteristics of the fruits to attack, as indicated by their increasing lignin content as fruits get older. Variations between studies are probably in part due to the different coconut germplasms involved. In one of those studies (Moore and Alexander 1987), coconut mite was observed on fruits up to 13 months after fertilization.

Distribution of coconut mite within a coconut field has not been adequately evaluated. Irregular distribution in many small-grower fields is to be expected, given the common mixture of germplasm under those conditions and the difference in susceptibility observed between germplasms, as discussed further on.

2.4. Distribution

Since first reported from Mexico, *A. guerreronis* has been reported from many coconut-growing regions of the Americas, in West Africa from Côte d'Ivoire to Nigeria (Hall and Espinosa 1981) and Gambia (Howard *et al.* 2001), Tanzania, India and Sri Lanka (Sathiama *et al.* 1998; CRI/UNDP 2000).

A record of *A. guerreronis* in Australia published in previous versions of the Compendium was erroneous and has been removed. Halliday and Knihinicki (2004) and Coutts *et al.* (2008) clearly refer to wheat curl mite, *Aceria tosichella*, in Australia and not *A. guerreronis*. The distribution of coconut mite is shown in table 1 (CABI 2020).

Table 2.1. Distribution table for Coconut mite (CABI 2020)

Continent	Country	Distribution	Reference
Africa	Benin	Present, Widespread	EPPO (2014)
	Cameroon	Present, Widespread	EPPO (2014)
	Côte d'Ivoire	Present, Widespread	EPPO (2014)
	Gambia	Present	Howard *et al.* (2001)
	Mozambique	Present	EPPO (2014)
	Nigeria	Present, Widespread	EPPO (2014)
	Tanzania	Present, Widespread	EPPO (2014)
	Togo	Present, Widespread	EPPO (2014)
Asia	India	Present	EPPO (2014)
	Malaysia	Present	EPPO (2014)
	Maldives	Present	EPPO (2014)
	Oman	Present	EPPO (2014)
	Philippines	Present	EPPO (2014)
	Sri Lanka	Present	Moore (2000)
Europe	Hungary	Present	Gólya *et al.* (2002)
	Poland	Present	Skoracka and Magowski (2002)
North America	Anguilla	Present	EPPO (2014)
	Bahamas	Present, Widespread	EPPO (2014)
	Belize	Present	EPPO (2014)
	Costa Rica	Present	EPPO (2014)
	Cuba	Present, Widespread	EPPO (2014)
	Dominica	Present	EPPO (2014)
	Haiti	Present, Widespread	EPPO (2014)
	Jamaica	Present, Widespread	EPPO (2014)

Continent	Country	Distribution	Reference
	Mexico	Present, Widespread	EPPO (2014)
	Saint Lucia	Introduced	Jn Pierre (2008)
	United States	Present	EPPO (2014)
South America	Brazil	Present, Widespread	EPPO (2014)
	Colombia	Present, Widespread	EPPO (2014)
	Venezuela	Present, Widespread	EPPO (2014)

The coconut palm is an important crop in the sub arid coastal plain of Dhofar, Oman, for the high demand for its nut water and its use as ornamental plant. Damage of coconut fruits by the eriophyid mite *Aceria guerreronis* Keifer was first reported in that region in the late 1980s, but background information about the ecology of the pest in Oman was missing. Four surveys were conducted in different seasons from 2008 to 2009, to assess the distribution and prevalence of the Coconut mite and its damage as well as the presence of natural enemies. Infestation by the Coconut mite was conspicuous on most (99.7 %) palm trees, with 82.5 % damaged fruits (Al-Shanfari *et al.* 2013).

Coconut mite was described by Keifer in 1965 from specimens collected in the state of Guerrero, Mexico, although, as suggested by Mariau and Julia (1970), some records indicated that it was already found in several regions of the American continent by the time of its original description (Ortega *et al.* 1967; Robbs and Peracchi 1965; Zuluaga and Sa´nchez 1971); in Colombia, symptoms had been observed since 1948 (Zuluaga and Sa´nchez 1971); in Brazil, since 1953 (GP Arruda, Instituto Agronoˆmico de Pernambuco, Recife, Brazil, pers. comm.); and in Mexico since 1960 (Ortega *et al.* 1967).

In addition, around the time of its description, Coconut mite was also found in 1963 in Sa˜o Tome´e Principe, on the coast of Africa, and in 1967 in Benin, Cameroon, Nigeria and Togo (Cabral and Carmona 1969; Mariau 1969). It was then reported in Colombia in 1970 (Estrada and Gonzalez 1975), Ivory Coast in 1975 (Mariau 1977), Dominica in 1976 (Moore and Alexander 1985), Saint Lucia in 1980 (Moore *et al.* 1989), Costa Rica in 1985 (Schliesske 1988), Jamaica in 1986 (McDonald 1996), Oman at the end of the 1980s (Al-shanfari *et al.* 2010), Puerto Rico in 1990

(Howard *et al.* 1990) and Tanzania in the late 1990s (Seguni 2000). In Asia, Coconut mite was first reported from SriLanka in 1997 (Fernando *et al.* 2002), and soon after, in central Kerala, southern India (Sathiamma *et al.* 1998). In 1999, it was reported from the entire states of Kerala and Tamil Nadu, in areas of Karnataka and on Lakshadweep islands (Minicoy, Kalpeni and Kavaratti) (Haq 1999). During the last decade, Coconut mite spread rapidly to all coconut growing states of India (Muthiah 2007). Surprisingly, the mite has never been reported in the presumed region of coconut origin, namely between the remaining of south-east Asia and Papua New Guinea (Chan and Elevitch 2006).

Since first reported from Mexico, *A. guerreronis* has been reported from many coconut-growing regions of the Americas, in West Africa from Côte d'Ivoire to Nigeria (Hall and Espinosa 1981) and Gambia (Howard *et al.* 2001), Tanzania, India and Sri Lanka (Sathiama *et al.* 1998; CRI/UNDP 2000).

A record of *A. guerreronis* in Australia published in previous versions of the Compendium was erroneous and has been removed. Halliday and Knihinicki (2004) and Coutts *et al.* (2008) clearly refer to wheat curl mite, *Aceria tosichella*, in Australia and not *A. guerreronis*.

Although Coconut mite has been reported to damage coconuts for over 40 years in the Americas and Africa (Zuluaga and Sa´nchez 1971, Cabral and Carmona 1969, Mariau 1969, Ortega *et al.* 1967, Robbs and Peracchi 1965); Coconut mite not only continues to cause considerable losses in American and African countries, but in the last 15 years it has also reached countries from southeast Asia-India and Sri Lanka(Fernando *et al.* 2002, Sathiamma *et al.* 1998), where coconut is economically and socially much more important than in the countries from where Coconut mite was known before. Several other countries of south-east Asia are also major coconut producers (FAOSTAT 2011). The impact by the mite in India and Sri Lanka (Haq 2011, Fernando *et al.*

2002) suggests that the dispersion of Coconut mite to these countries could lead to very heavy losses.

A snap survey on the incidence of coconut eriophyid mite was undertaken during 2009 at Coimbatore and Thanjavur districts (Tamil Nadu), Hassan and Tumkur districts (Karnataka), Retnagiri (Maharastra), Trivandrum and Kasaragod districts (Kerala) selecting six panchayats in each district. The average mite incidence ranged from 4.06 - 46.11% in different regions surveyed. Survey undertaken during April 2010 for assessing mite incidence in Lakshadweep Islands indicated a high infestation of 57.5% in Kavaratti, a moderate incidence of 23.2% in Kalpeni and a low infestation of 17.9% in Minicoy Island (CPCRI 2010). Mite incidence in Andhra Pradesh showed 28.9% (West Godavari) to 39.6% (East Godavari) (Rajan *et al.* 2012).

The Coconut mite is also very serious and devastating disease of the coconut. The tiny microscopic mites feed on the tissue of the nut surface. They damage, distort and reduce size of the fruits. The fruits eventually turn brown and finally drop. Incidence of Coconut mite has spread to most coconut production areas and it has been considered one of the most notorious and important pests of coconut fruits in coastal area (Solangi 2014).

In India, eriophyid mite (*Aceria guerreronis* K.) was first reported in 1998 in Ambalour panchayat, Ernakulum district of Kerala (Haq 1999, Sathiamma *et al.* 1998) and Sri Lanka (Fernando *et al.* 2002), at the end of the 1990´s. The feeding of mite causes scarring of growing nuts resulting in nut malformation and reduced copra yield (Ranjith 2003, Ramaraju *et al.* 2002, Moore *et al.* 1989). Heavy damage, result in the loss of quality and quantity of coconut (Lekeshmanaswamy and Prathipa 2014, Negloh *et al.* 2011, Ramaraju *et al.* 2000). Recently a new mite Aceria amrini n. sp. was collected from Tamarix aphylla (Tamaraceae), from India (Joshi *et al.* 2013).

The eriophyid mite infestation from India was first noticed in Kerala state and it spread in coastal belt like Karnataka and Goa. As per the area of transmission of mite, it was assumed that the eriophyid mite infestation started from Sindhudurg district because this district is close to Goa followed by Ratnagiri, Raigadh and then in Thane district. But mite was first noticed in Thane district of Maharashtra. In Thane district, tourism is well developed because it is adjoining to Mumbai city. The tender nuts are coming from Kerala and Karnataka state to this area because of the huge demand for tender coconut. As eriophyid mite first spread in Kerala and Karnataka, the mite infestation spread along with tender nuts in this area. Similarly though the eriophyid mite infestation was low in Ratnagiri and Raigadh districts, it may suddenly increase if the conditions favour this pest as found in Sindhudurg district. Therefore, it is necessary to start control measures to eradicate this pest from these districts also (Desai *et al.* 2009).

Coconut eriophyid mite, *Aceria guerreronis* Keifer (Eriophyidae: Acarina) is a potential and invasive pest of coconut causing heavy economic loss to be coconut Industry. In India, coconut eriophyid mite was first reported from Amballur Panchayat in Ernakulam district of Kerala during 1998 (Sathiamma *et al.* 1998). Within a short span of time the mite had spread rapidly to all major coconut growing regions of the country and currently its incidence is reported from the entire coconut growing states of West and East Coast and North-East part of India including Lakshadweep and Andaman and Nicobar Islands (Rabha *et al.* 2013, Nair *et al.* 2005, Singh and Rethinam 2004, Sujatha and Rao 2004, Mallik *et al.* 2003, Khan *et al.* 2003, Mullakoya 2003, Nair 2002, Ramaraju *et al.* 2000)

Of all the coconut pests, the Coconut mite is the most important one in Jamaica and the Caribbean. Although the Coconut mite was first recorded in Jamaica in 1941, it was not considered a pest until 1972 (Hall 1981). After this outbreak of the Coconut mite a survey was conducted throughout the island to assess its distribution (Hussey 1975). The very first record of Coconut mite injury was in 1928 in New Guinea (Martyn 1930). The injury was then believed to be due to a disease caused by a complex of fungi and bacteria (Cardona and Potes 1971). In the early 1960's the Coconut mite was discovered and the family identified (Acari: Eriophyidae) from samples of coconut in Guerrero, Mexico (Ortega *et al.* 1965) and Santa Marta, Colombia (Cardona and Potes 1971) during independent research. In 1965 the Coconut mite was described and identified as *Aceria guerreronis* Keifer (Ortega *et al.* 1965) and in 1971 reclassified by Newkirk and Keifer as *Eriophyes guerreronis* (Keifer) (Olvera-Fonseca 1986).

Colonization of coconuts by Coconut mites takes place shortly after fertilization (Moore *et al.* 1989). Coconut mite populations peak on 3- to 6-month old nuts, after which, the numbers decline sharply so that nuts over nine months old have relatively low populations (Moore and Alexander 1987). Coconut mites tend to leave nuts two to three months before the nuts are fully developed or when damage to the pericarp exceeds 15% because there is no renewal of meristematic tissue (Anonymous 1985). In addition, damaged nut surfaces tend to secrete resin which traps and kills the mites (Moore and Alexander 1987).

The occurrence of eriophyid mite, *A. guerreronis* K. on coconut was first reported from the Guerrero State in Mexico in the year 1965 as a nut inhabiting mite. Since then it has been reported from many coconut growing areas of the America, West Africa and the Caribbean Islands from Cuba to Trinidad and St. Lucia in the West Indies. In the Asia-Pacific region it was first noticed in Sri Lanka during 1997. In India it was first observed during 1998 in Ernakulam district in Kerala (Sathiamma *et al.* 1998), which later spread to all other coconut growing regions of the country. At present, the mite damage is wide spread in all coconut growing states in India causing moderate to heavy damage. Occurrence of this mite was also noticed in Bangladesh, Nepal, Maldives and other South East Asian countries. In Bangladesh the incidence of this mite was first noticed during 2004 (Islam *et al.* 2008). During that period mobile phone networks were expanding throughout the country and mobile phone towers were setting at different regions and the coconut farmers believed that the problem happened due to the effect of mobile phone network expansion. However, later on the real cause of this bud damage was identified by the scientists. Infestation of coconut mite is noticed all over Bangladesh but severe infestation of this pest was recorded from the southern part of the country especially in the coastal districts. Very few works have so far been reported on the management of the coconut mite in Bangladesh. The management of the coconut mite is following the same route of current pest management strategies for other pests. So, before discussion about the coconut mite management brief highlight on the current pest management situation is as follows: Till today crop protection of Bangladesh is mostly dependent on chemical pesticide. Pesticide use in Bangladesh started from mid-fifties and gained momentum in early 1970's with the introduction of green revolution through the use of high yielding rice varieties. Through the import of 3 metric tons (MT) of insecticides in 1956, Bangladesh entered into the era of the synthetic chemical pesticides for pest control and during 2011-12 about 51,560 ton pesticides have been imported, spending about 12 hundred crore taka (BCPA 2013), where 43.79% is insecticide, 56.07% fungicides and 0.14% miticide.

Das *et al.* (2013) studied on the Coconut mite infestation and observed that in Khulna district the infestation of Coconut mite was higher than Bagerhat district.

2.5. Seasonal abundance

The seasonal incidence of coconut eriophyid mite, A. guerreronis was studied during November 2000 to December 2001 in coconut plantations at Kadavasal, Chidambaram, Tamil Nadu. The incidence of mite was found throughout the year. But the peak incidence was observed during dry climate April, May and June and started declining during wet climate July. The correlation between temperature, rainfall and mite population revealed that the population density was positively correlated with temperature and negatively correlated with rainfall. The prediction model has been developed for the given set of parameters (Balaji and Hemavathy 2007).

Coconut mite populations and the extent of damage caused by the coconut mite have esponded differently to wet and dry seasons in different regions of its geographical range. In Jamaica, the coconut mite was first recorded in 1941, in St. Ann parish, but not was recognized as a pest until 1972. The Jamaica coconut industry suggested that an extended period of drought might have led to an outbreak of the mite (Hall 1981). In Benin and the Ivory Coast, Julia and Mariau (1979) found levels of attack four to five times higher in the wet seasons than in the dry; the reverse was reported from Guerrero, Mexico (Mariau 1969). Otterbein (1988) reported that in Costa Rica the greatest nut damage was associated with frequent heavy rainfall and high humidity.

Mallik *et al.* (2003) reported enhanced migration of mites during the cooler hours of the day. Infestation symptoms of mite are primarily observed approximately one-month after the initial colonization of the mite inside the fertilized buttons. Appearance of elongated white streaks below the perianth is the first external visual symptom on young buttons. In many cases, a yellow halo develops around the perianth. Within a few days, this halo develops into yellow triangular patch pointing towards the distal-end of the button. This can be clearly seen in two-three month old buttons. In a short time the yellow patch turns brown and show necrotic patches on the periphery of the perianth. As the nut grows, the injuries transform into warting and longitudinal fissures on the nut surface. In severe infestation the husk develops cracks, cuts and gummosis. Shedding of buttons and young nuts as well as malformation of nuts due to retarded growth are the other indications associated with severe attack of the pest. The distribution of eriophyid mite colony is not uniform inside the perianth. Normally in two or three places the mite colonies are congregated under the tepals varying in size and shape.

Pushpa (2006) indicated that the mite population occurred in Dharwad area throughout the year with variation during different season of the year. The variations in the range of infestation are may be due to changing environmental as well as biotic stresses.

Nair (2002) observed that the seasonal abundance of the mite showed the persistant nature of the pest with the population peaking in summer months (April-May). The extent of damage varies from 20-60%. Currently the management of the pest is achieved by spraying of pesticides like monocrotophos, dicofol and methyl dematon and botanical pesticide (2% neem oil, garlic mixture). Many people reported the incidence of this mite in various parts of world within tropical and sub tropical regions (Das *et al.* 2013, Al-Shanfari *et al.* 2013, Negloh *et al.* 2011, Lawson- Balgbo *et al.* 2008, Howard and Abreu-Rodrigeuz 1990, Griffith 1984, Mariau 1977, Zuluaga and Sanches 1971).

Zuluaga and Sanchez (1971) and Griffith (1984) who observed the presence of mites throughout the year with severe infestation during relatively dry climatesor during the dry periods of wetter climates. Haq (1999) also reported that variation in the incidence of mite population may be due to difference in the rainfall. Sujata and Chalapati Rao (2004) concluded that decreased population counts were observed during rainy and winter months where high relative humidity prevailed when compared to summer months. Kannaiyan *et al.* (2000) reported that maximum population was seen during May followed by April and March.

Mariau (1969) and Otterbein (1988) noted that climate affects the development of Coconut mite populations. Coconut plants nearer the Atlantic Ocean showed less Coconut mite damage (Mariau 1969). In Benin and the Ivory Coast, Julia and Mariau (1979) found levels of attack up to five times higher in the wet seasons than in the dry; the reverse was reported from Guerrero, Mexico (Mariau 1969). Otterbein (1988) reported that in Costa Rica the greatest nut damage was associated with frequent heavy rainfall and high humidity. Howard *et al.* (1990) found that the Coconut mite populations increased immediately after periods of high rainfall in Puerto Rico and Florida but noted that coconut mite population fluctuations were not associated with dry and wet seasons nor with mean daily temperatures.

The coconut palm puts forth on an average one inflorescence a month. Thus, throughout the year the mite could locate nuts of suitable age for initiating infestation and population build-up. Peak population was observed during the summer months and a sharp decline in subsequent rainy months indicating a negative relationship betweenmite population and rainfall (Mallik *et al.* 2004, Nair 2002, Nampoothiri *et al.* 2002, Mathew *et al.* 2000). Studies undertaken in Kerala coast revealed that a period ofhigh temperature with intermittent rains causing high humidity favoured higher multiplication and rapid spread of the mite (Nair *et al.* 2003). Observations on the population of the mite within various age groups of the nuts showed that third and fourth bunches harbour maximum mite population.

A study conducted to determine the population dynamics of the coconut mite and its relation with the local rainfall data in two areas namely, Kalpitiya and Madurankuliya in the north-western part of Sri Lanka revealed that the coconut mite densities varied significantly among years and months in each year (Aratchige*et al.* 2012). Although the amount and the frequency of rainfall of the same month and the previous month did not significantly affect the Coconut mite densities, the drought length (i.e. the number of days without rainfall of >5 mm) affected the Coconut mite densities; longer the dry period, higher was the Coconut mite densities. Generally peak densities of Coconut mite were observed during February-March and June-September i.e. during the period of either decreasing or low rainfall and the populations of Coconut mite remained low during rainy seasons (Aratchige *et al.* 2012).

Coconut mite was first reported in 1998 from the Kalpitiya Peninsula (North Western Province, dry-zone) (Fernando *et al.* 2002). Within two years, it was spread to almost all coconut growing areas in the dryand intermediate-zones of the country and few coconut growingareas in the wet-zone. At present, the Coconut mite has invaded all districts except NuwaraEliya which is mainly a hilly area where coconut is not as extensively grown as inother districts. However, the incidence of Coconut mite varies from district to district with higher incidences in dry and intermediate-zones than in the wet-zone.

Pushpa and Nandihalli (2009), reported that the course of surveillance the mite population on the nut surface ranged from 50.01 to 105.73 mites per 28.28 mm^2 area. The mite population during the period from secondfortnight of July to first fortnight of November ranged from 50.20 to 58.89 per 28.28 mm^2 area. A sudden increase in mite population was seen in second fortnight of December (68.92). Then onwards it increased upto second fortnight of January (84.26). The mite population decreased during second fortnight of February (72.29). Then onwards, the mite population started increasing and reached another peak during second fortnight of May (105.73). From then onwards the population of the mite decreased. The mite population on perianth fluctuated from the lowest of 18.28 mites (second fortnight of June) to the highest of 58.52 (second fortnight of May). During remaining months mite population on perianth was more or less constant. On an average the mite population on nut surface was more (69.80 mites) compared to perianth (30.41).

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Unfertilized flowers are free from Coconut mites (Fernando *et al.* 2003) and the colonization starts just after fertilization of the female flowers (Negloh *et al.* 2010, Fernando *et al.* 2003, Howard *et al.* 1990, Moore and Alexander 1987). In Sri Lanka,starting from the nuts after fertilization, mean number of Coconut mites is increased up to the bunch of 5 month old (i.e. 5 months after fertilization of the female flower) and declined thereafter (Fernando *et al.* 2003). In general, peak densities of Coconut mite are observed on 3-7 month old bunches (Negloh *et al.* 2011, Galvão *et al.* 2011, Thirumalai Thevan *et al.* 2004, Fernando *et al.* 2003, Mallik *et al.* 2003, Varadarajan and David 2002, Moore and Alexander 1987).

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Panchayat of Eranakulum district of Kerala (India). The infestation had spreadthroughout peninsular India and in parts of Pondicherry and Lakshadweep. Prasad and Ranganath (2000) also found the presence of perianth mites' infestation in Andaman.

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2.6. Host range of Coconut mite

Coconut mite has been reported from only three other palm species. Two of these are of American origin: *Lytocaryum weddellianum* (H. Wendl.) (*Cocos weddelliana* H. Wendl.) was found attacked by coconut mite in Brazil (Flechtmann 1989) and Syagrus romanzoffiana (Cham.) Glassm. in southern California, USA (Ansaloni and Perring 2002). In both cases, coconut mite was only found on plants in nurseries. It was not found on other wild and cultivated native or introduced palms in extensive surveys conducted in South America since the 1990s (Navia and Flechtmann 2002, Gondim *et al.* 2000, Flechtmann 1998, Santana and Flechtmann 1998). The third non-coconut host, the *Asian palmyra, Borassus flabellifer* L., was observed to be attacked by coconut mite in India, shortly after the first report of this mite on coconut there (Ramaraju and Rabindra 2002).

Typically, eriophyoid mites have restricted host ranges (Lindquist and Oldfield 1996). Many mites of this group co-exist with their host plants in such a way that they do not cause serious damage, perhaps as a result of co-evolution. Thus, serious harm caused to a plant by an eriophyoid has been conceived to suggest a recent association between the plant and the mite. It has been hypothesized that coconut was recently adopted by coconut mite as a new host (de Moraes and Zacarias 2002, Moore and Howard 1996). According to that hypothesis, coconut mite moved from its original host to coconut after it became extensively cultivated in the Americas or Africa, continents where the mite was first found (Moore and Howard 1996). Several facts support the hypothesis that the original host of coconut mite is not coconut: (1) it has never been reported from the suspected region of origin of coconut (Chan and Elevitch 2006, Lebrun *et al.* 1998, Persley 1992); (2) it seriously damages coconut, can cause extensive premature fruit drop and has been reported to kill coconut seedlings (Moore and Howard 1996, Doreste 1968, Aquino and Arruda 1967); and (3) it has been reported from other palm hosts. Studies carried out by Navia *et al.* (2005a) about the genetic variability of coconut mite populations supported the hypothesis of an American origin of this mite, possibly on a non-coconut palm, given that in contrast to the diversity in the Americas, all samples from Africa and Asia were identical or very similar to each other.

In Sri Lanka, coconut mite was reported in late 1997 from the Kalpitiya peninsula of the puttalum district (North-Western province). Subsequently, it spread the other parts of the district infeting nearly 6800 ha of coconut lands causing an outbreak by the end of 1998 (Fernando *et al.* 2002).

2.7. Dispersal of coconut mite

The coconut mite first achieved pest status in 1960 in Mexico (Cardona & Potes 1971) followed by Venezuela (1968), Columbia (1969), Trinidad (1975); Puerto Rico (1977), St. Vincent (1981), Grenada and St. Lucia (1982) and Virgin Islands (1985) (Griffith 1982, 1984, Medina-Guad and Abreu 1986). Griffith (1984). Damage was also seen in several parts of West Africa including Benin, Cameroon, and Nigeria attributed this rapid spread of the Coconut mite to its ability to take advantage of long distance dispersal by wind currents.

Mallik *et al.* (2003) reported enhanced migration of mites during the cooler hours of the day. Infestation symptoms of mite are primarily observed approximately one-month after the initial colonization of the mite inside the fertilized buttons. Appearance of elongated white streaks below the perianth is the first external visual symptom on young buttons. In many cases, a yellow halo develops around the perianth. Within a few days, this halo develops into yellow triangular patch pointing towards the distal-end of the button. This can be clearly seen in two-three month old buttons. In a short time the yellow patch turns brown and show necrotic patches on the periphery of the perianth. As the nut grows, the injuries transform into warting and longitudinal fissures on the nut surface. In severe infestation the husk develops cracks, cuts and gummosis. Shedding of buttons and young nuts as well as malformation of nuts due to retarded growth are the other indications associated with severe attack of the pest. The distribution of eriophyid mite colony is not uniform inside the perianth. Normally in two or three places the mite colonies are congregated under the tepals varying in size and shape.

Mite dispersal may occur actively and passively. Active dispersal involves voluntary migration by walking to new host tissues or to neighbor host plants to establish colonies or to a suitable spot where biotic (e.g. phoresy) or abiotic factors (mainly wind) can carry the mites to more distant places. Knowing the mechanisms of coconut mite dispersal is essential for understanding the infestation process of new bunches within or between plants, important for the establishment of management strategies.

It has been determined that coconut mite can walk at a rate of 22.5 Coconut mite in 30 min (Galva˜o *et al.* 2012). Being negatively geotactic, it tends to move from older to younger inflorescences or upwards (Galva˜o *et al.* 2012, Moore and Howard 1996, Moore and Alexander 1987). It has been observed that dispersal involves mostly movement of inseminated females (Moore and Howard 1996). Coconut trees provide a large target for aerially dispersing organisms, but the mortality associated with aerial dispersal is probably high (Moore and Howard 1996, Moore and Alexander 1987). The likelihood of arriving on a fruit is probably increased when air currents carry the mites to inflorescences or to the more vertical leaves in the crown, from which they may drop to bunch (Moore and Howard 1996). Mariau and Julia (1970) observed an increase in the proportion of infested nuts with the distance from the sea line, and related this with the action of the wind, dislodging (and thus, carrying) the mite from the fruits. In their study, the proportion of uninfested nuts decreased from about 45 % on plants growing about 20 m from the sea line to practically 0 on plants about 370 m inland. Similar results were reported by Mariau (1977) in a different study, who determined progressively higher coconut mite damage on plants growing at increasing distance from the sea line, relating it to the action of wind blowing inland.

It has been conjectured that some coconut mite dispersal may take place by phoresy, either on animals attracted to the inflorescences (e.g. pollinators) or fruits (rodents), or on those attracted to such animals (e.g. predatory lizards, birds, predaceous insects) (Moore and Howard 1996). However, these possibilities still remain unconfirmed. Griffith (1984) found adult coconut mite on bees visiting female flowers. He considered that the source of the mites would have to be an infested flower. However the presence of coconut mite on flowers has not been observed on coconut in the studies conducted by Lawson-Balagbo *et al.* (2008a), Moore and Alexander (1987) and Mariau and Julia (1970). It is possible that infested bees were attracted to fruit exudates allowing dispersing coconut mites to get on them. Galva˜o *et al.* (2012) evaluated the presence of coconut mite on small insects- the bees Apis mellifera L. and Trigona spinipes (Fabr.) and the curculionid Parisoschoenus obesulus Casey and large insects (e.g. the curculionid *Rhynchophorus palmarum* L.) visiting coconut trees in the field. She also conducted laboratory experiments, concluding that phoresy could occur occasionally. From a total of 1,500 insects collected in the field, only three coconut mite were found, all of them on *P. obesulus* studied specimens. Under laboratory conditions, these authors rarely found coconut mite on A. mellifera that had access to highly infested coconut fruits from which the bracts had been removed. Although those numbers are low, the results demonstrate the possibility that new infestations could be initiated by coconut mite dispersing on insects. Given the limitation of coconut mite for active dispersal and its specificity, not only in relation to the host plant but to the host organ attacked (meristematic tissue on coconut fruit), it seems logical to suppose that coconut mite would disperse mostly by climbing onto other organisms that move more efficiently and live on or visit infested coconut fruits or the plant parts next to it, onto which coconut mite may be found while dispersing.

2.8. Damage assessment of coconut mite

Thomas *et al.* (2004) reported that different grades of mite infested seed nuts could not significantly influence on the growth and vigour of the coconut seedlings in terms of number of leaves, collar girth, seedlings with split leaves as well as on the number of thick roots. They have also recommended that the mite infested seed nuts should besorted into different lots according to severity of infestation and nursery should beraised separately.

Table 2.2: Estimated impact of coconut mite on coconut

Continent	Countries	Estimated parameters	References
Africa	Benin	Copra yield loss: 6–18 % (ca. 10 %). Proportion of damaged fruits: 68–85 % (30–40 % of fruit surface damaged).	Mariau and Julia (1970) Negloh *et al.* (2011)
	Ivory Coast	Copra yield loss: 7–15 %; total yield losses: 16–24 %	Julia and Mariau (1979)
	Tanzania	Proportion of infested fruits: 70–100%; premature fruit drop: 10-100% (mean 21%); yield loss: 34%; dry and fresh weight of coconut meat loss: 20–30%. Proportion of damaged fruits: 43–81% (30–40% of fruit surface damaged).	Seguni (2000, 2002) Negloh *et al.* (2011)
America	Brazil	Proportion of infested fields: 87%	Lawson-Balagbo *et al.* (2008a)
	Costa Rica	Proportion of infested palms: 90%	Schliesske (1988)
	Colombia	Fruit infestation: 60%; reduction on commercial value of fruits: 38%	Zuluaga and Sanchez (1971)
	Cuba	Fresh weight of coconut loss: 15%; copra yield loss: 12–60%. Proportion of infested palms: 42–65% (ca. 53%); damage intensity on fruits: 29–41% (ca. 32%).	Suarez (1990) Suarez (1991b)
	Jamaica	Copra yield loss: 1–9 %	McDonald (1996), Howard *et al.* (2001)
	Mexico	Copra yield loss: ca. 7–24 %. Copra yield loss: 40 %.	Mariau (1967), Hernandez Roque

Continent	Countries	Estimated parameters	References
		Copra yield loss: 30–80 %	(1977), Olivera Fonseca (1986)
	Venezuela	Yield loss: 70% Proportion of damaged fruits: 43–81% (30–40% of fruit surface damaged)	Doreste (1968) Negloh *et al.* (2011)
Asia	India	Husk yield: 41.7% Husk fiber length: 53%; time dehusk: increase in 63% Proportion of infested palms: 9.2–100%; button drop: 30%; copra weight loss: 15–33% Total weight, husk weight, wet kernel, copra[50%; water content: 66.9%	Muralidharan *et al.* (2001) Paul and Mathew (2002) Rethinam *et al.* (2003) Ramaraju *et al.* (2005)
	Sri Lanka	Premature fruit drop: 2.9%; proportion of infested harvested fruits: 69.8–94.5%; total crop loss: 15.8% Proportion of infested palms: 2–100%	Wickramananda *et al.* (2007) Fernando and Aratchige (2010)
Middle East	Oman	Proportion of infested palms: 100%; proportion of infested fruits: 82%	Al-Shanfari *et al.* (2010)

A snap survey on the incidence of coconut eriophyid mite was undertaken during 2009 at Coimbatore and Thanjavur districts (Tamil Nadu), Hassan and Tumkur districts (Karnataka), Retnagiri (Maharastra), Trivandrum and Kasaragod districts (Kerala) selecting six panchayats in each district. The average mite incidence ranged from 4.06 -46.11% in different regions surveyed. Survey undertaken during April 2010 forassessing mite incidence in Lakshadweep Islands indicated a high infestation of 57.5% in Kavaratti, a moderate incidence of 23.2% in Kalpeni and a low infestation of 17.9% in Minicoy Island (CPCRI 2010). Mite incidence in Andhra Pradesh showed 28.9 % (West Godavari) to 39.6% (East Godavari) (Rajan *et al.* 2012)

Bagde and Pashte (2014) observed the infestation of eriophyid mites on the basis of per cent palm infestation as well as on the basis of nut infestation was more in Thane district (ranges between 73.23 to 84.40%) followed by Sindhudurg district (33.03 to 86.80%). The nut infestation in Thane district was mostly belongs to Grade III and ranges between 64.16 to 89.42%. The nut infestation in Thane district whereas in Sindhudurg, Ratnagiri and Raigad districts was most of the infested nuts belong to Grade II. However, during survey (2007-08) the highest nut infestation in Grade III was observed in Revedanda, Malgund and Dodamarg villages of Raigad, Ratanagiri and Sindhudurg districts, respectively with 43.45, 30.43 and 69.11 per cent infestation. Survey results can be concluded that the infestation of eriophyid mites to coconut in Thane district had reached to its maximum limit and was found to have started much earlier than in rest of the districts.In the recent past, the pest has spread rapidly to all coconut growing areas of India (Muthiah 2007). Naik (2003) revealed that the per cent infestation of palm varied from 8.33 (Sathpathi village of Palghar tahsil) to 80 per cent (Arnala village of Vasai tahsil) and 31.56 per cent palms were affected by mite in Thane district of Maharashtra State. The infestation was higher in Vasai tahsil (78.70%), followed by Palghar (52.86%) and Dhanu (24%). Out of total palms, 41.09 per cent palms were free from mite, while 42.77 per cent palms were moderately affected and 16.41 per cent palms were severely affected by mites (Sarmalkar 2004).

Desai *et al.* (2009) also observed that the intensity of infestation of Coconut mite and scale index was low in Ratnagiri and Raigadh districts.Survey about Coconut mite infestation was done during four years separately by visual observation scoring method as the standard method prescribed by Girisha (2005), Muralidharan *et al.* (2001) and Julia and Mariau (1979).

Solanki (2014) observed that, the Coconut mite had became major pest of coconut plantation in Pakistan and the attack was 30% higher in Lasbella as compared to Karachi and Thatta districts.

Incidence and severity of fruit damage caused by *A. guerreronis* were assessed *in situ* on 10 randomly selected palms per plantation by classifying all coconut fruits on each tree on the basis of the extent of characteristic *A. guerreronis* damage visible on fruit surfaces. Binoculars were used where trees were not reachable by a ladder. Coconut fruits were grouped into three grades based on the percentage of fruit surface damaged by *A. guerreronis* (Moore *et al.* 1989): grade 1 (0%), grade 2 (1 to 10%), grade 3 (11 to 25%), grade 4 (26 to 50%), grade 5 (>50%). Amongst the harvested coconuts, the infested coconuts were also graded on the basis of visual scoring method given by Murlidharan *et al.* (2001)

Grade	Surface damage
Free	No symptoms of Coconut mite
Grade I	1-25% of coconut surface damage by Coconut mite
Grade II	26-50% of coconut surface damage by Coconut mite
Grade III	Above 50% of coconut surface damage by Coconut mite

The Coconut mite has been reported to reduce nut size and copra yield (Anonymous 1985, Hall 1981, Julia and Mariau 1979). This study showed that the reduction in nut length (indicated by the polar arc) and girth (indicated by the equatorial circumference) are proportional to the severity of Coconut mite damage. The water content of Red Malayan Dwarf coconuts also showed a negative correlation with Coconut mite damage. This correlation was not detected with Maypan nuts due to the wide variability of their water content. This variability could be due to the relative maturity of the nuts at harvest. More mature nuts have tend to have less coconut water. Moore *et al.* (1989), Mariau (1977, 1986) and Julia and Mariau (1979) are among the few authors who have conducted experiments on actual losses in coconut yields due the Coconut mite. Moore *et al.* (1989) reported reduced copra yield with increased Coconut mite damage in St. Lucia. Julia and Mariau (1979), using four damage categories, compared the percentage copra losses in two coconut varieties and obtained similar trends. Observed copra losses were 1, 30, and 45% in damage categories 2, 3, and 4, respectively.

Losses in copra yields ranged from 10% in Benin (Mariau and Julia 1970), 16% in the Ivory Coast (Julia and Mariau 1979), 20-30% in St. Lucia (Moore *et al.* 1989), 25% in Grenada (Hall 1981) and 30-80% in different areas of Mexico (Hall 1981, Olvera-Fonseca 1986). Julia and Mariau

(1979) and Moore *et al.* (1989) found copra yield to decline with increasing severity of damage caused by the mite. Damage to the pericarp was categorized through a visual estimation method by Mariau and Julia (1970) and was modified by Moore *et al.* (1989).

Seguni, (2002) revealed that, the percentage of mite-infested nuts in various Sri Lankan cities was 94.4% in Anuradhapura, 94.5% in Pollonnaruwa, 90.5% in Rajangane, 85.1% in Puttalam, and 69.8% in Kurunegala, with a mean of 77.9%. In Tanzania, reduction in copra yield has been variable from 15-40%. Losses due to extensive premature dropping of fruits have been reported, ranging from 60% in Colombia (Zuluaga & Sánchez 1971) to 70% in Venezuela (Doreste 1968) and 10-100% (average 21%) in Tanzania (Seguni 2002). For the nuts that reach maturity, small-sized nuts cannot be sold at the price of a full size nut, thus reducing the income of the farmer since they fetch lower prices. Estimated loss of income for coconut growers in Sri Lanka to be 7% from rejected nuts and 43% from small-sized nuts. In Tanzania, loss of farmers' income due to Coconut mite is estimated to be about 30-50% (Seguni 2002).

During 1998, when the pest outbreak was reported in India, almost 70% of nuts were affected showing malformation and reduction of nut size (Nair 2002). In Kerala though pest damage has been reported initially ranging from 50-70%, later surveys carried out in Alappuzha district during 2000 has shown significant reduction in crop loss indicating an average loss of 30.94% in terms of copra and 41.74% in husk production (Muralidharan *et al.* 2001). Similar studies undertaken in the neighbouring state, Tamil Nadu during 2000 revealed an average loss of copra yield to the tune of 27.5% (Ramaraju *et al.* 2000) and 18-42% in Karnataka when severe infestation symptoms were seen on more than 50% of surface area of infested nuts (Mallik *et al.* 2003). Mite damage caused significant reduction in quality of fibres in terms of fibre length and tensile strength. Studies undertaken at Kerala Agricultural University during 2003 revealed that fibres from moderately to severely infested nuts suffered 26-53% reduction in length (Naseema Beevi *et al.* 2003). Observations recorded during subsequent years revealed overall reduction in incidence and intensity of pest in areas of its initial occurrence with loss in terms of copra ranging from 8-12% (Rajan *et al.* 2007, Nair *et al.* 2004). In India, estimates indicated an annual loss of 2000-2500 million rupees (INR) in Kerala alone due to this mite (Singh and Rethinam 2004). Yield loss in terms of infestation severity was also worked out. Reduction of kernel (59.4%) and copra (57.6%) was observed in infested nuts of category 4 (>75% nut surface damaged distorted nuts) whereas there was no significant difference in nut parameters viz., weight of nut, weight of husk, weight of kernel and shell between healthy nuts and nuts showing category 1, 2, and 3 (up to 75% nut surface symptoms).

Thomas *et al.* (2004) reported that different grades of mite infested seed nuts could not significantly influence on the growth and vigour of the coconut seedlings in terms of number of leaves, collar girth, seedlings with split leaves as well as on the number of thick roots. They have also recommended that the mite infested seed nuts should be sorted into different lots according to severity of infestation and nursery should be raised separately.

Naik (2003) observed the per cent infestation of palm nuts ranged between 33 per cent and 80 percent in Thane district and Sarmalkar (2004) who observed the per cent infestation of palm nuts ranged between 67 per cent and 85 per cent in Thane district. The level of infestation of eriophyid mite was highest in Thane district followed by Sindhudurg, Ratnagiri and Raigad (Desai *et al.* 2009). Also Pushpa (2006) indicated that the mite population occurred in Dharwad area throughout the year with variation during different season of the year. The variations in the range of infestation are may be due to changing environmental as well as biotic stresses.

The coconut perianth mite, *A. guerreronis* Keifer belonging to family Eriophyidae was unknown in Indian subcontinent till 1984, when it was first recorded from Srivilliputhur area of Tamil Nadu. In India, the mite attained a major pest status in the three peninsular states oflndia *viz.*, Kerala, Karnataka and Tamil Nadu and it is spreading towards north also (Sathiamma *et al.* 1998). Damage due to the attack of this mite may reach to the tune of 100%.

Keifer (1965) described first time *Aceria guerreronis* in Mexico infesting coconut fruits. The same year it was found in Rio de Janeiro, Brazil. Subsequently it was found in many countries of Tropical America and also in West Africa. It is controversial, whether it is native to the Eastern or Western hemisphere. In fact, in 1984, when the species was positively identified for the first time in the continental United States by H. A. Denmark from specimens collected by F. W. Howard from coconuts . The most dramatic extension of the range of Coconut mite in recent years occurred in the late 1990s, when it was found for the first time on coconuts in Tanzania, India and Sri Lanka Curiously, the Coconut mite has not been reported in the South Pacific Region, which is the original home of the Coconut palm. In India, the mite was reported from many coconut gardens of Kerala during 1997-98 and in Karnataka and Tamil Nadu during 1998-99 and has drawn national attention as a threat to the coconut plantation.

The coconut growers of India (third largest producing country) would never have faced such acrunch situation before, for, on the one hand, with the Indian government lifting imports restrictions on coconut and coconut products. Considering the importance of coconut as a plantation crop in the country and the potentiality of this mite to cause extensive damage to the coconut crop, Government of India has declared this pest as a National threat. This mite has spread and established rapidly in the main coconut production areas worldwide and is now a key pest of this crop. In the recent past, the pest has spread rapidly to all coconut growing stages of India (Muthiah 2007, Gopal and Gupta 2001, Vidyasagar 2000, Reddy and Naik 2000).

The pattern of population spread is also economically important: the coconut mite still represents a menace to other countries in Asia, where the pest has not yet been detected and understanding its spread may help to determine its potential for future invasions as well as guide quarantine measures to intercept the pest dissemination. One valuable approach to the study of sources and introduction routes of invasive arthropods involves the use of molecular markers (e.g. Solignac *et al.* 2005, Mun *et al.* 2003, Birungi and Munstermann 2002, Bonizzoni *et al.* 2001, Davies *et al.* 1999, Villablanca *et al.* 1998). Colonizing populations of invasive species are usually founded by only a few individuals (Elton 1958), causing random genetic drift which itself often leads to founder effects (Tsutsui *et al.* 2000, Lande and Barrowclough 1987). The reduction of genetic variability is a common feature of invasive species and introductions in general *(e.g.* Solignac *et al.* 2005, Roderick and Navajas 2003, Lande and Barrowclough 1987). In some cases, however, genetic variability of invasive populations may be higher than predicted by genetic drift, such as when the invasion phenomenon leads to the presence of different fixed heliotypes in diverse geographical :egio~s (Gasparich *et al.* 1997) or when multiple mvas1ons stem from different regions with fixed haplotypes (Kolbe *et al.* 2004, Stepien *et al.* 2002).

A. guerreronis K.is a serious threat and like many invasive agricultural pests displays dramatic population growth, leading to serious outbreaks resulting in high costs for control (Pimentel 2000, Pimm 1996). Acaricides must be applied frequently to control this mite. However, in mostproduction areas, coconut is traditionally grown by small farmers who cannot afford continuous use of insecticides/acaricides (Ramaraju *et al.* 2002, Muthiah and Bhaskaran 2000, Moore and Howard 1996). As an alternative, classical biological control has been considered as a promising strategy to check populations of *A. guerreronis* K. (Moraes and Zacarias 2002).

The information on surveillance helps to take up the control measures at appropriate time in minimizing the incidence. However, the information on the varietal interaction with the coconut perianth mite is scarce under south Indian conditions. Modest (less than 25%) surface damage of seed nuts due to eriophyid mite infestation has no profound adverse impact on germination and seedling growth or vigor. 10-25% nuts damage can, therefore, be safely used along with healthy nuts for nursery stock production (Beevi *et al.* 2006).

Among the different exotic coconut cultivars Strait Settlement (Apricot), Cochin China, Fiji and New Guinea are less susceptible. Among indigenous cultivars Bombay, Laccadive Micro, Chowghat Orange Drawf and Spicata are less susceptible to mite attack. (Girisha and Nandihalli 2009) The genotype British Solomon Island can harbour the highest percentage of nut damage by mites. In case of hybrids, Lakshaganga is highly susceptible where as Anandaganga is moderately tolerant to mite attack. The other cultivars, Ayirarnkachi and Andaman Dwarf are more susceptible to mite damage. In Tarnilnadu and Kerala, Andaman Ordinary and Gangabondam recorded minimum percentage of nutsdamaged by the Coconut mite (Muthaih and Bhaskaran 1999). Under West Bengal condition, "Jamaica Tall" has got some tolerance against this mite (Dey *et al.* 2001). Rao *et al.* (2001) have reported the incidence of eriophyid mite *A. guerreronis* on coconut (Cocus nucifera) for the first time in costal Orissa. The affected area estimated by several workers in the states like Tamil Nadu, Karnataka and Andhra Pradesh (Begum and Babu 2013, Sujatha *et al.* 2008, Pushpa 2006, Sumangala and Haq 2005, Sujatha and Rao 2004, Rethinam *et al.* 2003, Ramaraju *et al.* 2003, Arulmozhi *et al.* 2002, Kirathiga *et al.* 2002, Nair *et al.* 2002, Natarajan *et al.* 2002, Ramaraju *et al.* 2002, Ramaraju *et al.* 2000, Reddy and Naik 2000, Nair 2000, Haq 1999).

Yield loss to various levels has been reported world wide as a result of infestation by the pest. In general, pest incidence and extent of loss are comparatively high during the initial few years of pest occurrence in a particular locality due to the invasive nature of the pest. Yield loss depends on the cultivar, health and general maintenance of the crop as well as intensity of infestation. Increased difficulty in dehusking (leading to greater labour requirements for this job) also contributes to economic loss. Feeding by few mites causes only cosmetic damage to the husk without affecting the quality and quantity of copra and coconut water. During 1998, when the pest outbreak was reported in India, almost 70% of nuts were affected showing malformation and reduction of nut size (Nair 2002).

In Kerala though pest damage has been reported initially ranging from 50-70%, later surveys carried out in Alappuzha district during 2000 has shown significant reduction in croploss indicating an average loss of 30.94% in terms of copra and 41.74% in husk production (Muralidharan *et al.* 2001). Similar studies under taken in the neighbouring state, Tamil Nadu during 2000 revealed an average loss of copra yield to the tune of 27.5% (Ramaraju *et al.* 2000) and 18-42% in Karnataka when severe infestationsymptoms were seen on more than 50% of surface area of infested nuts (Mallik *et al.* 2003).

Mite damage caused significant reduction in quality of fibres in terms of fibre length and tensile strength. Studies undertaken at Kerala Agricultural University during 2003 revealed that fibres from moderately to severely infested nuts suffered 26-53% reduction in length (Naseema Beevi *et al.* 2003). Observations recorded during subsequent years revealed overall reduction in incidence and intensity of pest in areas of its initial occurrence with loss in terms of copra ranging from 8-12% (Rajan *et al.* 2007, Nair *et al.* 2004). In India, estimates indicated an annual loss of 2000-2500 million rupees (INR) in Kerala alone due to this mite (Singh and Rethinam 2004).

In Sri Lanka, the percentage of palms that are infested by the Coconut mite in plantations varies between 2-100% (Fernando and Aratchige 2010). In a survey conducted in Sri Lanka, the incidence of mite damage in harvested nuts has been as high as 86% of the total nuts sampled, ranging from 69.8 – 94.5% (Wickramananda *et. al*. 2007). It has also been observed that the percentage of small sized nuts and deformed nuts are considerably higher in infested palms (0.72-25.5% and 0.33-6.9% respectively) compared touninfestedpalms (<1%) (K P Waidyarathne, personal communication). An estimated loss of 15.8% of total crop loss was observed when the losses due to button and immature nut fall, size reduction in the harvested nuts and nut deformation were combined (Wickramananda *et al.* 2007). Furthermore, the same authors revealed 13.4% reduction in the fresh, unhusked weight of nutsin infestednuts suggesting that the Coconut mite infestation could reduce the husk production.

'Jelly coconuts' are often marketed locally for the liquid and the tender endosperms in these nuts. Copra, the dehydrated endosperm of more mature coconuts, is the major coconut export product of most coconut producing countries. Estimated losses in copra yields resulting from Coconut mite damage have ranged from 10% in Benin (Mariau and Julia 1970), 16% in the Ivory Coast (Julia and Mariau 1979), 20-30% in St. Lucia (Moore *et al.* 1989), 25% in Grenada (Hall 1981) and 30-80% in different areas of Mexico (Olvera-Fonseca 1986, Hall 1981). Julia and Mariau (1979) and Moore *et al.* (1989) found copra yield to decline with increasing severity of damage caused by the Coconut mite. Mariau and Julia (1970) developed a method to visually estimate the amount of Coconut mite damage to nuts. Their visual assessment technique was later modified by Moore *et al.* (1989).

Mariau (1986) found copra loss to decline with irrigation and suggested that during periods ofmoisture stress nut growth is slower, hence, meristematic tissue is subjected to extensive mitedamage. Moore *et al.* (1989) suggested that improved farming practices, combined with resistant varieties, could result in marked increases in crop yields. Sarangamath *et al.* (1976) also reported that copra yields were dependent on various factors, including variety, age of palm, soil, climate of the area, maturity of the nuts, seasons of harvest and period of storage.

2.9. Nature of damage

The Coconut mite breeds and feeds under the perianth of coconut fruit and is most active outside the perianth during late nights and early mornings (Moore and Alexander 1987, Hall 1986). Colonization of coconuts by Coconut mites normally takes place within one to six months after fertilization (Moore *et al.* 1989). Fertilization takes place within the second month of flowering (Child 1974). Coconut 18 mite populations peak on 3- to 6-month old nuts, after which, the numbers decline sharply. Thus, nuts over nine months old have relatively low populations (Moore and Alexander 1987). Mite populations are aggregated (Howard *et al.* 1990) so that peak densities may exceed 1500 mites/Coconut mite2 (Otterbein 1988) and may reach about 4600 mites per (Malayan dwarf) nut, about 3 to 4 months old (Howard and Rodriguez 1991).

Pushpa and Nandihalli (2009), reported that the course of surveillance the mite population on the nut surface ranged from 50.01 to 105.73 mites per 28.28 mm^2 area. The mite population during the period from secondfortnight of July to first fortnight of November ranged from 50.20 to 58.89 per 28.28 mm^2 area. A sudden increase in mite population was seen in second fortnight of December (68.92). Then onwards it increased upto second fortnight of January (84.26). The mite population decreased during second fortnight of February (72.29). Then onwards, the mite population started increasing and reached another peak during second fortnight of May (105.73). From then onwards the population of the mite decreased. The mite population on perianth fluctuated from the lowest of 18.28 mites (second fortnight of June) to the highest of 58.52 (second fortnight of May). During remaining months mite population on perianth was more or less constant. On an average the mite population on nut surface was more (69.80 mites) compared to perianth (30.41).

Populations of the mite develop on the meristematic zone of the fruits, which is covered by the perianth. Feeding of the mites in this zone apparently causes physical damage so that as newly formed tissues expand, the surface became s necrotic and supersized. Uneven growth results in distortion and stunting of the coconut, leading to reductions in copra yield. *A. guerreronis* infestations cause the coconut perianth mite, *A. guerreronis* extensive premature dropping of coconuts (Moore and Howard 1996). In addition to damaged fruits, *A. guerreronis* can kill coconut seedlings by feeding on growing tips (Aquino and Arruda 1967). Reductions in copra yield from 15-40% (Seguni 2002, Muthiah and Bhaskaran 2000, Nair and Koshy 2000, Julia and Mariau 1979, Herna'ndez Roque 1977).

The distribution pattern of the Coconut mite varies among palms and also among bunches of different ages within a single palm. Unfertilized flowers are free from Coconut mites (Fernando *et al.* 2003) and the colonization starts just after fertilization of the female flowers (Negloh *et al.* 2010, Fernando *et al.* 2003, Howard *et al.* 1990, Moore and Alexander 1987). In SriLanka, starting from the nuts after fertilization, mean number of Coconut mites is increased up to the bunch of 5 month old (i.e. 5 months after fertilization of the female flower) and declined thereafter (Fernando *et al.* 2003). In general, peak densities of Coconut mite are observed on 3-7 month old bunches (Galvão *et al.* 2011, Negloh *et al.* 2011, Thirumalai Thevan *et al.* 2004, Mallik *et al.* 2003, Fernando *et al.* 2003; Varadarajan and David 2002, Moore and Alexander 1987).

Coconut mites leave nuts two to three months before the nuts are fully developed or when damage to the pericarp exceeds 15% of the total surface area because there is no renewal of meristematic tissues (Anonymous 1985). In addition, damaged nut surfaces tend to secrete resin which traps and kills the mites (Moore and Alexander 1987). Migration may also be density dependent (Griffith 1984) and dispersal may be short ranged or long ranged. Short range dispersal is aided by water and insects. Rain may wash off mites on to nearby open flowers (Schliesske 1988, Griffith 1984). Coconut flowers are cross-pollinated by insects, particularly Hymenoptera, which also help to disperse Coconut mites (Otterbein 1988). Coconut mites may crawl from infested nuts onto uninfected nuts where these nuts are in contact with each other (Schliesske 1988, Griffith 1984). Wind currents are the most important means of long range dispersal. This is particularly so in the dry season when populations are high (Otterbein 1988, Schliesske 1988, Griffith 1984).

Young bunches are comprised of flowers and early stages of the developing nut (Moore *et al.* 1989). Normally, it is on these bunches that the mite population is just being established. By the time externally visible damage symptoms appear, most nuts would be more than two months old. The offset of the scarring process requires multiple puncture of epidermal cells by hundreds of these microscopic mites to produce sufficient injury for the cells to die (McCoy and Albrigo 1975). This is followed by loss of cell contents, cork formation and browning of the damaged surface. Fissures then develop on the nut surface as stress is created when the undamaged, neighboring cells begin to multiply (Mc Coy and Albrigo 1975).

A high level of inter-tree variability was found within the Red Malayan Dwarf variety. This variability within individual varieties is thought to be an expression of distinct physiological and genetic characteristics (Moore and Alexander 1990, Moore 1986, Hall 1986, Mariau 1977, 1986, Julia and Mariau 1979).

The meristematic zone of the coconuts covered by the perianth (also referred as tepals; bracts) is thesite for the mite development. The third fifth bunch nuts (post-fertilization) bear peak populations which can fluctuate unpredictably. The external husk became s very difficult to remove due to gummosis. Immature nuts may also fall and the yields 40 % less than normal. If the infested nuts are used as seeds, they are very slow to erminate with 10-25% mortality in the nursery bed (Girisha and Nandihalli 2009). The powdery white mites lay numerous eggs on the nut surface as well as on thinner side of the interior three bracts, which over the nut surface. The mites suck the sap from the tender tissues using their chelicerae styles, resulting in whitish triangular patches at the base of the perianthwhich later turns brown, followed by warring andsuberization (thickening) of the nut epidermis (Moore and Howard 1996). This leads to (a) drying of young buttons; (b) premature nut dropping; (c) reduction innut size; and most important of all (d) loss in copra yield to the extent of 20-30% .

2.10. Management practices

Nearly sixty systemic and contact insecticides have been evaluated world over and recommended from time to time for management of Coconut mite. In India also, a wide spectrum of pesticides have been evaluated by various research agencies including both Central Institutes and State Agricultural Universities (Mallik *et al.* 2003, Kannaiyan *et al.* 2002, Nair *et al.* 2002, Ramaraju *et al.* 2000, Saradamma *et al.* 2000). Though these pesticides *viz.*, triazophos, chlorpyriphos, phosalone, fenpropathrin, imidacloprid *etc* were effective in the field when given as spray/ root feeding / stem injection, none of the chemicals has been used for area-wide adoption in India due to environmental reasons.

The Coconut mite has proven to be difficult to control. A wide range of chemicals have been employed to control the pest over the past two decades, but the results have been unsatisfactory. Thus, efforts to eradicate it or minimize its damage have been expensive (Pimentel 2000). Meanwhile, farmers continue to suffer high economic loss (Aquino & Arruda 1967).

Mariau (1977) carried out the first experiments in the Ivory Coast to test the efficacy of 24 insecticides and acaricides on the Coconut mite. The four most effective chemicals were cyhexatin, chinomethionate (morestan), endosulfan and monocrotophos (nuvacron). Successful control was only achieved after up to six applications of these chemicals per year. Similar results were obtained by Mariau and Tchibozo (1973), Hernandez (1978) and Julia and Mariau (1979). However, Otterbein (1988) did not observe any significant control of the mite with these chemicals. Griffith (1984) noted that stem injection of systemic vamidithion was effective against the Coconut mite in Brazil and in Trinidad. However, this method of control is traumatic for the coconut trees and impractical for pure stands on large plantations (Moore *et al.* 1989 and Julia and Mariau 1979). Moore *et al.* (1989) also argued that these systemic pesticides posed a threat to human health; especially where jelly or water coconuts are heavily consumed.

Management of *A. guerreronis* Keifer is very difficult because of its cryptic nature of breeding beneath the tightly appressed bracts. Appreciable control had been achieved by using monocrotophos, methyl demeton and triazophos. In addition to these, endosulfan, dicofol and carbosulfan have also been proved to be effective for the management of the mite. Use of wettable sulphur, apart from botanicals based on combination of neem oil (*A. indica*) 2% and garlic (*A. cepa*) and azadirachtin, 0.004% has also given good results. Dey *et al.* (2001) valuated fenazaquin 10EC (Magister) against *A. guerrereronis*, according to them, the root feeding @10 ml planf1 and 200-250 ml litres- 100 were the most effective dose. Root feedings of neem oil 50,000 ppm and monocrotophos 36 SL three times at an interval of two months were found to be most effective against *A. guerreronis* and recorded least mite population followed by neem oil and monocrotophos as spray. Whereas, root feeding of neem oil was inferior in reducing mite population. Recently in case of tall trees distributed mainly in homestead gardens, root feeding is recommended as follows with any of the following combinations at 45 days interval at the rate of one application per plant (Dey *et al.*, 2001). a) Monocrotophos 15 ml+ water 15 ml+ urea 2 carbendazim lg b) Carbosulfan 10 ml+ water 10 ml+ urea 2 g + carbendazim lg c) Fenazaquin 10 ml + water 10 ml+ urea 2 g+ carbendazim lg.

The spraying should be done three times in a year: December-February, April-June and Sept-October Dey *et al.* (2001). On an average 1-1.5 litres spray fluid id required per palm. Care should be taken to harvest mature branches before spraying. The pesticide spraying has to be done at the right time. When the mite population is at its peak in summer, especially after the receipt of summer showers, farmers should resort to the use of the recommended insecticidal spray. The best seasons for taking up the spraying are March-April, October-November and December-January. It is particularly desirable that all the palms in the area are covered at the shortest interval.

Ramaraju *et al.* (2002) who reported that TNAU triazophos 5ml/l, triazophos 1.5ml/l and methyl demeton 4ml/l recorded 70.29%, 32.82% and 31.46% mite mortality, respectively, seven days after treatment. Fifteen days after spraying moncrotophos 1.5ml/l recorded 57.98% mortality followed by methayl demeton 4ml/l 44.59%, triazophos 5ml/l 42.79% dicofol 2.5ml/l 38.38%. At 23 days after treatment defferences among treatments are not significant. Also after the second round of treatment monocrotophos 1.5ml/l was significantly superior all other treatments and recorded 54.34% mortality seven days after second round spraying and monocrotophos 50.29%, dicofol 6ml/l 41.30% and fenthion 41.15%. Fifteen days after second round spraying, monocrotophos 3ml/l found to be the most effective causing 56.75% mortality, triazophos 5ml/l 49.97%, monocrotophos 1.5ml/l 49.75% and dicofol 6ml/l 47.76%. 23 days after treatments methayl demton 4ml/l 72.49%, triazophos 70.92%, phosanole 3ml/l 68.07%.

Spraying the bunces of developing fruits with dicrotophos, monocrotophos or chinomethionate every 20 or 30 days was found reduce damage significantly (Hernandez 1977). Similar results were obtained with acaricides applied at 15 days intervals (Mariau and Tchibozo 1973). Julia and Mariau 1979) found the stem injection of monocrotophos, at two month intervals, to be effective on young dwarf plants. While stem injection of vamidothion was proposed by Griffith (1984), the same was found in effective by Moore and Alexander (1987).

Mohanasundaram *et al.* (1999) reported that triazophos at 20 ml mixed with 20 ml water provided satisfactory control of the mite when the pesticide was applied at aninterval of 45 days. The trials at Tamil Nadu Agricultural University, Combatore, also indicated that administration of monocrotophos at 10-15 ml mixed with equal volume of water once in 45 days provided control of the mite and spraying of methyldemeton 4ml/l and triazophos 5ml/l was effective.

2.11. Chemical management

Apparently, the first evaluation of chemical products for coconut mite control was done by Mariau and Julia (1970) in Africa. They observed that most of the 23 tested products were not effective; only chinomethionate (Morestan) showed some efficiency. As a follow up, Mariau and Tchibozo (1973) also reported promising coconut mite control with the use of chinomethionate and monocrotophos (Nuvacron), when applications were repeated every 3 weeks. Herna´ndez Roque (1977) showed that coconut mite control with dicrotophos, monocrotophos or chinomethionate sprayed onto bunches of developing fruits every 20 or 30 days significantly reduced damage. Julia and Mariau (1979) verified that periodic injection of monocrotophos could effectively control the mite on young plants, but concluded that this application was too traumatic for use in adult plants. In the Caribbean region, Moore and Alexander (1987) and Moore *et al.* (1989) reported unsuccessful results with stem injection of vamidothion. However, in the same region Cabrera

(1991) considered dicrotophos, chinomethionate and monocrotophos to be efficient in coconut mite control.

Soon after the pest was first reported in Sri Lanka, trunk injection of monocrotophos was recommended. Although control seemed quite effective initially, it was soon abandoned, as the effectiveness lasted only for about 2 months (Fernando *et al.* 2002). Later, two botanical products were recommended, namely 2 % neem oil? Garlic mixture, and Neem Azal T/S (1 % azadirachtin). Studies are still being conducted, to identify chemicals of low toxicity to be integrated with other control strategies.

In India, quite many chemicals have been tried successfully, such as 2 % neem oil and garlic mixture (Nair *et al.* 2002), root feeding with monocrotophos (Nair 2002; Sujatha *et al.* 2003), fenpyroximate (Sujatha *et al.* 2003), triazophos (Rethinam *et al.* 2003, Ramaraju *et al.* 2002, Mohanasundaram *et al.* 1999), methyl demeton 25EC (Ramaraju *et al.* 2002), azadirachtin, endosulfan and carbosulfan (Rethinam *et al.* 2003, Sujatha *et al.* 2003), and sprays of carbosulfan (Muthiah *et al.* 2001), dicofol and triazophos (Rethinam *et al.* 2003, Muthiah *et al.* 2001) and fenazaquin, azadirachtin, NSKE and neem oil (Pushpa and Nandihalli 2010). Several other trials with chemical pesticides were reported by Pushpa and Nandihalli (2010). However, the need for repeated applications showed those techniques to be mostly unsustainable.

In Brazil, good control of coconut mite was reported by Moreira and Nascimento (2002) with the use of hexythiazox (Savey), either in isolation or when associated with other products.

Coconut growers were reported to obtain good control using botanical miticides (e.g. cotton, soybean, neem oil) mixed with a surfactant (detergent) each 3 or 4 weeks (Chagas *et al.* 2005).

Regardless of the results of efficiency tests of pesticides, chemical control is usually an expensive practice, especially when repeated applications are necessary, as seemingly the case for coconut mite control. The high cost turns this practice economically prohibitive for smallscale farmers (Ramaraju *et al.* 2002, Muthiah and Bhaskaran 2000, Moore and Howard 1996, Persley 1992), who in most countries are the main coconut producers. In addition, the frequent use of chemicals can cause undesirable environmental impact. Under these circumstances, alternative control measures seem highly desirable.

2.12. Biological control

Relatively little efforts had been dedicated to the evaluation of natural enemies of coconut mite until the end of the last century (de Moraes and Zacarias 2002, Moore and Howard 1996), but efforts have became more intense in the last 10 years, after the first detections of coconut mite in Asia. Predators and acaropathogenic fungi are the most common natural enemies collected.

NeemAzal (azadirachtin 1%) (Wickramananda *et al.* 2003) and a mixture of neem oil and garlic (Fernando *et al.* 2002) were effective in reducing the pest population to about 60%. A mixture of 30% ‘used engine-oil’ completely controlled the coconut mites on treated nuts (Chandrasiri & Fernando 2004).

2.13. Predator management

Information about predatory mites on coconut palms was reviewed by de Moraes and Zacarias (2002). The predators reported were species of the orders Prostigmata and Mesostigmata. Among the Mesostigmata, they reported a few species of Blattisociidae and Melicharidae (both then included in the Ascidae) and many more Phytoseiidae, in various parts of the world. Few of those species had been reported in close association with coconut mite, namely the blattisociid *Lasioseius* sp., the melicharids *Proctolaelaps* sp. and *Proctolaelaps bickleyi* (Bram), as well as the phytoseiids *Amblyseius largoensis* (Muma), *Neoseiulus baraki* Athias-Henriot, *Neoseiulus mumai* (Denmark), *Neoseiulus paspalivorus* De Leon and *Typhlodromips sabali* (De Leon).

Classical biological control has been considered an appropriate approach to provide a sustainable solution to the coconut mite problem. This approach essentially corresponds to the determination of effective natural enemies in the area of origin of the pest, which should then be introduced and field released in the new region where the pest was introduced, seeking the permanent establishment of the natural enemies and the subsequent pest control. In this context, efficient natural enemies of coconut mite should be prospected in the tropical areas in the Americas, considered to be its possible area of origin (Navia *et al.* 2005a).

As part of the first step to identify effective coconut mite natural enemies, surveys have been conducted throughout northern and northeastern Brazil. The first work conducted in that country specifically to determine the common predatory mites on coconut palms was reported by Gondim and de Moraes (2001). In that study, 18 phytoseiid species were found, but emphasis was then placed on mites on leaves. Subsequently, Navia *et al.* (2005b) reported the following predatory mites in direct association with coconut mite: the melicharids Proctolaelaps longipilis Chant and Proctolaelaps bulbosus de Moraes, Reis and Gondim Jr. (reported as Proctolaelaps sp.; see de Moraes *et al.* 2008) and the phytoseiids Typhlodromus (Anthoseius) ornatus (Denmark and Muma) and Amblydromalus manihoti (de Moraes). The first extensive work specifically to search for prospective natural enemies of coconut mite in Brazil was conducted by Lawson-Balagbo *et al.* (2008a). About 81 % of all predatory mites found were phytoseiids, mainly represented by *A. largoensis*, *N. paspalivorus* and *N. baraki*; 12 % were reported as melicharids and blattisociids, mainly *Proctolaelaps* sp., *P. bickleyi* and *Lasioseius subterraneus* Chant. *Neoseiulus paspalivorus* and *N. baraki* were the most abundant predators on fruits attached to the palms, melicharids and blattisociids were predominant on fallen coconuts, whereas *A. largoensis* was predominant on leaves. *Neoseiulus paspalivorus*, *N. baraki* and *P. bickleyi* were reported by those authors as the most promising coconut mite predators in the surveyed areas.

A new study was initiated in 2008 to evaluate the natural enemies in other coconutgrowing areas in the northern Brazilian states of Roraima and Rondonia, as well as in states of Colombia, Mexico and Venezuela (Silva *et al.* 2010). The most abundant predatory mite found on fruits was *N. paspalivorus*, followed by *P. bickleyi*. *Neoseiulus baraki* was rare in the visited areas. Phytoseiids and ascids were commonly found in association with coconut mite in Colombia and Venezuela, but not in Roraima, Rondonia or Mexico. The authors concluded that the predators found apparently could not prevent damage by coconut mite, but admitted that damage could be higher in the absence of predators. For unknown reasons, neither *N. baraki* nor N. paspalivorus were found in the state of Sa˜o Paulo, southeastern Brazil, in three surveys conducted within a period of one year in six coconut plantations (Oliveira *et al.* 2012). In that study, the most common predators on coconut fruits were *P. bickleyi* and *P. bulbosus*.

Studies on diversity of coconut mite natural enemies have also been conducted in other continents. Such studies are necessary, as a base line for subsequent determination of the role of native natural enemies in the control of the pest and to facilitate the analysis of eventual efforts for the establishment of introduced natural enemies. In Sri Lanka, de Moraes *et al.* (2004a) reported five phytoseiid species on coconut, three of which, N. baraki, N. paspalivorus and A. largoensis, on fruits, in association with coconut mite. Amblyseius largoensis was determined to be mostly found on leaves. The authors stated that what was reported by Fernando *et al.* (2002, 2003) and Fernando and Aratchige (2003) as *N. aff.* Paspalivorus most probably referred to *N. baraki*, determined to be much more abundant than *N. paspalivorus* in that country.

Several studies have also been conducted in India. Haq (2001) reported many predatory mites from that country, including *A. largoensis, N. paspalivorus* and *Bdella indicate* (could be a misspelling for B. distincta Baker and Balogh) (Bdellidae). Ramaraju *et al.* (2002) reported the predator *N. paspalivorus* in association with coconut mite on the surface of infested coconuts in southern India. Shobha (2004) reported the predatory mites from Kerala, including species reported as *Typhlodromus pyri* Scheuten (Phytoseiidae), *Cheyletus cocos* (Cheyletidae), *Agistemus industani* Gonzalez (Stigmaeidae), *Amblyseius* sp. and *Bdella* sp. It is possible that *T. pyri* corresponds to a misidentification, given that this species seems to occur mainly in temperate areas (de Moraes *et al.* 2004b). In the Indian state of West Bengal, the following predatory mites were reported in association with coconut mite: *A. largoensis, N. paspalivorus, Proctolaelaps* sp., *Lasioseius* sp. and the Cheyletidae Cheyletus malaccensis Oudemans (Banerjee and Gupta 2011).

In Oman, Middle East, the main natural enemies associated with coconut mite were the phytoseiids *N. paspalivorus* and *Cydnoseius negevi* (Swirski and Amitai) (Hountondji *et al.* 2010, Perez *et al.* 2010).

In Africa, the occurrence of *N. baraki* (Negloh *et al.* 2008) and *N. paspalivorus* (Negloh *et al.* 2010) was reported in Benin, while Sourassou *et al.* (2011) reported the latter species also in Benin and Ghana. Negloh *et al.* (2011) reported *N. baraki, N. paspalivorus* and *Neoseiulus neobaraki* Zannou, de Moraes and Oliveira as the most common predators in Benin and Tanzania, indicating that *N. neobaraki* was the prevalent predator in Tanzania, whereas *N. paspalivorus* was prevalent in Benin.

Given the widespread distribution of populations identified as *N. baraki* and *N. paspalivorus*, recent studies have been conducted to determine whether these are really two widespread species, or whether either could actually comprise a complex of very similar species. Comparisons of geographic populations identified as *N. paspalivorus* and *N. baraki* have shown considerable variation between them, in terms of their morphology, biology and predation potential on coconut mite. These differences have been observed for populations identified as *N. paspalivorus* from geographically largely separated populations, from Brazil, Benin and Ghana (Sourassou *et al.* 2011). Inter-population crosses showed complete reproductive isolation between them, despite the absence of interpopulation discontinuities in relation to evaluated morphological characters. The results suggested that the tested populations are distinct biological entities. Further molecular analysis to determine genetic distance between populations/taxons should be conducted to help understand whether these *N. paspalivorus* populations could represent cryptic species.

However, it could be argued that gene flow between the tested African populations could still occur, through crossings between geographically intermediate populations. In addition, the determined reproductive isolation could be the result of differential occurrence of endosymbionts between mite populations.

Studies to compare populations of *N. baraki* from Brazil and Africa have also been conducted, and important differences have been found (Negloh *et al.* 2008), suggesting that those differences could be due to the occurrence of a complex of species identified as *N. baraki* in Brazil and Africa. Morphological, molecular and cross-breeding studies of those populations provided evidence for the existence of cryptic species. Subsequent morphological research showed that the Benin population can be distinguished from the others by the number of teeth on the fixed digit of the female chelicerae (Sourassou *et al.* 2012).

Many predatory mites associated with coconut mite have been reported (Moraes & Zacarius 2002; Singh & Rethinam 2004). But the sheltered habitat where coconut mite colonies are usually found i.e. the small gap between bracts and nut surface, lowers the accessibility for many of these predators. In Sri Lanka, *Neaseiulus baraki* (Athias-Henriot), *N. paspalivorus* (De Leon), *Amblyseius largoensis* (Muma) (Moraes *et al.* 2004), *Bdella* sp., and transnomid species are associated with coconut mite. First three have been observed feeding on coconut mites (Fernando & Aratchige 2010).

Neoseiulus baraki has several morphological and behavioral adaptations that make it a potential candidate for biological control of coconut mites. They do not prefer too much light and their bodies are flat (Moraes & Zacarias 2002), with short distal setae (Moraes *et al.* 2004) which is an ideal morphological feature of a predator whose prey is in refuge inside a narrow habitat, such as under the perianth (Fernando & Aratchige 2010).

Spatial and temporal distribution patterns showed that on infested palms the mean numbers of *N. baraki* followed a similar patterns to that of coconut mites in associated with the maturity of nuts, but they reached a peak 1 month later than the coconut mites, suggesting a typical predator-prey interaction (Fernando *et al.* 2003).

According to the categorization of Gerson *et al.* (2003), *N. baraki* is more like a type III generalist predator species. Under laboratory conditions it developed well on pollen, but did not reproduce successfully on this food (Fernando *et al.* 2004).

Presence of *N. baraki* in Algeria (Althias-Henriot 1966), Thailand (Ehara & Bhandhufalck 1977), Taiwan (Tseng 1983) and China (Wu 1986) where coconut mite is not reported confirms its generalist nature. Although generalist predators are not usually considered in biological control programmes, certain characteristics could be considered in using them as biological control agents, such as their habitat performances.

2.14. Acaropathogenic fungi management

The possibilities of producing and using acaropathogenic fungi for coconut mite control have been explored (Lampedro and Luis Rosas 1989, Cabrera 1982, Hall *et al.* 1980). Work conducted until the end of the 1990s was summarized by Cabrera (2002). This author reported two fungi, Hirsutella thompsonii Fisher and Hirsutella nodulosa Petch, infecting coconut mite. At about the same time, Beevi *et al.* (1999) also reported Hirsutella thompsoni var. synnematosa Samson, McCoy and O'Donnell infecting coconut mite in India.

Promising results have been reported with the use of a commercial formulation of *H. thompsonii* in India (Gopal and Gupta 2001, Sreerama Kumar and Singh 2000). Mycohit, a commercial formulation of *H. thompsonii*, has been reported as effective under laboratory and field conditions in India (Sreerama Kumar 2010, Rabindra and Sreerama Kumar 2003). Sreerama Kumar and Singh (2008) conducted laboratory and field studies to examine the prospect of applications of mycelia of an Indian coconut mite isolate of *H. thompsonii*- MF(Ag) 66 in association with nine adjuvants. The result was positive, especially when glycerol was used as adjuvant. Multilocation trials are in progress in six Indian states.

Experiments with coconut mite have also been conducted in Sri Lanka. Here, the fungus seems suitable to be used in combination with other dominant control agents, as it appears to have no detrimental effects on *N. baraki* (Edgington *et al.* 2008, Fernando *et al.* 2007). A survey carried out in coconut mite-infested areas revealed a naturally low incidence of *H. thompsonii* on coconut mite (Edgington *et al.* 2008). Out of the isolates of H. thompsonii collected from different geographical regions of Sri Lanka, four isolates, namely IMI 390486, 391722, 391942 and 390486, were more promising in relation to growth and sporulation in culture. These were used in biological laboratory (Edgington *et al.* 2008) and field (Fernando *et al.* 2007) evaluations. Despite the positive results, the effect of a single application of *H. thompsonii* is of relatively short duration, producing inconsistent results and suggesting the need of frequent applications for long-term effect (Fernando *et al.* 2007). Therefore, experiments with those promising isolates were recently discontinued in Sri Lanka.

Why *H. thompsonii* did not persist long enough on treated fruits to cause significant epizootics in Sri Lanka is not clear. As suggested by Fernando *et al.* (2007), the movement of coconut mite underneath the coconut perianth is mostly confined to individual colonies and therefore the chances of a slow-growing fungus such as *H. thompsonii* spreading between colonies are low, especially in a situation where the number of mites on a fruit is lowered after fungus application.

The entomopathogenic fungus *H. thompsonii* attacks several tetranychid and eriophyoid mites of many crop plants (McCoy & Selhime 1974, Baker & Neunzig 1968) including the coconut mite (Beevi *et al.* 1999, Cabrea 1982, Hall *et al.* 1980). Hence, it is considered a potential control agent. A number of attempts have been made to control coconut mites with partial success (Rabindra & Kumar 2003, Cabrea 2002, Suarez *et al.* 1989, Espinosa-Becerril & Carrillo-Sanchez 1986).

2.15. Cultural management

After unsuccessfully trying the use of different chemical pesticides as well as applications of *H. thompsonii*, Moore *et al.* (1989) concluded that in order to increase coconut yield in a region where coconut mite is present, emphasis should be placed not on controlling the mite with these products, but rather on using improved agronomic practices and replanting with improved and mite-resistant varieties.

In Sri Lanka, when the pest was first reported in 1998, it was declared as a quarantine pest and transportation of infested fruits out of the infested area was banned, but this was discontinued because of the fast spread of the mite in the country. Present recommendation in Sri Lanka when infestation is first found on low numbers of palms in new areas, is for infested bunches to be pruned and burnt in situ. In India, a ‘holistic’ approach to coconut mite control is recommended, by incorporating cultural practices that improve palm vigour (CPR Nair, Central Plantation Crops Research Institute, Kayangulam, India, pers. comm.). Destruction of fallen buttons and restriction on transportation of mite-infested fruits from place to place have also been recommended in India (Rethinam *et al.* 2003).

In Brazil, cultural practices have been recomended to small farmers, including the pruning of infested bunches and the cleaning of palms (Araga˜o *et al.* 2002, Alencar *et al.* 1999). However, the effectiveness of these practices has never been evaluated. Studies conducted by da Melo *et al.* (2012) could not demonstrate the efficiency of these practices, probably because of the ability of the mite to disperse by wind from infested palms from the same area or from infested neighbor areas (Galva˜o 2009, Moore and Alexander 1987).

Efforts have been dedicated to the determination of the effect of agronomic practices on the population level of coconut mite. Some authors have observed a reduction of coconut mite damage when coconut was planted in association with other crops (Varadarajan and David 2003, Muthiah *et al.* 2001, Moore *et al.* 1989).

Damage by coconut mite generally increased with increasing levels of nitrogen in coconut leaves and it was suggested that higher levels of potassium could result in less damage by the mite (Moore *et al.* 1991). The use of organic fertilizers and potassium was reported to result in reduced mite damage in India (Muthiah *et al.* 2001). Sujatha and Rao (2004) reported less severe damage by coconut mite in well managed, fertilized and irrigated plantations, as well as in intercropped plantations in Andhra Pradesh, India. In the state of Tamil Nadu, also in India, Muthiah and

Natarajan (2004, 2005) reported reduced damage by this pest with the application of borax, calcium and manure in addition to adequate fertilization with NPK.

They also reported reduced damage when palms were treated with any of four types of biofertilizers. Yet, the response of the plants to the application of fertilizers is expected to vary according to prevailing soil conditions. Michereff Filho *et al.* (2008) did not find significant differences in proportion of fruits attacked by coconut mite or degree of damage caused by coconut mite among plants receiving various levels of application of nitrogen or potassium. This result might have been influenced by the fact that the plantation where the experiment was conducted had been fertilized for at least 2 years before the study was initiated.

2.16. Host plant resistance

Varietal differences in susceptibility to coconut mite have been observed in Costa Rica (Schliesske 1988), Cuba (Suarez 1991b), India (Muthiah and Natarajan 2004, Thirumalai Thevan *et al.* 2004, Varadarajan and David 2003, Nair 2002, Ramaraju *et al.* 2002), Ivory Coast (Julia and Mariau 1979, Mariau 1977, 1986), Saint Lucia (Moore and Alexander 1990) and Sri Lanka (IR Wickramananda and C Perera, CRI, Lunuwila, Sri Lanka, pers. comm.). Tightness of the perianth to the fruit, most probably related to the shape of the fruits, has been suggested as mechanism for resistance (Moore and Alexander 1990, Moore 1986, Hall and Espinosa Becerril 1981, Julia and Mariau 1979). Usually, rounded fruits have been reported to be less damaged by coconut mite than angular fruits (Varadarajan and David 2003, Moore and Alexander 1990, Moore 1986). Tightness of the perianth could also be related to its radius or to the angle between the inner overlapping bracts. Varadarajan and David (2003) reported less coconut mite damage on fruits having perianth with less than 2 coconut mite in radius and on fruits onto which the angle between the inner bracts was greater than 136. Resistance has also been related to fruit color. In Saint Lucia, Moore and

Alexander (1990) observed that dark green fruits of Jamaica Tall cultivar were consistently less attacked by coconut mite than lighter fruits. In India, Muthiah and Bhaskaran (2000) and Varadarajan and David (2003) reported orange colored fruits to be less injured by coconut mite than green and yellow fruits.

Relatively little effort has been dedicated to the use of varietal resistance against coconut mite in Sri Lanka and in-depth studies are necessary in this direction. In addition to morphological features, anatomical and biochemical characters of different varieties deserve consideration for varietal resistance/tolerance to coconut mite. Moore and Alexander (1990) considered that the lower coconut mite attack on the dark green fruits of the Jamaica Tall cultivar may not be directly linked to its color, but to the biochemical characteristics of those fruits.

2.17. IPM packages for management coconut mite

In Bangladesh very limited research and development works has so far been reported on the overall insect pest management of coconut including coconut eriophyid mite. Recently scientists of BARI worked on different aspects of coconut mite at Jassore region of Bangladesh with the financial assistance of Krishi Govasona Foundation (KGF). The developed integrated management package against coconut eriophyid mite by KGF project is as follows (Islam 2008):

a) Nutrient/Fertilizer application: Application of recommended doses of Urea and Triple Super Phosphate and increased dose of Muriate of Potash to increase the plant resistance to the mite infestation. Application of the well decomposed Farm Yard Manure (@ 50 kg/tree/year). Soil application of micronutrients (Borex 50 g/tree/year, Gypsum 1.0 kg/tree/year, Magnesium sulphate 0.5 kg/tree/year).

b) Sanitation: Removal of mite infested nuts, branches and inflorescences.

c) Application of miticide: Spot application of miticide, Propergite (Omite 57 EC) @ 1.5 ml/ liter of water. Division of Entomology, BARI has started a research and development work on the bio-rational based integrated management of three devastating insect pests of coconut, viz. Rhinoceros Beetle, Oryctes rhinoceros, Red Palm Weevil, Rhynchophorus ferrugineus and Coconut Eriophyid Mite, Aceria guerreronis at the coastal belt of Bangladesh (Alam and Islam 2014).

Currently neem based botanical formulations are recommended for mite management in the field. Spraying of neem oil-garlic soap mixture at 2% or commercial neem formulation containing azadirachtin 10,000 ppm @ 0.004% or root feeding with neem formulations containing azadirachtin 50,000 ppm (7.5 ml) or azadirachtin 10,000 ppm (10 ml) mixed with equal volume of water is recommended for mite management (Rajan *et al*, 2009, Mallik *et al.* 2003, Nair *et al.* 2000, 2003, Saradamma *et al.* 2000).

In India, adoption of integrated mite management approach with need-based application of botanical pesticides either by spraying or root feeding and adequate nutrient management of the affected palm has given encouraging results in the field. An integrated strategy blending plant protection and nutrient management is currently recommended for management of the pest.

Plant protection includes spraying on the terminal five pollinated coconut bunches thrice a year during December-January, April-May and September-October coinciding with population build up of the pest 0.02% neem oil-garlic soap mixture/neem formulation containing azadirachtin

10000 ppm (0.004%)/palm oil (200 ml) and sulphur (5g) emulsion/talc based preparation of *Hirsutella thompsonii* @ 20 g/litre/ palm containing 1.6 x 108cfu Or- Root feeding of neem formulations containing azadirachtin 50000 ppm @ 7.5 ml / azadirachtin 10000 ppm @ 10 ml mixed with equal volume of water.

The nutrient management package consists of:

- Balanced application of NPK fertilizers at recommended doses in two splits (Urea 1.0 kg, super phosphate 1.5 kg, muriate of potash 2.5 kg).
- Application of well-decomposed Farm Yard Manure @ 50 kg and neem cake @ 5 kg per palm per year.
- *Insitu* growing of green manure crops like cow pea, *Calapagonium* sp. Or sunn hemp (seed rate of 100g/palm basin) in the garden and its incorporation in coconut basin.
- Judicious irrigation and mulching with coconut leaves and husk in the basin.
- Soil application of micronutrients: Borax-50 g/palm/year; Magnesium sulphate–500g /palm/year especially in Onattukara region of Kerala. In South India, State Agricultural Universities, ICAR Institutions and private institutions have recommended an integrated and holistic approach for managing the mite population based on the findings of individual tactics tested against the pest. Removal of dried spathes, inflorescence parts, and fallen nuts etc. and burying in the soil or by burning minimizes the pest inoculum. Crown cleaning is to be taken up periodically. The movement of mite infested nuts from place to place is to be restricted to minimize the spread of mite. If locally acceptable, raise genotypes like Kalpa Haritha, Lakshadweep ordinary, Cochin China, Andaman ordinary and Gangabondam (which recorded minimum nut damage) in areas of severe mite infestation.

IPM package was demonstrated in farmer's fields at Krishnapuram village, Kerala covering 25 ha area of coconut gardens in 208 farmer holdings. Here the integrated nutrient management technology was implemented along with recommended practice of azadirachtin spraying thrice a year and the mite incidence could be brought down to 15.3% from 68% in period of three years (Rajagopal *et al.* 2003).

An IPM package consisting of two components *viz*., plant protection and nutritional care was developed and field validated. A natural decline in the mite incidence could be observed especially in most of the pest infested tracts in the West Coast. Both biotic and abiotic factors can be attributed as probable reasons for the reduction in mite incidence. The slow and steady increase in the population of predatory fauna, natural infection of mite population by pathogenic fungi particularly *H. thompsonii* and uniform distribution of rainfall in the major coconut growing areas of West Coast of the country are considered to be the major factors for natural regulation of the pest. However, in depth studies on biocontrol agents with tolerance to abiotic stress, role of plant nutrition including PGPRs, breeding for mite resistance are highly essential to chalk out a cost effective, eco-friendly and sustainable management of the pest. Adoption/cultivation of mite tolerant coconut varieties like Kalpa Haritha in endemic zones would be encouraged (Mohan *et al.* 2014).

In Pakistan, Neem cake is widely used to fertilize cash crops. The mixture of neem oil + Castor oil + soap powder + Wet able Sulphur 80% (100ml+100ml+12g+5g)/liter/palm/year was sprayed on the crown of affected palms with a modified Knapsack sprayer to control the Coconut mite (Solanki 2014).

Nutrient management as a component of integrated pestmanagement. Soil test based balanced nutrition play a key role in improving the palm health status thereby imparting tolerance to the mite attack. The nutrient management package consists of balanced application of NPK fertilizers at recommended doses in two splits (NPK @500g, 300g, 1200g/palm/year), recycling of organic biomass in coconut ecosystem using *in situ* vermi-composting or growing of green manure crops like cow pea or sunn hemp at a seed rate of 100g/palm and its incorporation in coconut basin and conservation of soil moisture by appropriate mulching methods. Well maintained trees, with appropriate fertilizer application, were found to suffer less from mite attack. Inter cropping of sunnhemp with coconut reduced the mite incidence upto 13.6 per cent and reduced the damage grade. The least damage of 29% was seen in palms treated with neem cake 2 kg+bone meal 0.5 kg+mill ash 4 kg (per tree/year) (Muthiah and Bhaskaran 2000). Low incidence of coconut eriophyid mite was observed in coconut gardens with intercrops *viz*., flowering plants, banana *etc* than the garden raised as monocrop in Andhra Pradesh. They also recorded that well maintained coconutplantations with proper irrigation and nutritional careexhibited a marked reduction in mite incidence when compared to neglected plantations (Rajan *et al.* 2012).

Ramaraju *et al.* (2002) evaluate the influence of organic and inorganic nutrients and the effect of botanicals and insecticide against coconuteriophyid mite. Soil application of nutrients along with spraying of Triazophos 40 EC (5 ml/lit.),azadirachtin 1% (5 ml/lit.) and neem oil (30 ml/lit.) as first, second and third round of sprayings, respectively were evaluated. The results revealed that there was a significant reduction in mite population(65%) after two years in the Integrated Management (IM) treated trees (application of organic and inorganic nutrients, basin cultivation of sun hemp and three rounds of spraying) followed by trees treated with Nitrogen: Phosphorus: Potash (1.3:2.0:3.5 kg/palm/year) + Farm Yard Manure 50kg/palm/year + neem cake 5 kg /palm/year + micronutrients + three rounds of sprayings (52.8%).Similarly, therewas also a significant reduction in the per cent damaged green nuts after two years. After second year, the per cent damaged nut was lowest (41.9) in the IM treated trees which was statistically onpar with treatment 6 (42.9) as against control (71.8).

Different pesticides (miticides, insecticides, fungicides) having acaricidal propertieswere used for the management of Coconut mite throughout the world. However, mitemanagement with sole synthetic chemical pesticides is not dependable and sustainablebecause mite population may grow resistance against those pesticides. Not only is that environmental pollution and health hazarding the bi-products of indiscriminate use ofsynthetic chemical pesticides. Therefore, an integrated package should be developedand used for the sustainable mite management of coconut. The integrated managementshould be bio-rational based where sole dependency on pesticides can be avoided. In Bangladesh very limited research and development works has so far been reportedon the overall insect pest management of coconut including coconut eriophyid mite.Recently scientists of BARI worked on different aspects of Coconut mite at Jassoreregion of Bangladesh with the financial assistance of Krishi Govasona Foundation (KGF). The developed integrated management package against coconut eriophyid miteby KGF project is as follows**:**Nutrient/Fertilizer application: Application of recommended doses of Urea and Triple Super Phosphate and increased dose of Muriate of Potash to increase the plant resistance to the mite infestation. Application of the well decomposed Farm Yard Manure (@ 50 kg/tree/year). Soil application of micronutrients (Borex 50 g/tree/year, Gypsum 1.0 kg/tree/year, Magnesium sulphate 0.5 kg/tree/year). Sanitation: Removal of mite infested nuts, branches and inflorescences. Application of miticide: Spot application of miticide, Propergite (Omite 57 EC) @ 1.5 ml/ liter of water Division of Entomology, BARI has started a research and development work on the bio-rational based integrated management of devastating coconut eriophyid mite, *Aceria guerreronis* at the coastal belt of Bangladesh (Islam 2008).

CHAPTER III

MATERIALS AND METHODS

The methodology had been drawn in line with the objectives of the study. The suitable tools for survey had been developed on particular parameters in respect of perception of farmers regarding coconut mite infestation; level of infestation of Coconut mite, perception of traditional management practices and health hazard effects of chemical control measures practised by the farmers. The specific methodology for different activities such as study design, review of secondary documents, field visits and field survey and discussion with the farmers, processing & analysis primary survey data are summarized in the following sub-headings:

Experiment 1. Survey and documentation of coconut mite infestation in major coconut growing regions of Bangladesh

3.1.1. Sources of data

The study had been conducted to generate stipulated primary data. Before that, the relevant secondary information on the coconut mite (*Aceria guerreronis* Keifer) and its extent of damage in different stages of coconut, traditional management practices and their level of infestation and subsequently these secondary documents had been reviewed meticulously. To develop the study instruments accurately and comparison with major indicators of the study, the secondary data were carefully scanned and had been collated according to the objectives of the study. For generating the desired primary data, the proposed sample study had been conducted using an appropriate sampling design and a formatted questionnaire.

3.1.2. Study location

The survey had been conducted in major coconut growing districts in south-western region of Bangladesh (Plate 1). Based on area and production, ten major coconut growing districts such as

Jassore, Khulna, Bagherhat, Pirojpur, Satkhira, Barisal, Patuakhali, Noakhali, Cox's Bazar and Dhaka had been considered as sampled districts. Under this study, two Upazilas from each districts had been sampled. The name of sampled Upazila's under ten sampled districts are as follows:

Table 3.1. List of the sampled districts and sampled upazilas

Sl. No.	District	Upazila
1	Jassore	Sadar, Bagharpara
2	Khulna	Sadar, Fultala
3	Bagherhat	Mongla, Chitolmari
4	Pirojpur	Sadar, Mothbaria
5	Satkhira	Kalaroa, Kaliganj
6	Barisal	Sadar, Uzirpur
7	Patuakhali	Kalapara, Mirzaganj
8	Noakhali	Sadar, Hatiya
9	Cox's Bazar	Sadar, Ramu
10	Dhaka	Savar, Dhamrai

3.1.3. Study period

Field survey for this study had been conducted from September 2015 to December 2015. Analytical study had been conducted from September 2015 to February 2016.

3.1.4. Stakeholders

The coconut growers and field level officials (FLO) of DAE worker under the sampled upazila of the selected coconut growing districts had been interviewed through pre-designed structured questionnaire. Among the field level officials, the Upazila Agriculture Officer (UAO), Agriculture Extension Officer (AEO) and Sub-Assistant Agriculture Officer (SAAO) had been considered from each of the sampled upazila for face-to-face interview under this survey study.

3.1.5. Sample design

Two types of analysis had been made to gather information about the study and those were-

a. Quantitative analysis: In order to ensure representativeness of the data and information collected, the proposed sampling strategy was delineated below:

The population under the study were constituted to assess the farmers' perception on the extent of damage caused by Coconut mite; commonly used management practices and their health hazard issues; as well as identify the coconut mite and suggestions for more economic and eco-friendly management issues. The survey study had been conducted from 10 districts in the south-western regions of Bangladesh namely Jassore, Khulna, Bagherhat, Pirojpur, Satkhira, Barisal, Patuakhali, Noakhali, Cox's Bazar and Dhaka, where the coconut is intensively grown. Two upazilas were covered for respondent selection from each of the sampled districts and 20 farmers were chosen for data collection from each upazila. Thus, the sample size of the study was considered 400 farmers. Using 95% confidence level with 5% margin of error it was needed to obtain a representative sample size of farmers 400 for this study. For such purpose a sound statistical formula with Finite Population Correction (FPC) recommended by Daniel (1999) had been adopted to determine the appropriate sample size as given below;

$$n = \frac{Z^2 PQ}{e^2}$$

Where,

n = Sample size without finite population correction (FPC),

P = Proportion/Probability of success (If the prevalence is 30%, P=0.3),

Q = 1-P (1-0.3= 0.7, Q=0.7),

Z = Z statistic for a level of confidence, Z=1.96 (The value of the standard variation at 95% Confidence level)

e = Precision or allowable margin of error (If the precision is 2%, then e=0.02) e=0.045 (Allowable margin of error at 4.5%)

Therefore, using this formula the sample size (n) for respective stakeholders had been calculated as follows:

$n = \{(1.96)^2 \times 0.3 \times 0.7\}/(0.045)^2 = 3.8416*0.21/0.002025 = 0.806736/0.002025 = 398.$

The sample size became 400 by using round figure of 398 for respondents. The respondents/farmers had been selected by using simple random sampling technique.

However, the determined number of respondents had been proportionately allotted to the sampled districts. In order to reach stipulated respondents at sampled districts a census had been done in the chosen respondents before the study. Such census was aimed at identifying targeted population of respondents in the districts.

Table 3.2. District and upazila-wise distribution of respondents under the field survey study

Sl. No.	District	Upazila	No. of coconut growers	No. of FLO of DAE		
				UAO	AEO	SAAO
1	Jassore	Sadar	20	1	1	3
		Bagharpara	20	1	1	3
2	Khulna	Sadar	20	1	1	3
		Fultala	20	1	1	3
3	Bagherhat	Mongla	20	1	1	3
		Chitolmari	20	1	1	3
4	Pirojpur	Sadar	20	1	1	3
		Mothbaria	20	1	1	3
5	Satkhira	Kalaroa	20	1	1	3
		Kaliganj	20	1	1	3
6	Barisal	Sadar	20	1	1	3
		Uzirpur	20	1	1	3
7	Patuakhali	Kalapara	20	1	1	3
		Mirzaganj	20	1	1	3
8	Noakhali	Sadar	20	1	1	3
		Hatiya	20	1	1	3
9	Cox’s Bazar	Sadar	20	1	1	3
		Ramu	20	1	1	3
10	Dhaka	Savar	20	1	1	3
		Dhamrai	20	1	1	3
Total	**10**	**20**	**400**	**20**	**20**	**60**

3.1.6. Variables/Indicators Covered

The following variables had been considered during development of questionnaire for data collection from the respondents.

1. Demographic: Name, Age, Sex etc., information were included so that the data were collected from the respondent coconut grower who were selected for face to face interview conducted by the researcher.

2. Social : Education, Profession and Experience etc. information were also needed to collect from the respondent coconut grower who were selected for face to face interview conducted by the researcher.

3. **Study related indicators:**

- **Demographic information:** Some demographic information of seclected respondent coconut grower from the sample area were collected. This information was collected for getting information as individual as respondent coconut grower. Some of these information was represented in this study.
- **Years of coconut plantation:** Years of coconut plantation, area of coconut orchard, types of coconut orchard etc. data were collected from the coconut grower of the sample area.
- **Types of coconut cultivation:** Types of coconut button, types of coconut plant, yield of coconut production etc. informations were colleted from the sample area.
- **Problems of coconut production:** To identify the problems of the production of coconut at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by the using of appropreat questioner and then data were codded for analysis.

- **Insect pests of coconut:** To identify the insect pests of coconut at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by the using of appropreat questionnaire and then codded it for analysis.
- **Infestation of insect pest on coconut:** To determine the infestation level of insect pests of coconut at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by the using of appropreat questionnaire and then codded it for analysis.
- **Intensity of coconut mite infestation on coconut:** To estimate the infestation of coconut mite at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by using of appropreat questioner and then codded it for analysis.
- **Management practices for coconut mite by the farmers:** To identify the management practices of coconut mite at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by the using of appropreat questioner and then codded it for analysis.
- **Present status of coconut yield**: To evaluate the production of coconut at the sample area, response of the coconut grower of sample area was collected via face to face interview. Data were collected by the using of appropreat questioner and then codded it for analysis.

3.1.7. Development of study tools/questionnaire

In consultation with the Research Supervisor and other members of the Advisory Committee, the questionnaire for coconut growers (Appendix I) and field level officials (Appendix II) had been prepared based on the objectives and indicators for the survey study and proposed methodologies. The study questionnaire pre-tested in the study location and thereafter, it had been finalized with due care to include appropriate questions for collection of necessary information from different levels and types of respondents to reflect the indicators relevant to the objectives of the study. The final questionnaire had been translated into Bangla also.

3.1.8. Method of data collection

The face-to-face interview of the coconut growers under the sampled districts had been collected for the study and those are given below:

- Direct personal interview approach had been adopted for collection of primary data. The method was effectively related to the collection of data directly from the coconut growers and people relevant with coconut production.
- The targeted sample coconut growers had been selected and finalized in consultation with the UAO and SAAO of the respective upazila selected for sampled districts.
- The enumerators recorded the data only after being fully satisfied that he had been able to make understand the question to the respondents and the respondents were offering any of the probable answers in his own perception.
- The investigators had made all efforts to have a friendly and open-minded interaction with the respondent. All questions had been asked one by one, and data were filled up on the spot.
- The enumerators had been conducted the face-to-face interview of targeted number of UAO, AEO and SAAO of the respective sampled districts.

As per sample design, the 400 survey respondents had been interviewed for 20 upazilas, where 2 upazila for each of 10 sampled districts.

3.1.9. Data Analysis

The filled up questionnaire had been coded according to the upazilas and districts. The filled up questionnaire for coconut growers and filed level officials of DAE had been coded separately. Then the entry of data had been performed using SPSS computer package and accordingly analyzed to generate objective wise desired information.

Experiment 2. Seasonal abundance of coconut mites in major coconut growing regions of Bangladesh

The study had been conducted in four major coconut growing districts like Jassore (23º10'12"N 89º12'E), Barisal (22º48'N 90º22'12"E), Satkhira (22º21'N 89º4'48"E) and Bagherhat (22º40'N 89º48'E) to assess the existence of coconut mite. To evaluate the effect of weather factor (i.e. temperature, rainfall and relative humidity) on coconut mite at these sample area this study also had been conducted. Collected data were summarized and the methodology was given as follows:

3.2.1. Study location

- The study on seasonal abundance of coconut mites had been conducted in major four coconut growing districts in South-Western region of Bangladesh viz; Jassore, Bagherhat, Satkhira and Barisal.
- The relevant laboratory works for counting of coconut mites were conducted under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka and Regional Agricultural Research Station, Jassore.

3.2.2. Study period

To determine the infestation of coconut mite and the level of infestation of coconut mite, this study was conducted throughout the year. According to the primary survey report of (followed by study

1) this study period was taken just before the winter season. So, the study had been conducted from September 2016 to August 2017.

3.2.3. Data collection

The data on the following parameters had been collected from infested green nuts/buttons from the study area throughout the year considering one month interval.

a. Number of mite per nut for different ages of nuts (particularly from 1 to 6 months old buttons considering 30 days interval): For counting the number of coconut mite, coconut of different ages was collected randomly from the target locations. Buttons were collected particularly 1 to 6 month old for observing the incidence of coconut mite. This data was collected at an interval of 30 days through the year round.

b. Number of mites per unit areas (per 4 sq. mm): For counting the number of coconut mite 4 sq. mm area was taken from the 3 different spots from each button. Number of mite was counted through sterio microscope and recorded it.

c. Monthly weather data (e.g. Temperature, RH and rainfall): Mothly weather data (e.g. temperature, rainfall and relative humidity) were collected from the southern region of Bangladesh viz; Jashore, Satkhira, Barishal and Bagerhat district.

3.2.4. Data collection procedure

The data on the incidence of mite population had been collected considering two counting methods such as Water wash counting method and Template counting method developed by Ramaraju *et al.* (2005) and Ramaraju (2001), respectively. One to six months old infested coconut buttons had been sampled from the palms. One button had been collected randomly from each palm and the number of alive Eriophyid mites (both nymphs and adults) had been counted through the following two methods like water washing counting method and template/direct counting method. Between these two methods template/direct counting method was followed for this study and details of this method was given bellow:

Template/Direct counting method (Population/4 mm^2): Live Eriophyid mite population (both nymphs and adults) had been recorded in an area of 4 sq. mm (2x2 mm) on three (3) places each on the inner side of the inner most of the bracts (three observation on 4th, 5th and 6th bracts) and on the nut surface (at three places) in every sample. The observations had been made on the place where the maximum populations noticed/observed using binocular stereo zoom microscope (Rama raju *et al.* 2001).

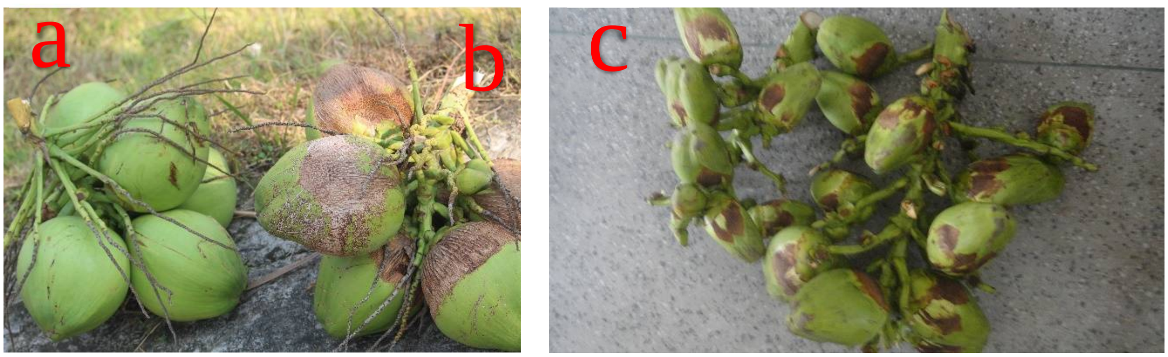

Plate 1: Healthy (a) and infested bunch (b, c)of coconut infested by coconut mite

3.2.5. Data analysis

For study both laboratory and field experiment was conducted through Complete Randomized Design (CRD) method. Collected data on different parameters was analyzed using MSTAT-C computer package.

Experiment 3. Damage assessment of coconut mites in major coconut growing regions of Bangladesh

This study had been conducted at the four major coconut growing regions of south-western part of Bangladesh like Jassore (23º10'12''N 89º12'E), Barisal (22º48'N 90º22'12''E), Satkhira (22º21'N 89º4'48''E) and Bagherhat (22º40'N 89º48'E). To assess the damage severity of coconut mite on coconut plantation in major coconut growing regions of Bangladesh, various sub-headings of methodology used are as follows:

3.3.1. Study location

- The study on the damage assessment of coconut mites had been conducted in major four coconut growing districts in South-Western region of Bangladesh such as Jassore, Bagerhat, Satkhira and Barisal. Two upazila of each district had been covered under the study.
- The relevant works for assessment had been conducted at field level of sampled locations at the same time.

3.3.2. Study period

To determine the damage assessment of coconut mite this study was conducted in the major coconut growing regions of Bangladesh like Jassore, Satkhira, Barisal and Bagherhat. According to the primary survey (followed by study 1) this study period was taken in the winter season. So, the study had been conducted from September 2016 to August 2017.

3.3.3. Data collection

The data on the following parameters had been collected from the harvested fruits in the study area throughout the year considering three month interval.

a. **Coconut tree infestation**

i. **Number of tree observed:** From the each sample districts two upazila were selected for this study. From each upazila one coconut orchard was selected. Five coconut plants were identified for the observation for this study.

ii. **Number of tree bears mite infested nuts:** From the each sample districts two upazila were selected for this study. From each upazila one coconut orchard was selected. Five coconut plants were identified for the observation and number of coconut mite infested coconut trees were counted and recorded for this study.

b. **Nut infestation**

i. **Total number of harvested nuts per sampled trees:** From the each coconut orchard five coconut plant were selected for observation. From these coconut plant bunches of coconut were harvested and total number of nut per sampled tree were counted and recorded.

ii. **Number of mite infested nuts among harvested nuts per sampled trees:** From the each coconut orchard five coconut plant were selected for observation. From these coconut plant bunches of coconut were harvested and total number of nut per sampled tree were counted and number of coconut mite infested nuts were also counted and recorded for this study.

c. **Damage severity/Damage Index**

According to the incidence and desparsal of coconut mite damage severity of coconut mite was calculated. For the calculation of damage severity grading scale of coconut mite infestation was needed. So, the damage index considering '1 to 5' grading scales of damage severity of nuts adopted by Mariau and Julia (1979).

3.3.4. Grading scale

Grading scale for coconut mite infestation per nut was given by Devi and Umapathy (2014) and as given bellow:

Grade	Level of Damage	Intensity of Damage
1	0%	Nuts with no mite damage
2	1-10%	Nuts with superficial damage
3	11-25%	Nuts with significant mite damage but not greatly reduced in size
4	26-50%	Nuts with significant mite damage showing diminished size and distortion in shape
5	> 50%	Nuts very heavily attacked, very much reduced size and often greatly distorted

3.3.5. Data collection procedure

The data on the damage incidence of nuts and damage severity/index had been collected round the year from both green and matured coconuts at harvest in the palm orchard considering one month interval. The sample nuts had been collected from the palm orchards of sampled area of selected upazila and districts.

a. Coconut tree infestation: At least five spot or locations had been sampled for each of the selected upazila under sampled districts. And 10 coconut trees had been sampled and tagged for each of the sampled spots or locations. The nuts of each coconut trees had been observed, whether the nuts are infested or not by the Eriophyid mites. If one nut is found infested then this tree had been categorized as mite infested tree, if there is no mite infested nut found, the tree had been categorized as un-infested tree. The percent mite infested tree had been calculated from the infested and un-infested coconut trees of the sampled areas. These data had been collected from the sampled areas at the study period.

b. Nut infestation: The sample green and matured coconuts had been harvested from the more or less similar aged tagged palm trees of the selected orchard from the selected locations. The number of total and infested nuts had been counted aiming to get percent damage incidence of nuts. Considering the replication, five palm trees had been tagged from each orchard.

c. **Damage Severity/Index:** The damage index had been measured considering a relatively simple visual grading system developed by Mariau and Julia (1979). The harvested nuts had been categorized based on the external damage system produced by the mite, into five following grades:

Grading designation	**Grading Scale**	**Level of damage**	**Numbering designation**	**No. of observed nuts**
G_1	1	0%	N_1	20
G_2	2	1-10%	N_2	20
G_3	3	11-25%	N_3	20
G_4	4	26-50%	N_4	20
G_5	5	> 50%	N_5	20
Total number of observed nuts			**N**	**100**

3.3.6. Mean Grading Index (MGI)

Mean grade index (MGI) scale and formula for coconut eriophyid mite was worked out as per Bagde *et al.* (2015). For calculating mean grading index (MGI) following equation was used:

$$MGI = \frac{G_1N_1 + G_2N_2 + G_3N_3 + G_4N_4 + G_5N_5}{N}$$

Where, G_n = Grading Scale (from G_1 to G_5)

N = Total number of nuts infested

N_n= Number of nuts at each grade

3.3.7. Data Analysis: The study was conducted through randomized complete block design with three replications. The data were collected on different parameters and had been analyzed using MSTAT-C computer package.

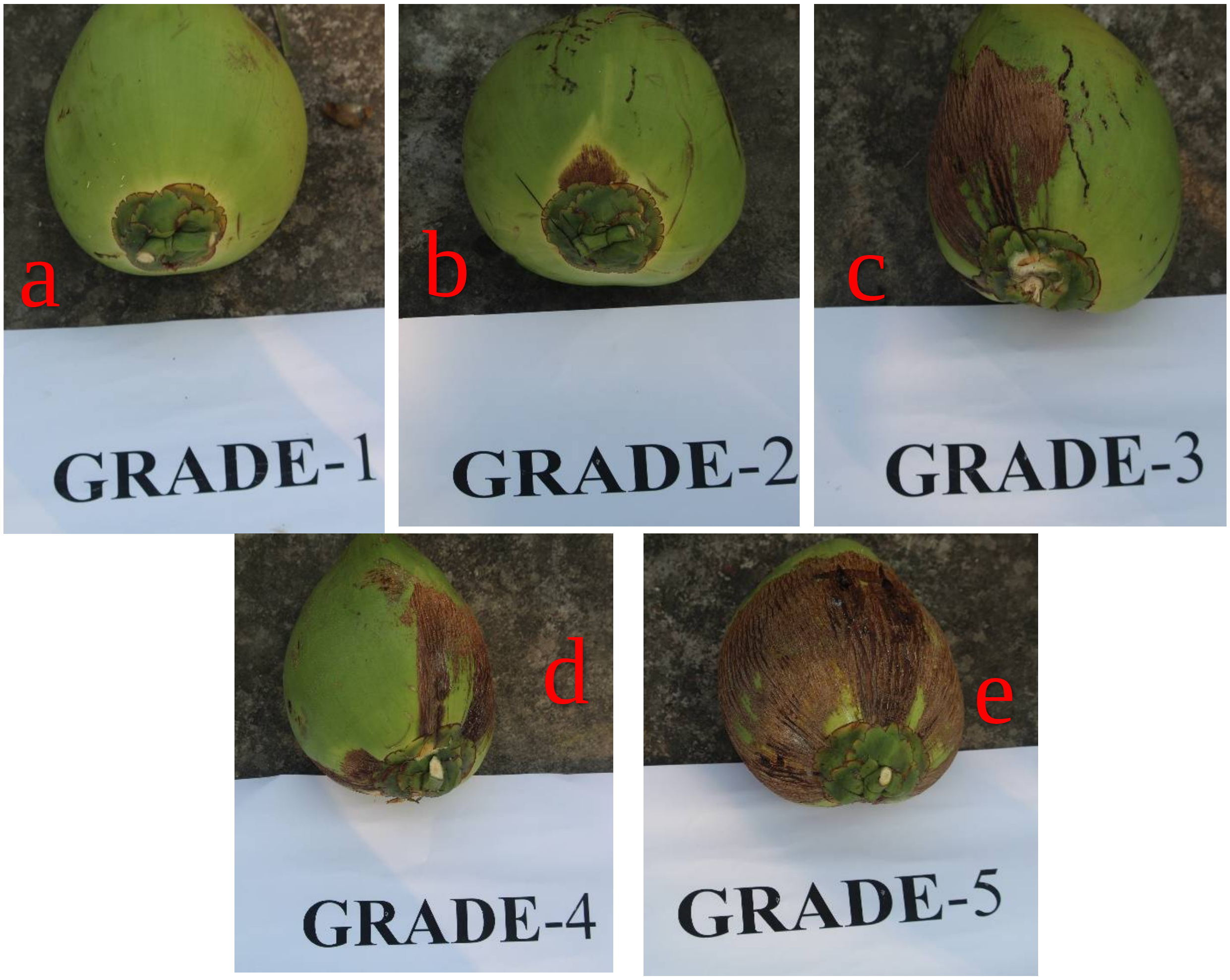

Plate 2. Coconut nut of different severity grades (a-e) infested by coconut mite

Experiment 4. Test on toxic action of chemical pesticides against coconut mites in laboratory condition

This study had been conducted for determining the bioassay of chemical pesticides against coconut mites in laboratory condition. This study was conducted during February to March 2017. For this study, methodology is given under following sub-headings:

3.4.1. Study location

The study of efficacy of different chemicals and bio-pesticides had been conducted in the laboratory under Entomology Division of RARS, BARI, Jassore as well as in the laboratory under the Department of Entomology, SAU, Dhaka.

3.4.2. Study period

To evaluate the efficacy of different chemical insecticides against coconut mite, this study was conducted in the peak period of coconut mite infestation. According to the primary survey (followed by study 1) this study period was taken in the winter season. So, the present study had been conducted during the period from February to March 2017.

3.4.3. Treatments

The treatments comprising chemical pesticides and biopesticides available in the market had been bio-assayed against coconut mites present on the nuts aiming to find out their efficacy as well as to determine their most effective dose(s). The treatments were used as follows:

Table 3.3. Treatments used in the bioassay

Treatment	Name of pesticides	Type of pesticide	Doses	Doses to be used	Recommended dose for vegetables
T_1	Chlorfenapyr (10 SC)	Insecticide + Acaricide	D_1	0.2%	0.2%
			D_2	0.3%	
			D_3	0.4%	
T_2	Abamectin (1.8 EC)	Insecticide + Acaricide	D_1	0.2%	0.02%
			D_2	0.3%	

			D_3	0.4%	
T_3	Diafenthiuron (50 WP)	Acaricide	D_1	0.1%	
			D_2	0.2%	
			D_3	0.3%	
T_4	Hexylhiazox (5.45 EC)	Acaricide	D_1	0.1%	
			D_2	0.2%	
			D_3	0.3%	
T_5	Trizofos (40 EC)	Acaricide	D_1	0.2%	
			D_2	0.3%	
			D_3	0.4%	
T_6	Thiovit (80 WG)	Acaricide	D_1	0.2%	
			D_2	0.3%	
			D_3	0.4%	
T_7	Fenpropathrin (30 EC)	Acaricide	D_1	0.1%	
			D_2	0.2%	
			D_3	0.3%	
T_8	Propargite (57 EC)	Acaricide	D_1	0.1%	
			D_2	0.2%	
			D_3	0.3%	
T_9	Mitisol	Bio-pesticide	D_1	0.2%	
			D_2	0.3%	
			D_3	0.4%	
T_{10}	Neem oil + Garlic extract	Botanical	D_1	1%+2.5%	
			D_2	2%+2.5%	
			D_3	2.5%+2.5%	
T_{11}	Untreated control	No treatment	D_0	-	-

3.4.4. Design of the experiment

The present experiment had been laid out in Two Factor Complete Randomized Design (CRD) in the laboratory condition with four replications. The pesticides had been considered as Factor A with 11 levels (T_1 to T_{11}) including untreated control and the doses of each pesticide had been considered as Factor B with 3 levels (D_1, D_1 and D_3).

Different factors for this stufy were given bellow:

Faactor A: Different types of pesticides

T_1= Chlorfenapyr (10%)

T_2= Abamectin (1.8%)

T_3= Diafenthiuron

T_4= Hexylhiazox (5.45 EC)

T_5= Trizofos (40 EC)

T_6= Thiovit (80 WG)

T_7= Fenpropathrin

T_8= Propargite

T_9= Mitisol

T_{10}= Neem oil + Garlic extract

T_{11}= Untreated control

Factor B: Doses of insecticide

Doses of insecticide had been determined according to the active ingradient of the insecticide. According to this three doses had been selected for this study as D_1, D_2 and $D_{3,}$ which were given to the section number 3.4.3.

3.4.5. Treatment application

T_1: Chlorfenapyr (10 SC) @ 2.00 ml/L of water, 3.00 ml/L of water and 4.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_2: Abamectin (1.8 EC) @ 2.00 ml/L of water, 3.00 ml/L of water and 4.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_3: Diafenthiuron (50 WP) @ 1.00 mg/L of water, 2.00 mg/L of water and 3.00 mg/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_4: Hexylhiazox (5.45 EC) @ 1.00 ml/L of water, 2.00 ml/L of water and 3.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_5: Trizofos (40 EC) @ 2.00 ml/L of water, 3.00 ml/L of water and 4.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_6: Thiovit (80 WG) @ 2.00 ml/L of water, 3.00 ml/L of water and 4.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_7: Fenpropathrin (30 EC) @ 1.00 ml/L of water, 2.00 ml/L of water and 3.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_8: Propargite (57 EC) @ 1.00 ml/L of water, 2.00 ml/L of water and 3.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_9: Mitisol @ 2.00 ml/L of water, 3.00 ml/L of water and 4.00 ml/L of water were prepared individually as three individual doses and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

T_{10}: Neem oil + Garlic extract @ 1.00 + 2.5 ml/L of water, 2.00 + 2.5 ml/L of water and 2.5 +2.5 ml/L of water were prepared individually as three individual doses with trix liquid detergent @ 1 ml (1%) to make the oil easy soluble in water and sprayed these at once. For this study these sprays had been sprayed on two to three months button which were infested by coconut mite.

3.4.6. Data recorded

The percent mortality of the Coconut mites on tested coconut buttons had been recorded through this bio-assay study. The specific data on following parameters had been recorded for this bio-assay study:

a) **Total number of mite per 4 sq. mm area of tested button:** Coconut mite infested surface of button was taken and placed under the the sterio microscope, where a hard paper with $4mm^2$ area measured whole was placed on the specimen and count the total number of coconut mite present there.

b) **Number of dead mite per 4 sq. mm area of tested button:** Coconut mite infested surface of button was taken and placed under the the sterio microscope, where a hard paper with $4mm^2$ area measured whole was placed on the specimen and count the number of dead and alive coconut mite present there.

3.4.7. Detail procedure

Collection of coconut buttons: Three months old mite infested coconut buttons from the trees had been collected and preserved in the polythene bag for further use in the bio-assay study.

Setting up of coconut buttons: The plastic trays had been collected and filled with wetted sands. The collected coconut buttons had been placed in the sands in such a way that the buttons can be retained fresh for survival of mite population. The trays along with sands and coconut buttons had been kept in the ambient temperature of the laboratory for study. The number of buttons had been set up in the trays according to the number of pesticide treatments and their doses along with the replication of the design of experiment. The additional water had been poured on the sands as needed to keep remain the sands at moist condition.

Treatment application: The treatment and dose wise pesticides had been applied on the coconut buttons. The foliar application of the pesticides was done on the surface of the targeted buttons along with bracts. The hand sprayers were used for the spray of the pesticides.

Counting of mite population: Template/Direct counting method had been followed for counting the mite population. The total number of live and dead eriophyid mite population (both nymphs and adults) had been recorded in an area of 4 sq. mm (2x2 mm) on one place from inner side of the inner most bracts and another from nut surface in each sample. The observations had been made at 12 hours, 24 hours and 72 hours exposure of the treatment applications. At 12 hours exposure, the inner fourth bract of each sampled button had been considered for counting mite population; then the inner fifth bract had been considered at 24 hours exposure. Lastly, the inner most sixth bract had been considered at 72 hours exposure of treatment application for counting mite population. The observations had been made on the spot where the maximum mite populations noticed/observed using binocular stereo zoom microscope (Ramaraju *et al.*, 2001).

3.4.8. Data Analysis

The study was conducted through complete block design (CRD) with four replications.The data were collected on different parameters had been analyzed using MSTAT-C computer package.

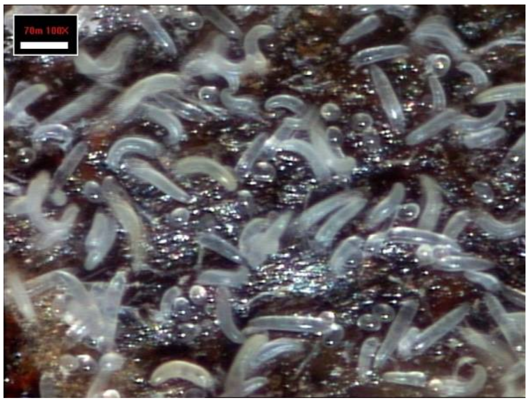

Plate 3: Coconut mite colony (Under sterio microscope)

Plate 4: Coconut with different treatments

Experiment 5. Development of suitable IPM package for the management of coconut mites in Bangladesh

This study had been conducted to develop of IPM package for the management of coconut mites in field condition. For this study, the methodology used are given bellow with sub-headings:

3.5.1. Study location

The study for development of IPM package for the management of coconut mites in field condition had been conducted in the coconut orchard under the Division of Entomology, RARS, BARI, Jassore.

3.5.2. Study period

To develop the IPM packages against coconut mite this study was conducted in Jassore. According to the primary survey (followed by study 1) this study period was taken during the period from April to December 2017.

3.5.3. Treatments

The treatments for this study had been selected from the effective chemical and botanical based bio-pesticides with most effective dose to be found from the bio-assay study. For this study treatments are as follows:

Treatment	Name of IPM packages
P_1	Hexythiazox (Mite Scavenger 10EC) @ 4ml/L of water and Mitisol @ 3ml/L of water
P_2	Abamectin (Vertimec 18EC) @ 4ml/L of water and Neem oil @ 3ml/L of water
P_3	Diafenthiuron (Pegasus 50SC) @ 4ml/L of water and balanced fertilizer that includes TSP @ 700 g/tree, Urea @ 600 g/tree, MP @ 1700 g/tree, Gypsum @ 500 g/tree, Magnesium Sulphate @ 250 g/tree, Boron @ 25 g/tree and Cow dung @ 40 kg/tree
P_4	Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree
P_5	Trizofos 40EC @ 4ml/L of water and and Neem oil @ 3ml/L of water
P_6	Sulpher (Thiovit 80WG) @ 5mg/L of water and Neem oil @ 3 ml/L of water
P_7	Fenpropathrin (Danitol 10EC) @ 4ml/L of water and Mitisol @ 3 ml/L of water
P_8	Propargite (Omite) @ 4ml/L of water and Neem oil @ 3 ml/L of water

Treatment	Name of IPM packages
P_9	Mitisol @ 3 ml/L of water
P_{10}	Azadiractin (Neem oil) @ 3 ml/L of water and balanced fertilizer that includes TSP @ 700 g/tree, Urea @ 600 g/tree, MP @ 1700 g/tree, Gypsum @ 500 g/tree, Magnesium Sulphate @ 250 g/tree, Boron @ 25 g/tree and Cow dung @ 40 kg/tree
P_{11}	Control

3.5.4. Design of the experiment

The present experiment had been laid out in Completely Randomized Design (CRD) in the laboratory condition with four replications. The pesticides had been considered as Factor A with 11 levels (P_1 to P_{11}) including untreated control.

3.5.5. Data collection

The data on the following parameters had been collected from the harvested fruits in the study area throughout the year considering three month interval.

a. **Coconut tree infestation**

i. **Number of tree observed:** From the each sample districts two upazila were selected for this study. From each upazila one coconut orchard was selected. Five coconut plants were identified for the observation for this study.

ii. **Number of tree bears mite infested nuts:** From the each sample districts two upazila were selected for this study. From each upazila one coconut orchard was selected. Five coconut plants were identified for the observation and number of coconut mite infested coconut trees were counted and recorded for this study.

b. Nut infestation

i. **Total number of harvested nuts per sampled trees:** From the each coconut orchard five coconut plant were selected for observation. From these coconut plant bunches of coconut were harvested and total number of nut per sampled tree were counted and recorded.

ii. **Number of mite infested nuts among harvested nuts per sampled trees:** From the each coconut orchard five coconut plant were selected for observation. From these coconut plant bunches of coconut were harvested and total number of nut per sampled tree were counted and number of coconut mite infested nuts were also counted and recorded for this study.

c. Damage severity/Damage Index

According to the incidence and desparsal of coconut mite damage severity of coconut mite was calculated. For the calculation of damage severity grading scale of coconut mite infestation was needed. So, the damage index considering '1 to 5' grading scales of damage severity of nuts adopted by Mariau and Julia (1979) which was given to the study number 3.

3.5.6. Data collection procedure

The data on the damage incidence of nuts and damage severity/index had been collected round the year from both green and matured coconuts at harvest in the palm orchard considering two months interval. The sample nuts had been collected from the palm orchards of sampled area of selected upazila and district.

a. Coconut tree infestation: At least five spot or locations had been sampled for each of the selected upazila under sampled districts. And 10 coconut trees had been sampled and tagged for each of the sampled spots or locations. The nuts of each coconut trees had been observed, whether the nuts are infested or not by the Eriophyid mites. If one nut is found infested then this tree had been categorized as mite infested tree, if there is no mite infested nut found, the tree had been categorized as un-infested tree. The percent mite infested tree had been calculated from the infested and un-infested coconut trees of the sampled areas. These data had been collected from the sampled areas at the study period.

b. Nut infestation: The sample green and matured coconuts had been harvested from the more or less similar aged tagged palm trees of the selected orchard from the selected locations. The number of total and infested nuts had been counted aiming to get percent damage incidence of nuts. Considering the replication, five palm trees had been tagged from each orchard.

c. Damage Severity/Index: The damage index had been measured considering a relatively simple visual grading system developed by Mariau and Julia (1979). The harvested nuts had been categorized based on the external damage system produced by the mite, into five following grades:

Grading designation	**Grading Scale**	**Level of damage**	**Numbering designation**	**No. of observed nuts**
G_1	1	0%	N_1	20
G_2	2	1-10%	N_2	20
G_3	3	11-25%	N_3	20
G_4	4	26-50%	N_4	20
G_5	5	> 50%	N_5	20
Total number of observed nuts			**N**	**100**

3.5.7. Mean Grading Index (MGI)

Mean grade index (MGI) scale and formula for coconut eriophyid mite was worked out as per Bagde *et al.* (2015). For calculating mean grading index (MGI) following equation was used:

$$MGI = \frac{G_1N_1 + G_2N_2 + G_3N_3 + G_4N_4 + G_5N_5}{N}$$

Where, G_n = Grading Scale (from G_1 to G_5)

N = Total number of nuts infested

N_n = Number of nuts at each grade

3.5.8. Data Analysis: The study was conducted through complete block design with three replications.The data were collected on different parameters had been analyzed using MSTAT-C computer package.


Plate 5: Treatmented coconut plant


Plate 6: Treatmented coconut plant


Plate 7: Infested coconut plant


Plate 8: Coconut orchard under the study


Plate 9: Coconut bunch harvesting


Plate 10: Healthy coconut bunch

CHAPTER IV

RESULTS AND DISCUSSION

Studies were conducted in the Southern districts of Bangladesh viz; Jassore, Sathkhira, Barishal and Bagerhat from the year of 2016 to 2017 to determine the level of infestation by coconut mite through farmers' perception, the population dynamics of coconut mite, to identify the severity of coconut mite infestation, to determine the bio-assay of chemical pesticides against coconut mite and to develop IPM package for the management of coconut mite. The results and discussion of four experiments are given bellow:

Experiment 1: Survey and documentation of coconut mite infestation in major coconut growing regions of Bangladesh

This study was conducted during September 2016 to February 2017 in 10 districts of south-western region of Bangladesh aiming to assess the farmers' perception on coconut mite infestation in major coconut growing regions of Bangladesh. The survey was conducted among 400 farmers in 20 upazilas under 10 districts of south-western regions of Bangladesh, of which almost all (97.2%) of the farmers were male. Their education level varied from illiterate to literate persons. Maximum (39.2%) of the farmers participated in the survey were 41 to 50 years old as well as the educational level of the maximum farmers (39.5%) was Class I-V, Class VI-VIII (24.2%), SSC (15.5%), illiterate (13.3%), HSC (4.5%), Bachelor degree (1.5%) and Master's degree (1.5%). The findings of the survey study have been interpreted and discussed in the following sub-headings:

4.1.1. Information about coconut production

4.1.1.1. Range of year for coconut production

There was significant variation on the coconut growers' respond on the range of year for coconut production at the survey area. Among the respondents, maximum 45.0% respondent reported that they have been grown coconut tree from more than 20 years and followed by 16-20 years (27.2%) and 11-15 years (19.0%). On the other hand, only 8.8% respondent reported that they started coconut production from only 6-10 years back.

Table 4.1.1. Coconut growers' response on the range of year for coconut production

Range of year for coconut production	Number of respondents [N=400]	% response
6-10 years	35	8.8
11-15 years	76	19.0
16-20 years	109	27.2
20 years <	180	45.0
Total	**400**	**100**

From this above findings it was revealed that, maximum coconut grower's (45.0%) were involved with coconut production for more than 20 years. And only 8.8% coconut growers' were involved with coconut production for 6-10 years.

4.1.1.2. Types of coconut orchard

From the graphical presentation bellow, it is revealed that majority of respondents (97.2%) have home stead orchard and only 2.8% respondent reported that they have commercial coconut orchard.

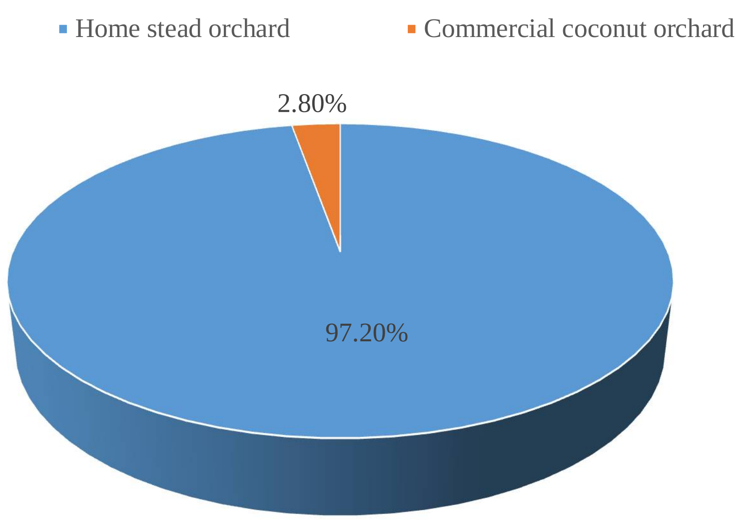

Figure 4.1.1. Coconut growers' response on the type of coconut orchard

From this above graph it was revealed that, maximum coconut grower's (97.2%) had home steade coconut orchard and few respondents (2.8%) had commercial coconut orchard.

4.1.1.3. Number of coconut tree in the coconut orchard

From the bellow findings, maximum respondent (76.5%) admitted that tey have less than 25 coconut trees which was followed by 15.2% respondent who have 26-50 coconut trees, 4.8% have 51-75 coconut trees, 2.5% have 76-100 coconut trees and only 1.0% respondent who have more than 100 coconut trees (Table 4.1.2.).

Respondents who have coconut trees, among them maximum 79.0% reported that they have less than 25 fruit bearing coconut trees at their coconut orchard, followed by 15.5% respondent have 26-50 fruiting coconut trees, 2.8% respondent have 51-75 fruiting coconut trees, 2.0% respondent have 76-100 fruiting coconut trees and only 0.7% respondent have more than 100 fruiting coconut trees at their coconut orchard (Table 4.1.2.).

Table 4.1.2. Coconut growers' response on the number of coconut plantation and fruiting coconut plantation of coconut orchard

Coconut plantation		
Number of coconut tree	**Number of respondents [N=400]**	**% response**
< 25	306	76.5
26-50	61	15.2
51-75	19	4.8
76-100	10	2.5
100 <	4	1.0
Total	**400**	**100**
Fruiting coconut plantation		
Number of coconut tree	**Number of respondents [N=400]**	**% response**
< 25	316	79.0
26-50	62	15.5
51-75	11	2.8
76-100	8	2.0
100 <	3	0.7
Total	**400**	**100**

From this above findings it was concluded that, mostly (76.5%) coconut growers' respondent had less than 25 coconut tree cause they had home stead coconut orchard. Again, maximum (79.0%) coconut growers' had also less than 25 fruiting coconut plantation.

4.1.1.4. Coconut production from the coconut orchard

Among the 400 respondent coconut growers', maximum 24.7% respondents collected 61-80 coconut from their coconut orchard a year round, followed by 22.0% collected 41-60 coconut, 18.0% collected 21-40 coconut, 17.2% collected more than 100 coconut, 16.3% collected 81-100 coconut and only 1.8% respondents collected less than 20 coconut from their coconut orchard throughout the year.

Table 4.1.3. Coconut growers' response on the range of number of coconut collected per plant through a year round

Range of coconut collected	Number of respondents [N=400]	% response
< 20	7	1.8
21-40	72	18.0
41-60	88	22.0
61-80	99	24.7
81-100	65	16.3
100 <	69	17.2
Total	**400**	**100**

From this above findings it was observed that, maximum (24.7%) coconut growers' respondent admire that they harvested 61-80 coconut button from their orchard in a year round.

4.1.1.5. Cost of production of coconut

Range of income: From the coconut growers' response, maximum 51.0% respondents reported that their income ranged more than 1000 taka per coconut tree per year, followed by 12.8% respondents earned 501-600 taka per coconut tree per a year. On the other hand, only 1.2% respondents reported that their income range was 401-500 taka per coconut tree per a year (Table 4.1.4).

Range of expenditure: From the coconut growers' response, maximum 46.5% respondents reported that their range of expencess was less than 100 taka per coconut tree per year, followed by 36.5% respondents ranged 101-200 taka per coconut tree per a year. On the other hand, only 2.0% respondent reported that their range of expencess was 301-400 taka per coconut tree per a year (Table 4.1.4).

Table 4.1.4. Coconut growers' response on expenditure and income per coconut tree per year

Income		
Number of taka	**Number of respondents [N=400]**	**% response**
>200 taka	6	1.5
201-300 taka	21	5.3
301-400 taka	6	1.5
401-500 taka	5	1.2
501- 600 taka	51	12.8
601-700 taka	36	9.0
701-800 taka	36	9.0
801-900 taka	9	2.2
901-1000 taka	26	6.5
1000 taka <	204	51.0
Total	**400**	**100**
Expenditure		
Number of cost	**Number of respondents [N=400]**	**% response**
< 100 taka	186	46.5
101-200 taka	146	36.5
201-300 taka	40	10.0
301-400 taka	8	2.0
401-500 taka	20	5.0
Total	**400**	**100**

4.1.2. Information about coconut and coconut tree

4.1.2.1. Size of coconut

From the bellow graphical presentation, it is demonstrated that majority of respondents (96.0%) reported that they have round shaped coconut in his/her coconut orchard and 63.5% respondent reported that they have tall shaped coconut in his/her coconut orchard.

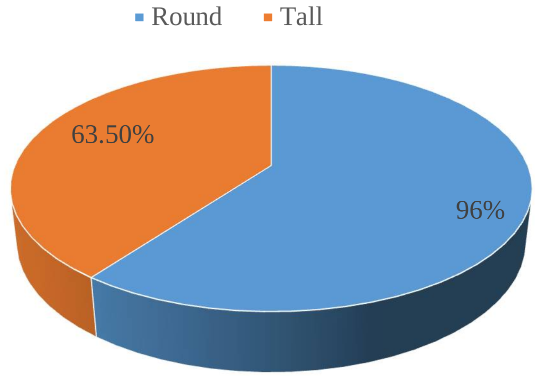

Figure 4.1.2. Coconut growers' response on the size of coconut of his/her coconut orchard

4.1.2.2. Color of coconut

There is significant difference on the response on the color of coconut grown in their coconut orchards. Among them, maximum of 98.8% respondent reported that they grew green colored coconut in their coconut orchard, followed by 58.5% respondent grew yellow colored coconut. On the other hand, minimum 24.0% respondents reported that they grew brownish yellow colored coconut in their coconut orchard.

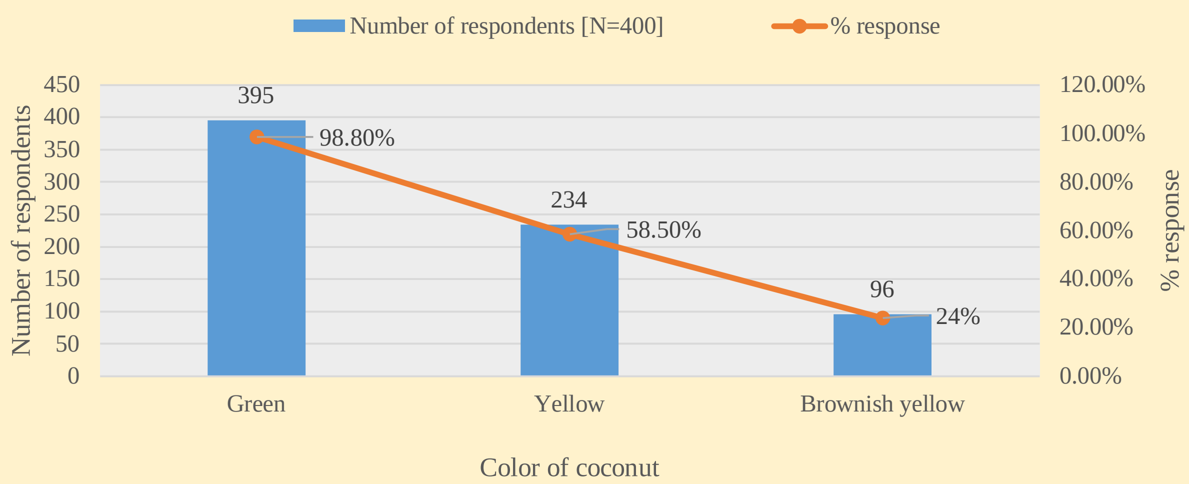

Figure 4.1.3. Coconut growers' response on the growing of coconut color

In case of the color of coconut at coconut orchard by coconut mite, maximum 97.2% respondent informed that coconut mite infested green color coconut mostly. On the other hand, minimum 1.0% respondent reported that, coconut mite infestation was low in yellow color coconut.

Table 4.1.5. Coconut grower's response about coconut mite infestation on coconut

Types of coconut	Number of respondents [N=400]	% response
Green	389	97.2
Yellow	4	1.0
Brownish yellow	7	1.8
Total	**400**	**100**

4.1.2.3. Variety of coconut plant

There was significant variation on the response on the variety of coconut plant in their coconut orchard. Among them, maximum 98.0% respondent reported that they had tall variety in their coconut orchard, followed by 18.0% respondent had medium variety. On the other hand, minimum 5.0% respondents reported that they had short variety in their coconut orchard.

Table 4.1.6. Coconut growers' response on growing different variety of coconut plant

Variety of coconut plant	Number of respondents [N=400]	% response
Tall variety	392	98.0
Medium variety	72	18
Short variety	20	5
Multiple Response		

4.1.2.4. Yield of different coconut variety

There was significantly variance among the response on the yield of coconut variety in their coconut orchard. Among them, maximum 70.5% respondent reported that tall variety coconut provided maximum production of coconut, followed by 22.8% respondent reported as medium variety. On the other hand, minimum 7.3% respondents reported that short variety of coconut produce minimum production of coconut in their coconut orchard.

Table 4.1.7. Coconut growers' response on the yield of coconut of different coconut varieties

Variety of coconut plant	Number of respondents [N=400]	% response
Tall variety	282	70.5
Short variety	29	7.3
Medium variety	91	22.8
Multiple Response		

In terms of varietal performance against coconut mite infestation, heighest 57.7% respondent reported that tall variety of coconut was more vulnerable to coconut mite. On the other hand, lowest 1.0% respondent reported that short variety of coconut was less infested by coconut mite.

Table 4.1.8. Coconut grower's response on coconut mite infestation of different coconut varieties

Variety	Number of respondents [N=400]	% response
Tall Variety	231	57.7
Short Variety	4	1.0
Medium Variety	165	41.3
Total	**400**	**100**

4.1.3. Information about the problems faced in coconut production

4.1.3.1. Problems faced in coconut production

Among the respondent coconut growers', maximum 92.3% respondent reported that insect pest was the major problem for coconut production, followed by drop out immature coconut (73.3%), diseases (57.5%), rough skin & rapture turning into black of coconut (49.8%) and nutritional deficiency (15.8%). On the other hand, only 0.5% respondent reported that dry out of coconut water was one of the problem for their coconut production.

Table 4.1.9. Coconut growers' response about the problems faced in coconut production

Types of problem	Coconut growers' response	
	No. of respondents	% Response
Drop out immature coconut	293	73.3
Insects	369	92.3
Diseases	230	57.5
Nutritional deficiency	63	15.8
Rough skin & rapture turning into black of coconut	199	49.8
Unavailability of hybrid variety	31	7.8
Dry out of coconut water	2	0.5
Multiple Response		

4.1.3.2. Incidence of insect pests

Out of 369 respondents who reported insect pest problem was one of the major problem in their coconut production, maximum 96.5% respondent admitted that rhinoceros beetle was one of the major destructive insect for coconut orchard, followed by mite (88.8%), red palm weevil (56.5%), termite (43.0%), rodent (31.0%), squirrel (31.0%), mealybug (8.8%) and scale insect (7.0%). On the other hand, minimum 2.0% respondent reported that bark weevil is also one of the insect pest of coconut orchard (Table 4.1.10.).

Among these insect pests of coconut orchard, 63.8% respondent reported that mite infestation was severe in their coconut orchard, followed by rhinoceros beetle (22.0%), squirrel (10.0%), red palm weevil (4.0%) and mealybug (0.2%) (Table 4.1.10.).

Table 4.1.10. Coconut growers' response on the incidence and severity of insect pest infestation in the coconut orchard

Incidence of insect pests of coconut in the coconut orchard		
Types of insects	**Coconut growers' response**	
	No. of respondents	**% Response**
Rhinoceros beetle	386	96.5
Red palm weevil	226	56.5
Termite	172	43.0
Mealybug	35	8.8
Scale insect	28	7.0
Mite	355	88.8
Rodent	124	31.0
Squirrel	126	31.5
Bark weevil	8	2.0
Multiple Response		
Seveirty of insect pests at the coconut orchard		
Types of insects	**Coconut growers' response**	
	No. of respondents	**% Response**
Rhinoceros beetle	88	22.0
Red palm weevil	16	4.0
Mealybug	1	0.2
Mite	255	63.8
Squirrel	40	10.0
Multiple Response		

4.1.4. Information about infestation of coconut mite

4.1.4.1. Symptom of rough & compact skin of coconut

From the respondents of coconut grower, maximum 99.0% respondents opined that they were aware about the symptom of rough & compact skin of coconut. On the other hand, only 1.0% respondent opined that they were unaquainted about the symptom of rough & compact skin of coconut in their coconut orchard.

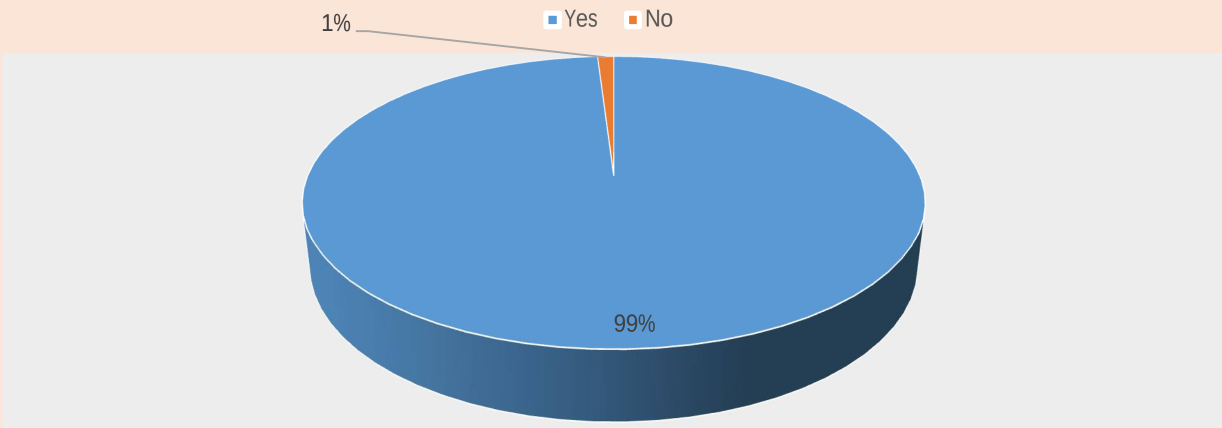

Figure 4.1.4. Coconut growers' response about the symptom of rough & compact skin of coconut

4.1.4.2. Knowledge about coconut mite

From the respondents of the coconut grower, maximum 55.0% respondents opined that they were informed about coconut mite which cause the symptom of rough & compact skin of coconut. On the other hand, minimum 45.0% respondent opined that they were unaware about coconut mite which causes the symptom of rough & compact skin of coconut in their coconut orchard.

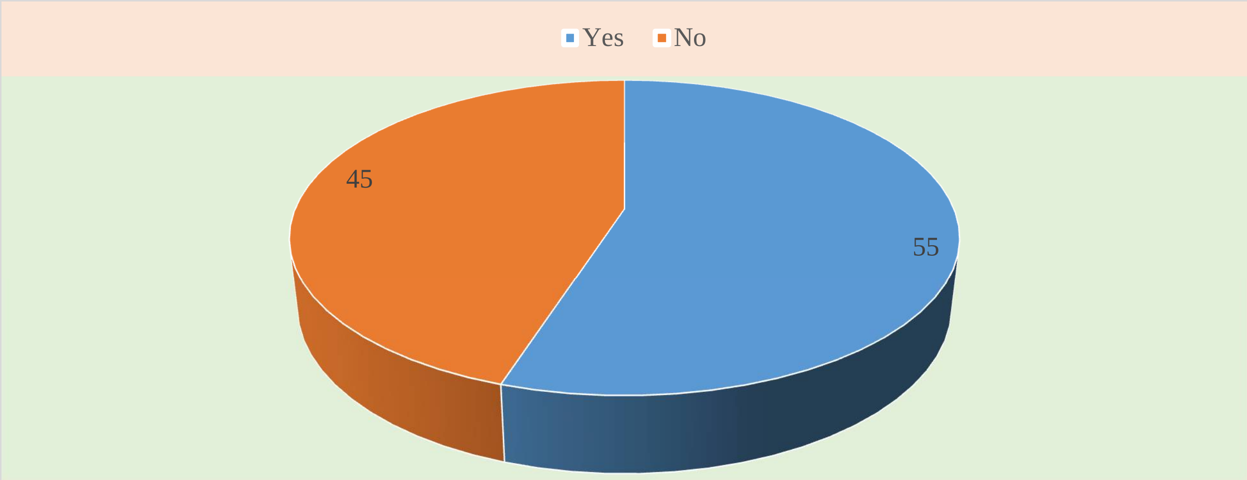

Figure 4.1.5: Knowledge about coconut mite which cause rough & compact skin symptom

4.1.4.3. Knowledge about coconut mite infestation

From the respondents of the coconut grower, maximum 95.5% respondents opined that they were informed about the infestation of coconut mite. On the other hand, minimum 4.5% respondent opined that they were unaquinted about the infestation of coconut mite.

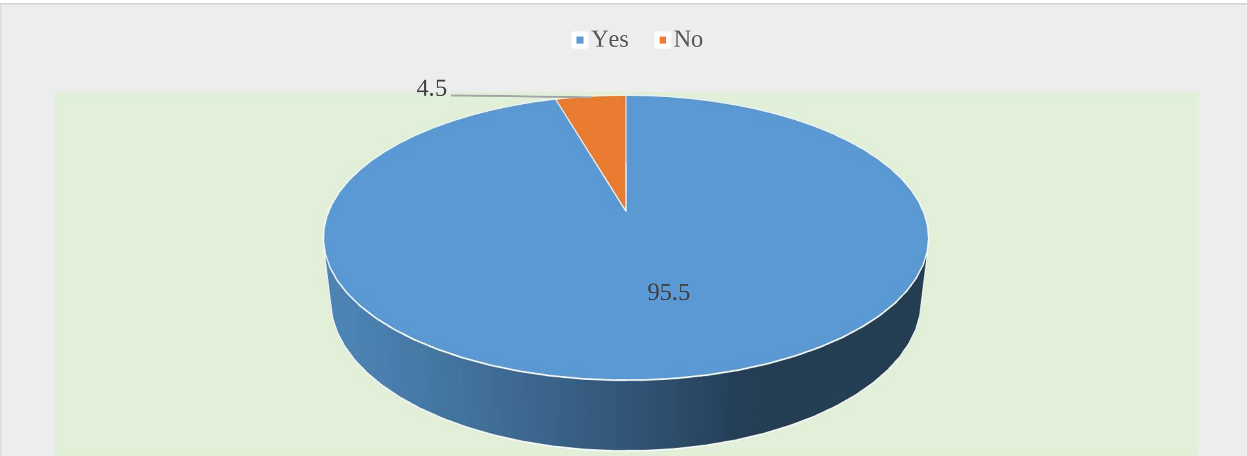

Figure 4.1.6. Coconut growers' response on the presence of coconut mite in the coconut orchard

Out of 382 respondents, who were conscious about the coconut mite infestation, maximum 48.2% respondent knew about coconut mite infestation from 6-10 years, followed by 3-5 yearas (34.8%) and 1-2 years (9.5%). On the other hand, only 7.5% respondent were known about coconut mite infestation from 1-2 years.

Table 4.1.11. Coconut growers' response on the range of years for presence of coconut mite in coconut orchard

Period of coconut mite presence	Number of respondents	% response
1-2 years	38	9.5
3-5 years	139	34.8
6-10 years	193	48.2
11-15 years	30	7.5
Multiple Response		

4.1.4.4. Validation of coconut mite presence

Among the respondent coconut growers', heighest 91.8% respondent informed that they consented the presence of coconut mite in their coconut orchard through agricultural officer, followed by neighbors (35.0%), agricultural researcher (14.0%) and pesticide dillers' (9.3%). On the other hand, only 5.5% respondent informed that they conformed the presence of coconut mite in their coconut orchard through mass media.

Table 4.1.12. Coconut growers' response on the validation of coconut mite presence

Types of response	Number of respondents [N=400]	% response
Neighbors	140	35.0
Agricultural Officer	367	91.8
Agricultural Researcher	56	14
Pesticide Diller's	37	9.3
Mass media	22	5.5
Multiple Response		

4.1.4.5. Symptoms of coconut mite infestation

Among the total respondent coconut growers, heighest of 91.5% respondent reported that the main symptom of coconut mite infestation was rough skin due to blast of coconut, followed by rupture of coconut (67.3%), dwarf coconut (63.5%), green skin turns into black (60.3%), drop out immature coconut (52.8%), compact skin on coconut (51.0%), leaching of sap through rapture on coconut (40.3%) and angular coconut (21.8%).

Table 4.1.13. Coconut grower's response about the symptoms of coconut mite infestation

Types of response	Number of respondents	% response
Rough skin due to blast of coconut	366	91.5
Rupture of coconut	269	67.3
Leaching of sap through rapture on coconut	161	40.3
Green skin turns into black	241	60.3
Compact skin on coconut	204	51.0
Dwarf coconut	254	63.5
Angular coconut	87	21.8
Drop out immature coconut	211	52.8
Multiple Response		

4.1.4.6. Severity of coconut mite infestation

Among the respondents, heighest 57.7% respondent reported that the infestation of coconut mite in their coconut orchard was medium, followed by high (25.0%) and low (13.5%). On the other hand, only 3.8% respondent reported that the infestation of coconut mite was severe.

Table 4.1.14. Coconut grower's response about severity of coconut mite infestation

Infestation level	Number of respondents [N=400]	% response
Severe	15	3.8
High	100	25.0
Medium	231	57.7
Low	54	13.5
Total	**400**	**100**

4.1.4.7. Seasonal abundance of coconut mite infestation

The heighest number of respondents (68.5%) informed that the infestation of coconut mite was severe in winter season, following summer season (29.2%). On the other hand, only 2.3% respondents informed that lowest coconut mite infestation in winter (Table 4.1.15.).

The heighest number of respondents (57.8%) informed that the infestation of coconut mite was severe at winter season, followed by summer (32.7%). On the other hand, only 9.53% respondents informed that lowest coconut mite infestation in winter (4.1.15.).

Table 4.1.15. Knowledge about the season of severe and low coconut mite infestation in a year

Knowledge about the season of severe coconut mite infestation in a year		
Time of sever infestation	**Number of respondents [N=400]**	**% response**
Winter	274	68.5
Rainy season	9	2.3
Summer	117	29.2
Total	**400**	**100**
Knowledge about the low of severe coconut mite infestation in a year		
Time of low infestation	**Number of respondents [N=400]**	**% response**
Winter	38	9.5
Rainy season	231	57.8
Summer	131	32.7
Total	**400**	**100**

4.1.4.8. Coconut mite infestation

Most of the respondent 41.5% reported that 50% of coconut was infested by coconut mite, followed by 25% of coconut (27.0%), 75% of coconut (19.0%) and few amount (<25%)of coconut (10.7%). On the other hand, 1.8% respondent reported that total number of coconut was infested by coconut mite (Table 4.1.16.).

Among the respondents, maximum 99.3% respondent informed that they have knowledge on coconut mite damage of exosperm of coconut, followed by low amount of coconut water (77.5%) and rough shape of endosperm (64.5%) (4.1.16.).

Table 4.1.16. Knowledge about the coconut loss due to coconut mite infestation

Knowledge about the loss of coconut due to coconut mite		
Coconut loss (%)	**Number of respondents [N=400]**	**% response**
Total coconuts	7	1.8
75% of coconuts	76	19.0
50% of coconuts	166	41.5
25% of coconuts	108	27.0
Few amount (<25%) of coconuts	43	10.7
Total	**400**	**100**
Knowledge about the damage of coconut due to coconut mite infestation		
Damage of coconut	**Number of respondents [N=400]**	**% response**
Damage of exosperm	397	99.3
Low amount of coconut water	310	77.5
Rough shape of endosperm	258	64.5
Multiple response		

4.1.5. Information about the management practices against coconut mite

4.1.5.1. Curative measures taken against pests of coconut

Maximum respondents (93.0%) of coconut growers' admitted that they took management practices against pests of coconut as curative measures. On the other hand, only 7.0% respondents informed that they did not do that.

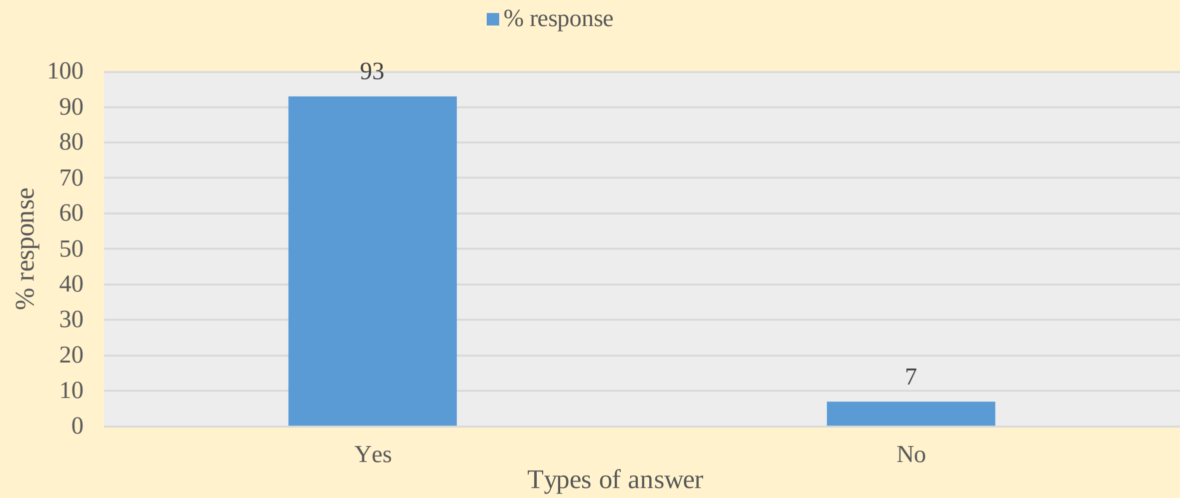

Figure 4.1.7. Coconut growers' response on the management practices taken against insect pests of coconut as curative measures

4.1.5.2. Types of curative measures taken against coconut pests

Out of 372 respondents who took curative measures against insect pests of coconut, all of them (100%) practices sanitary as the curative measurement against coconut mite, followed by using insecticides (47.6%), water management (26.9%) and basal doses of fertilizers (8.1%).

Table 4.1.17. Types of curative measures taken against coconut pests

Type of measures	Number of respondents [N=372]	% response
Sanitary practices	372	100.0
Use insecticides/miticides	177	47.6
Basal doses of fertilizers	30	8.1
Water management	100	26.9
Multiple Response		

4.1.5.3. Preventive measures taken against coconut pests

Among the respondents, heighest 58.8% respondents reported that they took preventive management practices against coconut mite and 41.2% respondent did not do that (4.1.18.).

Out of 235 respondents, who took preventive measures against coconut mite, almost (98.7%) respondent reported that they took sanitary practices for coconut mite infestation as preventive measure, followed by use acaricide (48.5%) and water management (28.5%). On the other hand, only 7.7% respondent took basal doses of fertilizers as a preventive management practices (4.1.18.).

Table 4.1.18. Coconut growers' response on the management practices taken against coconut mite as preventive measures

Management practices against coconut mite		
Type of response	**Number of respondents [N=400]**	**% response**
Yes	235	58.8
No	165	41.2
Total	**400**	**100**
Preventive measures against coconut mite		
Preventive measures	**Number of respondents [N=235]**	**% response**
Sanitary practices	232	98.7
Use acaricides	114	48.5
Basal doses of fertilizers	18	7.7
Water management	67	28.5
Multiple response		

4.1.5.4. Taking about different advice for coconut mite

Majority of the respondents, maximum (71.8%) respondents admitted that they took advice for coconut mite infestation. On the other hand, 28.2% respondents did not do that (4.1.19).

Out of 287 respondents, who took advice for coconut mite infestation, maximum (88.50%) respondent took their advice from agriculture officer, followed by neighbor (35.89%), insecticide dealers (14.50%) and agricultural researcher (11.50%) (4.1.19.).

Table 4.1.19. Coconut growers' response about taking advice for coconut mite

Taking advise for coconut mite		
Type of response	**Number of respondents [N=400]**	**% response**
Yes	287	71.8
No	113	28.2
Total	**400**	**100**
Type of advisors	**Number of respondents [N=287]**	**% response**
From neighbors	103	35.89
From Agriculture Officer	254	88.5
From Agricultural Reseacher	33	11.5
From insecticide dealers	41	14.3
Multiple response		

4.1.5.5. Most effective control measures against coconut mite

Among the respondents, heighest 33.50% respondent expressed their opinion as they did not know anything, followed by applying insecticides (30.50%), applying acaricides (21.2%), sanitation (14.5%) and applying ash and lime (0.3%) for controlling coconut mite in their coconut orchard.

Table 4.1.20. Coconut growers' response on the most effective control measures against coconut mite

Type of control measures	**Number of respondents [N=400]**	**% response**
Applying insecticides	122	30.5
Sanitation	58	14.5
Applying acaricides	85	21.2
Applying ash and lime	1	0.3
Not known	134	33.5
Total	**400**	**100**

Experiment 2: Seasonal abundance of coconut mite in major coconut growing regions of Bangladesh

This study was conducted in the four Southern districts viz Jassore, Satkhira, Bagerhat and Barishal districts of Bangladesh from September 2016 to August 2017 to know the population dynamics of coconut mite.

4.2.1. Population of coconut mite in Jassore region

The population dynamics on the number of coconut mite on infested nuts at different ages during September, 2016 to August, 2017 at Jassore region are presented in the table 4.2.1. The highest number of 35.92 coconut mites/ 4 sq mm was observed in April, 2017 on 2 months old coconut. Then the number of coconut mite decreased gradually from May 2017 as 30.72 mites/ 4 sq mm, to August, 2017 as 1.64 mites/4 sq mm. The mite population increased in January to March, 2017 with numbers 27.52-30.04 mites/4 sq mm. During September to December, 2016 the number of coconut mites were 16.96-26.80 mites/4 sq mm.on 2 months old coconut nut. More or less similar trend was observed in 4 and 6 months old coconut nuts in these years and and lowest numbers were observed on 6 months old coconut nuts.

Table 4.2.1. Seasonal abundance of mite on coconut in laboratory condition at Jassore region

Month	2 months old		4 months old		6 months old	
	Range	Mean	Range	Mean	Range	Mean
Sep./16	0-32	16.96	0-26	8.86	0-11	1.83
Oct./16	8-46	19.52	0-35	9.12	0-14	1.97
Nov./16	4-35	17.44	0-21	8.72	0-9	1.67
Dec./16	5-82	26.80	0-49	12.88	0-28	2.74
Jan./17	6-113	27.52	0-35	12.42	0-23	2.78
Feb./17	3-118	27.36	0-37	13.86	0-31	2.98
Mar./17	7-176	30.04	0-26	12.94	0-21	3.23
Apr./17	8-214	35.92	0-43	15.72	0-32	3.68
May/17	7-187	30.72	0-33	14.39	0-28	3.12
Jun./17	0-24	9.94	0-15	4.33	0-17	1.48
Jul./17	0-15	1.84	0-12	0.81	0-14	0.17
Aug./17	0-13	1.64	0-16	0.77	0-13	0.15
Average	-	20.48	-	9.57	-	2.15

4.2.2. Population of coconut mite at Satkhira region

The population dynamics on the number of coconut mite on infested nuts at different ages during September, 2016 to August, 2017 at Satkhira region are presented in the table 4.2.2. The highest number of 27.74 coconut mites/ 4 sq mm was observed in April, 2017 on 2 months old coconut. Then the number of coconut mite decreased gradually from May 2017 as 25.26 mites/ 4 sq mm, to August, 2017 as 0.76 mites/4 sq mm. The mite population increased in January to March, 2017 with numbers 19.34-22.62 mites/4 sq mm. During September to December, 2016 the number of coconut mites were 12.68-20.28 mites/4 sq mm.on 2 months old coconut nut. More or less similar trend was observed in 4 and 6 months old coconut nuts in these years and and lowest numbers were observed on 6 months old coconut nuts.

Table 4.2.2. Seasonal abundance of mite on coconut in laboratory condition at Satkhira region

Month	2 months old		4 months old		6 months old	
	Range	Mean	Range	Mean	Range	Mean
Sep./16	0-31	12.68	0-28	6.21	0-9	1.25
Oct./16	0-33	15.33	0-29	7.78	0-11	1.53
Nov./16	4-48	14.26	0-28	7.13	0-10	1.43
Dec./16	9-54	20.28	3-33	10.24	0-13	2.03
Jan./17	7-68	19.34	0-27	9.68	0-11	1.93
Feb./17	6-83	22.21	4-35	11.14	0-13	2.22
Mar./17	5-87	22.62	6-41	11.82	0-15	2.26
Apr./17	8-106	27.74	6-49	13.92	0-15	2.77
May/17	9-98	25.26	5-38	12.58	0-14	2.53
Jun./17	0-21	5.24	0-26	2.89	0-10	0.57
Jul./17	0-18	1.26	0-22	0.83	0-9	0.42
Aug./17	0-11	0.76	0-18	0.47	0-9	0.31
Average	-	15.58	-	7.89	-	1.60

4.2.3. Population of coconut mite at Barishal region

The population dynamics on the number of coconut mite on infested nuts at different ages during September, 2016 to August, 2017 at Barishal region are presented in the table 4.2.3. The highest number of 18.87 coconut mites/ 4 sq mm was observed in April, 2017 on 2 months old coconut.

Then the number of coconut mite decreased gradually from May 2017 as 17.31 mites/ 4 sq mm, to August, 2017 as 0.62 mites/4 sq mm. The mite population increased in January to March, 2017 with numbers 11.14-15.63 mites/4 sq mm. During September to December, 2016 the number of coconut mites were 1.84-13.64 mites/4 sq mm.on 2 months old coconut nut. More or less similar trend was observed in 4 and 6 months old coconut nuts in these years and and lowest numbers were observed on 6 months old coconut nuts.

Table 4.2.3. Seasonal abundance of mite on coconut in laboratory condition at Barishal region

Month	2 months old		4 months old		6 months old	
	Range	Mean	Range	Mean	Range	Mean
Sep./16	0-19	1.84	0-16	0.92	0-11	0.18
Oct./16	0-21	10.78	0-18	5.41	0-13	1.08
Nov./16	0-22	8.32	0-18	4.17	0-15	0.82
Dec./16	0-28	13.64	0-19	6.79	0-13	1.36
Jan./17	0-31	11.14	0-22	5.52	0-18	1.11
Feb./17	0-36	14.49	0-25	7.21	0-21	1.44
Mar./17	0-37	15.63	0-43	7.83	0-28	1.56
Apr./17	0-63	18.87	0-49	9.21	0-27	1.84
May/17	0-48	17.31	0-34	8.64	0-16	1.72
Jun./17	0-19	1.71	0-21	0.87	0-13	0.17
Jul./17	0-18	0.83	0-19	0.42	0-10	0.08
Aug./17	0-13	0.62	0-16	0.33	0-10	0.07
Average		9.60		4.78		0.95

4.2.4. Population of coconut mite at Bagerhat region

The population dynamics on the number of coconut mite on infested nuts at different ages during September, 2016 to August, 2017 at Bagerhat region are presented in the table 4.2.4. The highest number of 7.42 coconut mites/ 4 sq mm was observed in April, 2017 on 2 months old coconut. Then the number of coconut mite decreased gradually from May 2017 as 5.21 mites/ 4 sq mm, to August, 2017 as 0.98 mites/4 sq mm. The mite population increased in January to March, 2017 with numbers 4.23-6.33 mites/4 sq mm. During September to December, 2016 the number of coconut mites were 2.61-4.81 mites/4 sq mm.on 2 months old coconut nut. More or less similar trend was observed in 4 and 6 months old coconut nuts in these years and and lowest numbers were observed on 6 months old coconut nuts.

Table 4.2.4. Seasonal abundance of mite on coconut in laboratory condition at Bagerhat region

Months	2 months old		4 months old		6 months old	
	Range	Mean	Range	Mean	Range	Mean
Sep./16	0-14	2.61	0-12	1.28	0-14	0.26
Oct./16	0-22	4.11	0-19	2.14	0-18	0.41
Nov./16	0-29	3.68	0-27	1.81	0-23	0.37
Dec./16	0-24	4.81	0-21	2.43	0-18	0.48
Jan./17	0-31	4.23	0-28	2.22	0-12	0.42
Feb./17	0-37	5.78	0-25	2.93	0-14	0.58
Mar./17	0-28	6.33	0-19	3.27	0-12	0.63
Apr./17	0-33	7.42	0-21	3.89	0-17	0.74
May/17	0-27	5.21	0-15	2.71	0-18	0.52
Jun./17	0-18	2.41	0-11	1.11	0-11	0.24
Jul./17	0-12	1.13	0-13	0.49	0-9	0.11
Aug./17	0-11	0.98	0-12	0.32	0-8	0.09
Average	-	4.06	-	2.05	-	0.40

4.2.5. Effect of weather factors on coconut mite population at Jassore region

Weather factors like average temperature, rainfall and relative humidity had the significant effect on population dynamics of coconut mite in Jassore region. From the figure 4.2.1. it is revealed that, the population of coconut mite was suppressed when the mean temperature, rainfall and relative humidity remained high in the month of June to August, 2017. When the rainfall became higher in the month of July, 2017 and August, 2017, then the population of coconut mite declined. But the lower rainfall in the month January, 2017, February, 2017 and March, 2017, caused raising the population of coconut mite. Again when the relative humidity became higher in the month of July and August, 2017, then the population of coconut mite reduced. And when the relative humidity became lower in the month of February, 2017, March, 2017 and April, 2017, then the population of coconut mite became high.

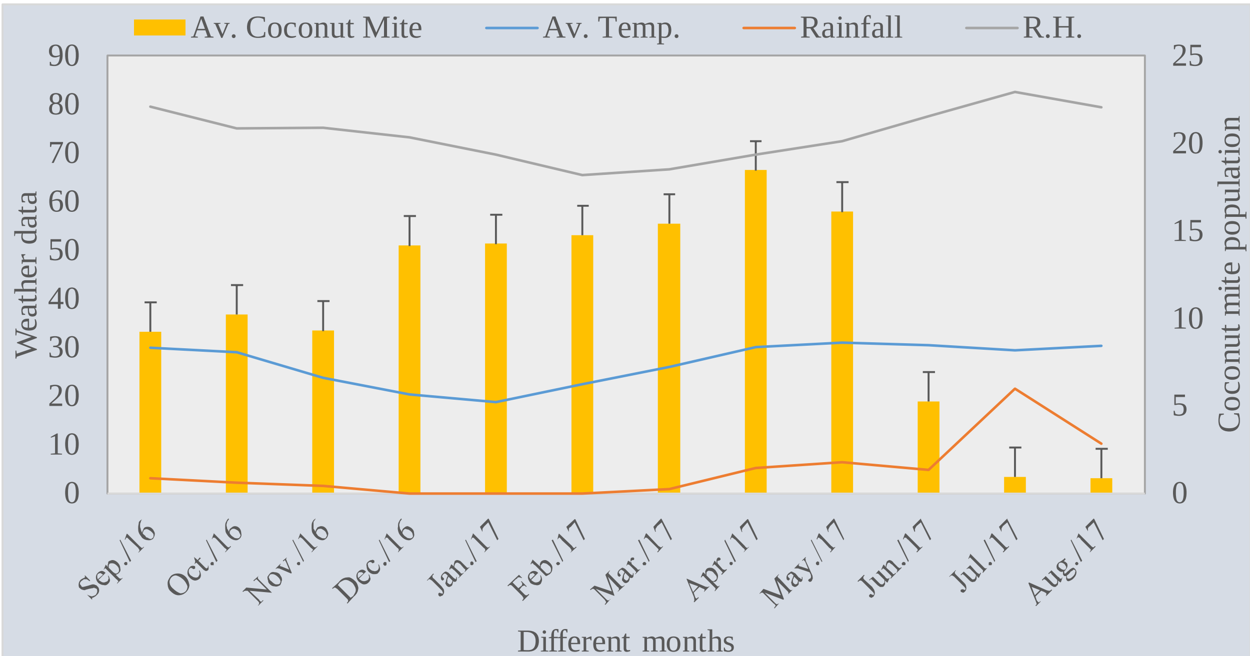

Figure 4.2.1. Population abundance of coconut mite with temperature, rainfall and relative humidity in Jashore region

4.2.6. Effect of weather factors on coconut mite population at Satkhira region

Weather factors like average temperature, rainfall and relative humidity had the significant effect on population dynamics of coconut mite in Satkhira region. From the figure 4.2.2. it is revealed that, the population of coconut mite was suppressed when the mean temperature, rainfall and relative humidity remained high in the month of June to August, 2017. When the rainfall became higher in the month of July, 2017 and August, 2017, then the population of coconut mite declined. But the lower rainfall in the month January, 2017, February, 2017 and March, 2017, caused raising the population of coconut mite. Again when the relative humidity became higher in the month of July and August, 2017, then the population of coconut mite reduced. And when the relative humidity became lower in the month of February, 2017, March, 2017 and April, 2017, then the population of coconut mite became high.

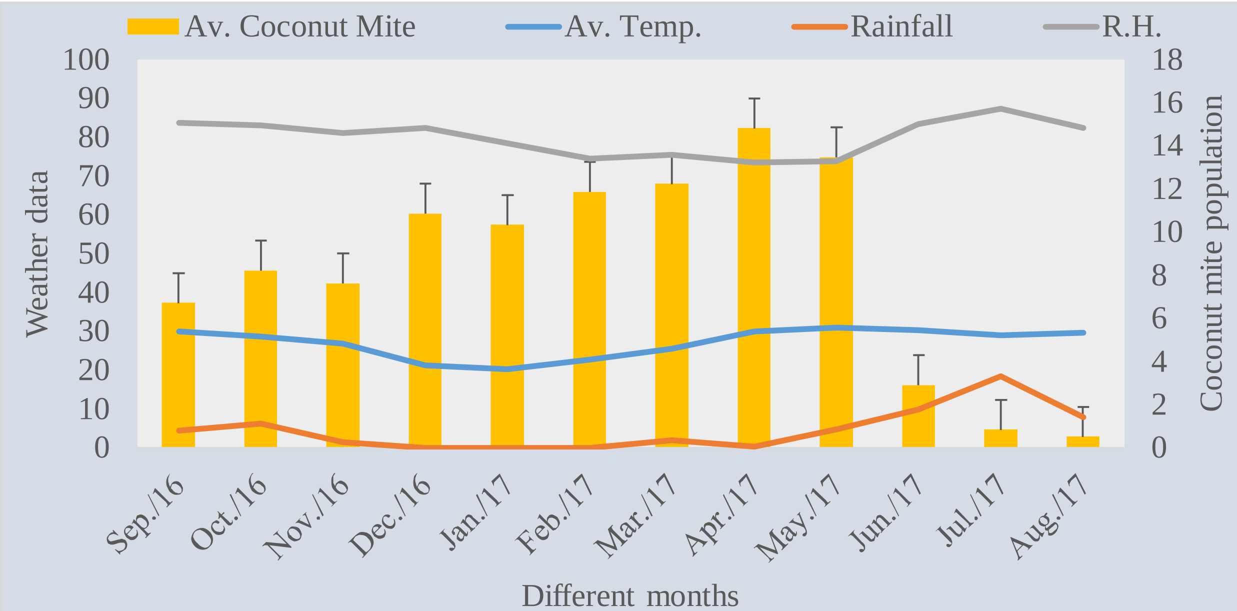

Figure 4.2.2. Population abundance of coconut mite with temperature, rainfall and relative humidity in Satkhira region

4.2.7. Effect of weather factors on coconut mite population at Barishal region

Weather factors like average temperature, rainfall and relative humidity had the significant effect on population dynamics of coconut mite in Barishal region. From the figure 4.2.3. it is revealed that, the population of coconut mite was suppressed when the mean temperature, rainfall and relative humidity remained high in the month of June to August, 2017. When the rainfall became higher in the month of July, 2017 and August, 2017, then the population of coconut mite declined. But the lower rainfall in the month January, 2017, February, 2017 and March, 2017, caused raising the population of coconut mite. Again when the relative humidity became higher in the month of July and August, 2017, then the population of coconut mite reduced. And when the relative humidity became lower in the month of February, 2017, March, 2017 and April, 2017, then the population of coconut mite became high.

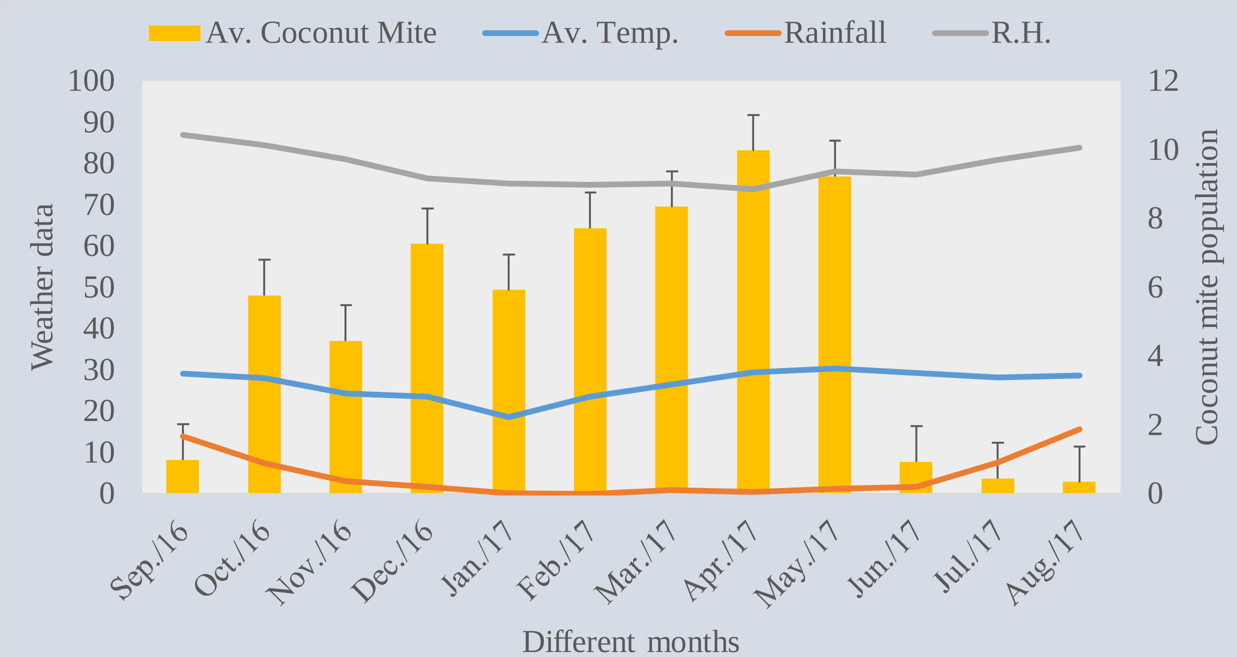

Figure 4.2.3. Population abundance of coconut mite with temperature, rainfall and relative humidity in Barishal region

4.2.8. Relationship between weather factors and coconut mite population at Bagerhat region

Weather factors like average temperature, rainfall and relative humidity had the significant effect on population dynamics of coconut mite in Bagerhat region. From the figure 4.2.4. it is revealed that, the population of coconut mite was suppressed when the mean temperature, rainfall and relative humidity remained high in the month of June to August, 2017. When the rainfall became higher in the month of July, 2017 and August, 2017, then the population of coconut mite declined. But the lower rainfall in the month January, 2017, February, 2017 and March, 2017, caused raising the population of coconut mite. Again when the relative humidity became higher in the month of July and August, 2017, then the population of coconut mite reduced. And when the relative humidity became lower in the month of February, 2017, March, 2017 and April, 2017, then the population of coconut mite became high.

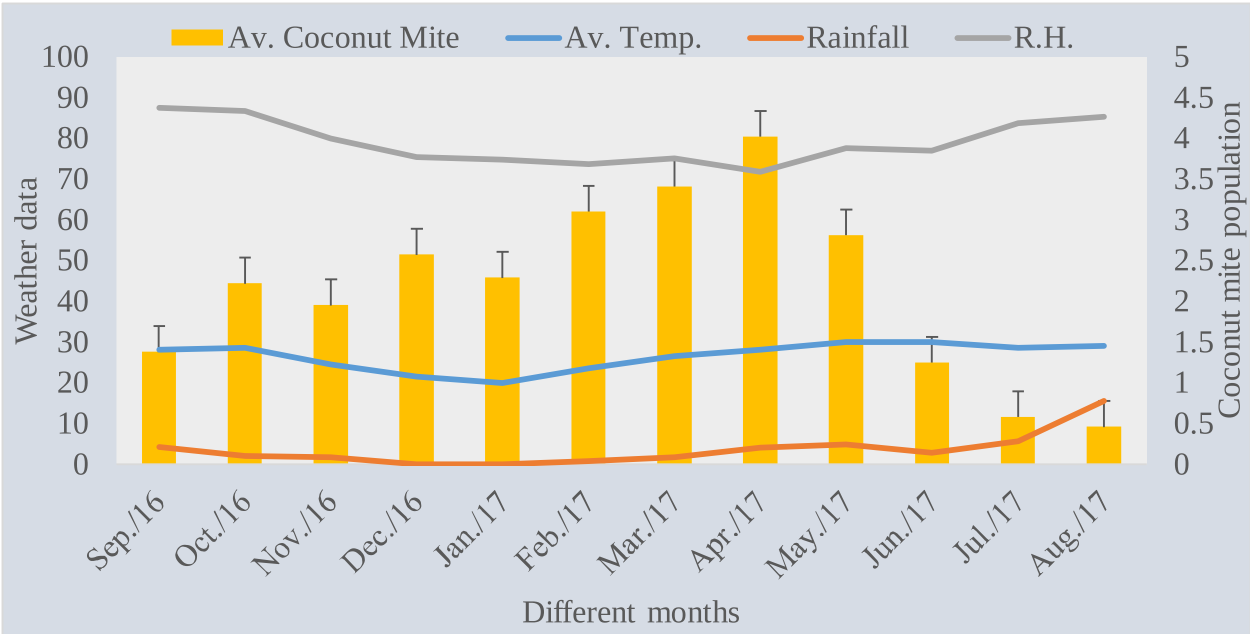

Figure 4.2.4. Population abundance of coconut mite with temperature, rainfall and relative humidity in Bagerhat region

Experiment 3: Damage assessment of coconut mites in major coconut growing regions of Bangladesh

This study was conducted during September, 2016 to August, 2017 in two upazilla from each of the four South-Western districts (Jassore, Satkhira, Barishal and Bagerhat) to identify the severity of the coconut mite infestation at these location in Bangladesh. For this study detail sub-headings are given bellow:

4.3.1. Coconut mite infestation in the month of September 2016

4.3.1.1. Coconut tree infestation

In the month of September, 2016, all observed coconut trees were infested by coconut mite in Jassore, Satkhira, Barishal and Bagerhat regions which is shown in the table 4.3.1. There was no significant difference among the infestation of coconut mite of different upazila of Jassore, Satkhira, Barishal and Bagerhat districts in Bangladesh.

Table 4.3.1. Coconut tree infestation by eriophyid mite in different coconut growing districts in September, 2016

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	5	5	100
	Bagherpara	5	5	100
District Average		5	5	100
Satkhira	Mongla	5	5	100
	Chitolmari	5	5	100
District Average		5	5	100
Barishal	Barishal Sadar	5	5	100
	Uzirpur	5	5	100
District Average		5	5	100
Bagherhat	Kolaroa	5	5	100
	Kaligonj	5	5	100
District Average		5	5	100
Grand Average		5	5	100

4.3.1.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented at table 4.3.2. From this table 4.3.2. it is revealed that, percentage of coconut nut infestation was highest at Jassore region (91.37%). In Jassore region, the percent infestation of coconut nut were 92.61% in Jassore Sadar and 90.12% Bagherpara upazila. In case of Satkhira region the percent of coconut mite infestation of coconut nut was 86.90%. In Satkhira region, the percent infestation of coconut nut were 89.47% in Mongla and 88.80% Chitolmari upazila. In case of Barishal region the percent of coconut mite infestation of coconut nut was 89.14%. In Barishal region, the percent infestation of coconut nut were 87.97% in Barishal Sadar and 85.83% Uzirpur upazila. In case of Bagerhat region the percent of coconut mite infestation of coconut nut was 82.43%. In Bagerhat region, the percent infestation of coconut nut were 84.21% in Kolaroa and 80.65% Kaligonj upazila. From the table 4.3.2. it is observed that, the nut infestation (87.46%) caused by coconut mite (eriophyid mite) in different coconut growing districts in South-West region of Bangladesh in the month of September, 2016.

Table 4.3.2. Nut infestation by eriophyid mite in different coconut growing districts in September, 2016

Districts	Upazila	Nut observed (%)	Mite infested nut (%)	Nut infestation (%)
Jassore	Jassore Sadar	176	163	92.61
	Bagherpara	81	73	90.12
District Average		128.5	118	91.37
Satkhira	Mongla	133	119	89.47
	Chitolmari	125	111	88.80
District Average		129	115	89.14
Barishal	Barishal Sadar	133	117	87.97
	Uzirpur	120	103	85.83
District Average		126.5	110	86.90
Bagherhat	Kolaroa	76	64	84.21
	Kaligonj	31	25	80.65
District Average		53.50	44.50	82.43
Grand Average		109.38	96.88	87.46

4.3.1.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.3.3. From the table 4.3.3. it is demonstrated that, in Jassore region in the month of September, 2016, coconut nut infestation by coconut mite at grade-5 was high (28.06%) and follows grade-4 (27.26%), grade-3 (21.82%), grade-2 (14.24%) and grade-1 (8.64%), where grade-1 represents non-infestation of coconut nut. In case of Satkhira region in the month of September, 2016, coconut nut infestation by coconut mite at grade-5 was high (29.63%) and follows grade-3 (27.60%), grade-4 (26.81%), grade-1 (10.87%) and grade-2 (5.11%). In case of Barishal region in the month of September, 2016, coconut nut infestation by coconut mite at grade-4 was high (31.84%) and follows grade-5 (31.67%), grade-3 (17.69%), grade-1 (13.10%) and grade-2 (5.72%). Again, in case of Bagerhat region in the month of September, 2016, coconut nut infestation by coconut mite at grade-2 was high (29.78%) and follows grade-4 (28.57%), grade-3 (21.16%), grade-1 (17.58%) and grade-5 (2.93%). In average, South-West region of Bangladesh in the month of September, 2016, coconut nut infestation by coconut mite at grade-4 was high (28.62%) and follows grade-5 (23.07%), grade-3 (22.07%), grade-2 (13.71%) and grade-2 (12.54%).

In terms of mean grading index in the month of September, 2016, Jassore region showed the high value 4.13 and follows Satkhira region was 3.64, Barisal region was 3.56, Bagerhat region was 3.05 and the South-West region of Bangladesh was 3.59.

Table 4.3.3. Damage index of eriophyid mite in different coconut growing districts in September, 2016

Districts	Upazila	G-1 (% infestation)	G-2 (% infestation)	G-3 (% infestation)	G-4 (% infestation)	G-5 (% infestation)	Mean grading index
Jassore	Jassore Sadar	7.39	6.25	16.48	33.52	36.36	4.16
	Bagherpara	9.88	22.22	27.16	20.99	19.75	4.09
District Average		8.64	14.24	21.82	27.26	28.06	4.13
Satkhira	Mongla	10.53	3.01	37.59	24.81	24.06	3.70
	Chitolmari	11.20	7.20	17.60	28.80	35.20	3.58
District Average		10.87	5.11	27.60	26.81	29.63	3.64
Barishal	Barishal Sadar	12.02	2.26	19.55	35.34	30.83	3.56
	Uzirpur	14.17	9.17	15.83	28.33	32.50	3.55
District Average		13.10	5.72	17.69	31.84	31.67	3.56
Bagherhat	Kolaroa	15.79	43.42	19.74	18.42	2.63	3.19
	Kaligonj	19.36	16.13	22.57	38.71	3.23	2.9
District Average		17.58	29.78	21.16	28.57	2.93	3.05
Grand Average		12.54	13.71	22.07	28.62	23.07	3.59

4.3.2. Coconut mite infestation in the month of December 2016

4.3.2.1. Coconut tree infestation

In the month of December, 2016, all observed coconut trees were infested by coconut mite in Jassore, Satkhira, Barishal and Bagerhat regions which is shown in the table 4.3.4. There was no significant difference among the infestation of coconut mite of different upazila of Jassore, Satkhira, Barishal and agerhat districts in Bangladesh.

Table 4.3.4. Coconut tree infestation by eriophyid mite in different coconut growing districts in December, 2016

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	5	5	100
	Bagherpara	5	5	100
District Average		5	5	100
Satkhira	Mongla	5	5	100
	Chitolmari	5	5	100
District Average		5	5	100
Barishal	Barishal Sadar	5	5	100
	Uzirpur	5	5	100
District Average		5	5	100
Bagherhat	Kolaroa	5	5	100
	Kaligonj	5	5	100
District Average		5	5	100
Grand Average		5	5	100

4.3.2.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented at table 4.3.5. From this table 4.3.5. it is revealed that, percentage of coconut nut infestation was high at Jassore region (95.33%). In Jassore region, the percent infestation of coconut nut were 95.42% in Jassore Sadar and 95.24% Bagherpara upazila. In case of Satkhira region, the percent of coconut mite infestation of coconut nut was 94.91%. In Satkhira region, the percent infestation of coconut nut were 95.08% in Mongla and 94.74% Chitolmari upazila. In case of Barishal region, the percent of coconut mite infestation of coconut nut was 94.13%. In Barishal region, the percent infestation of coconut nut were 94.23% in Barishal Sadar and 94.02% Uzirpur upazila. In case of Bagerhat region, the percent of coconut mite infestation of coconut nut was 93.04%. In Bagerhat region, the percent infestation of coconut nut were 93.40% in Kolaroa and 92.68% Kaligonj upazila.

From the table, it is observed that the nut infestation (94.35%) caused by coconut mite (eriophyid mite) in different coconut growing districts in South-West region of Bangladesh in the month of December, 2016.

Table 4.3.5. Nut infestation by eriophyid mite in different coconut growing districts in December, 2016

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	153	146	95.42
	Bagherpara	105	100	95.24
District Average		129	123	95.33
Satkhira	Mongla	61	58	95.08
	Chitolmari	171	162	94.74
District Average		116	110	94.91
Barishal	Barishal Sadar	156	147	94.23
	Uzirpur	117	110	94.02
District Average		136.5	128.5	94.13
Bagherhat	Kolaroa	106	99	93.40
	Kaligonj	123	114	92.68
District Average		114.5	106.5	93.04
Grand Average		124	117	94.35

4.3.2.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.3.6. From the table 4.3.6 it is revealed that, in Jassore region in the month of December, 2016, coconut nut infestation by coconut mite at grade-4 was high (30.66%) and follows grade-3 (27.12%), grade-5 (27.03%), grade-2 (10.53%) and grade-1 (4.67%), where grade-1 represents non-infestation of coconut nut. In case of Satkhira region in the month of December, 2016, coconut nut infestation by coconut mite at grade-5 was high (43.78%) and follows grade-4 (29.20%), grade-3 (18.84%), grade-1 (5.10%) and grade-2 (3.10%). In case of Barishal region in the month of December, 2016, coconut nut infestation by coconut mite at grade-4 was high (36.11%) and follows grade-5 (23.40%), grade-3 (22.87%), grade-2 (11.75%) and grade-1 (5.88%). Again, in case of Bagerhat region in the month of December, 2016, coconut nut infestation by coconut mite at grade-5 was high (36.46%) and follows grade-4 (30.72%), grade-3 (18.95%), grade-1 (6.96%) and grade-2 (6.91%). In average, South-West region of Bangladesh in the month of December, 2016, coconut nut infestation by coconut mite at grade-5 was high (32.67%) and follows grade-4 (31.67%), grade-3 (21.94%), grade-2 (8.07%) and grade-1 (5.65%). In terms of mean grading index in the month of December, 2016, Jassore region showed the high value 4.17 and follows Satkhira region 3.87, Barisal region 3.76, Bagerhat region 2.99 and the South-West region of Bangladesh 3.70.

Table 4.3.6. Damage index of eriophyid mite in different coconut growing districts in December, 2016

Districts	Upazila	G-1 (% infestation)	G-2 (% infestation)	G-3 (% infestation)	G-4 (% infestation)	G-5 (% infestation)	Mean grading index
Jassore	Jassore Sadar	4.58	14.38	31.37	24.18	25.49	4.18
	Bagherpara	4.76	6.67	22.86	37.14	28.57	4.15
District Average		4.67	10.53	27.12	30.66	27.03	4.17
Satkhira	Mongla	4.92	3.27	13.12	26.23	52.46	3.89
	Chitolmari	5.27	2.92	24.56	32.16	35.09	3.85
District Average		5.10	3.10	18.84	29.20	43.78	3.87
Barishal	Barishal Sadar	5.77	6.41	16.67	32.05	39.10	3.78
	Uzirpur	5.99	17.09	29.06	40.17	7.69	3.73
District Average		5.88	11.75	22.87	36.11	23.40	3.76
Bagherhat	Kolaroa	6.60	0.00	9.44	38.68	45.28	3.5
	Kaligonj	7.32	13.82	28.46	22.76	27.64	2.49
District Average		6.96	6.91	18.95	30.72	36.46	2.99
Grand Average		5.65	8.07	21.94	31.67	32.67	3.70

4.3.3. Coconut mite infestation in the month of March, 2017

4.3.3.1. Coconut tree infestation

In the month of March, 2017, all observed coconut trees were infested by coconut mite in Jassore, Satkhira, Barishal and Bagerhat regions which is shown in the table 4.3.7. There was no significant difference among the infestation of coconut mite of different upazila of Jassore, Satkhira, Barishal and Bagerhat districts in Bangladesh.

Table 4.3.7. Coconut tree infestation by eriophyid mite in different coconut growing districts in March, 2017

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	5	5	100
	Bagherpara	5	5	100
District Average		5	5	100
Satkhira	Mongla	5	5	100
	Chitolmari	5	5	100
District Average		5	5	100
Barishal	Barishal Sadar	5	5	100
	Uzirpur	5	5	100
District Average		5	5	100
Bagherhat	Kolaroa	5	5	100
	Kaligonj	5	5	100
District Average		5	5	100
Grand Average		5	5	100

4.3.3.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented at table 4.3.8. From this table 4.3.8. it is clear that, percentage of coconut nut infestation was high at Jassore region (99.40%). In Jassore region, the percent infestation of coconut nut were 100.00% in Jassore Sadar and 98.80% Bagherpara upazila. In case of Satkhira region, the percent of coconut mite infestation of coconut nut was 98.06%. In Satkhira region, the percent infestation of coconut nut were 98.11% in Mongla and 98.01% Chitolmari upazila. In case of Barishal region, the percent of coconut mite infestation of coconut nut was 97.01%. In Barishal region, the percent infestation of coconut nut were 97.91% in Barishal Sadar and 97.08% Uzirpur upazila. In case of Bagerhat region, the percent of coconut mite infestation of coconut nut was 96.83%. In Bagerhat region, the percent infestation of coconut nut were 97.06% in Kolaroa and 96.64% Kaligonj upazila.

From the table 4.3.8., it is observed that the nut infestation (97.95%) caused by coconut mite (Eriophyid mite) in different coconut growing districts in South-West region of Bangladesh in the month of March, 2017.

Table 4.3.8. Nut infestation by eriophyid mite in different coconut growing districts in March, 2017

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	157	157	100.00
	Bagherpara	167	165	98.80
District Average		162	161	99.40
Satkhira	Mongla	104	106	98.11
	Chitolmari	151	148	98.01
District Average		127.5	127	98.06
Barishal	Barishal Sadar	191	187	97.91
	Uzirpur	137	133	97.08
District Average		164	160	97.01
Bagherhat	Kolaroa	102	99	97.06
	Kaligonj	119	115	96.64
District Average		110.5	107	96.83
Grand Average		141	138.75	97.95

4.3.3.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data was presented into table 4.3.9. From the table 4.3.9., in Jassore region in the month of March, 2017, coconut nut infestation by coconut mite at grade-4 was high (36.85%) and follows grade-5 (34.40%), grade-3 (24.26%), grade-2 (3.89%) and grade-1 (0.61%), where grade-1 represents non-infestation of coconut nut. In case of Satkhira region in the month of March, 2017, coconut nut infestation by coconut mite at grade-4 was high (34.06%) and follows grade-5 (29.42%), grade-3 (28.63%), grade-2 (5.96%) and grade-1 (1.94%). In case of Barishal region in the month of March, 2017, coconut nut infestation by coconut mite at grade-4 was high (32.29%) and follows grade-5 (31.36%), grade-3 (24.09%), grade-2 (9.77%) and grade-1 (2.51%). Again, in case of Bagerhat region in the month of March, 2017, coconut nut infestation by coconut mite at grade-5 was high

(33.97%) and follows grade-4 (31.65%), grade-3 (24.44%), grade-2 (6.80%) and grade-1 (3.15%). In average, South-West region of Bangladesh in the month of March, 2017, coconut nut infestation by coconut mite at grade-4 was high (33.71%) and follows grade-5 (32.28%), grade-3 (25.35%), grade-2 (6.60%) and grade-1 (2.05%).

In terms of mean grading index in the month of March, 2017, Jassore region showed the high value 4.23 and follows Satkhira region 3.93, Barisal region 3.75, Bagerhat region 3.38 and the South-West region of Bangladesh 3.82.

Table 4.3.9. Damage index of eriophyid mite in different coconut growing districts in March, 2017

Districts	Upazila	G-1 (% infestation)	G-2 (% infestation)	G-3 (% infestation)	G-4 (% infestation)	G-5 (% infestation)	Mean grading index
Jassore	Jassore Sadar	0.00	0.00	20.38	40.77	38.85	4.27
	Bagherpara	1.21	7.78	28.14	32.93	29.94	4.19
District Average		0.61	3.89	24.26	36.85	34.40	4.23
Satkhira	Mongla	1.89	0.00	25.47	33.02	39.62	4.03
	Chitolmari	1.98	11.92	31.79	35.10	19.21	3.83
District Average		1.94	5.96	28.63	34.06	29.42	3.93
Barishal	Barishal Sadar	2.09	7.85	24.08	32.46	33.52	3.79
	Uzirpur	2.92	11.68	24.09	32.12	29.19	3.71
District Average		2.51	9.77	24.09	32.29	31.36	3.75
Bagherhat	Kolaroa	2.94	6.87	30.39	37.25	22.55	3.49
	Kaligonj	3.36	6.72	18.49	26.05	45.38	3.27
District Average		3.15	6.80	24.44	31.65	33.97	3.38
Grand Average		2.05	6.60	25.35	33.71	32.28	3.82

4.3.4. Coconut mite infestation in the month of June, 2017

4.3.4.1. Coconut tree infestation

In the month of June, 2017, all observed coconut trees were infested by coconut mite in Jashore, Satkhira, Barishal and Bagerhat regions which was shown in the table 4.3.10. There was no significant difference among the infestation of coconut mite of different upazila of Jassore, Satkhira, Barishal and agerhat districts in Bangladesh.

Table 4.3.10. Coconut tree infestation by eriophyid mite in different coconut growing districts in June, 2017

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	5	5	100
	Bagherpara	5	5	100
District Average		5	5	100
Satkhira	Mongla	5	5	100
	Chitolmari	5	5	100
District Average		5	5	100
Barishal	Barishal Sadar	5	5	100
	Uzirpur	5	5	100
District Average		5	5	100
Bagherhat	Kolaroa	5	5	100
	Kaligonj	5	5	100
District Average		5	5	100
Grand Average		5	5	100

4.3.4.2. Coconut nut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented at table 4.3.11. From this table it is revealed that, percentage of coconut nut infestation was high at Jassore region (100.00%). In Jassore region, the percent infestation of coconut nut were 100.00% in Jassore Sadar and 100.00% Bagherpara upazila. In case of Satkhira region, the percent of coconut mite infestation of coconut nut was 99.32%. In Satkhira region, the percent infestation of coconut nut were 99.34% in Mongla and 99.30% Chitolmari upazila. In case of Barishal region, the percent of coconut mite infestation of coconut nut was 98.29%. In Barishal region, the percent infestation of coconut nut were 98.33% in Barishal Sadar and 98.24% Uzirpur upazila. In case of Bagerhat region, the percent of coconut mite infestation of coconut nut was 98.02%. In Bagerhat region, the percent infestation of coconut nut were 98.23% in Kolaroa and 97.81% Kaligonj upazila.

From the table, it is observed that the nut infestation (98.90%) caused by coconut mite (Eriophyid mite) in different coconut growing districts in South-West region of Bangladesh in the month of June, 2017.

Table 4.3.11. Nut infestation by eriophyid mite in different coconut growing districts in June, 2017

Districts	Upazila	Tree observed (No.)	Mite infested tree (No.)	Tree infestation (%)
Jassore	Jassore Sadar	91	91	100.00
	Bagherpara	77	77	100.00
District Average		84	84	100.00
Satkhira	Mongla	152	151	99.34
	Chitolmari	142	141	99.30
District Average		147	146	99.32
Barishal	Barishal Sadar	120	118	98.33
	Uzirpur	170	167	98.24
District Average		145	142.5	98.29
Bagherhat	Kolaroa	113	111	98.23
	Kaligonj	137	134	97.81
District Average		125	122.5	98.02
Grand Average		125.25	123.75	98.90

4.3.4.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.3.12. From the table it is clear that, in Jassore region in the month of June, 2017, coconut nut infestation by coconut mite at grade-4 was high (34.02%) and follows grade-3 (32.82%), grade-5 (25.98%), grade-2 (7.19%) and grade-1 (0.00%), where grade-1 represents non-infestation of coconut nut. In case of Satkhira region in the month of June, 2017, coconut nut infestation by coconut mite at grade-5 was high (53.50%) and follows grade-4 (26.54%), grade-3 (15.67%), grade-2 (3.62%) and grade-1 (0.70%). In case of Barishal region in the month of June, 2017, coconut nut infestation by coconut mite at grade-5 was high (47.97%) and follows grade-4 (27.48%), grade-3 (13.12%), grade-2 (9.73%) and grade-1 (1.72%). Again, in case of Bagerhat region in the month of June, 2017, coconut nut infestation by coconut mite at grade-5 was high

(50.96%) and follows grade-4 (27.56%), grade-3 (15.03%), grade-2 (4.48%) and grade-1 (1.98%). In average, South-West region of Bangladesh in the month of June, 2017, coconut nut infestation by coconut mite at grade-5 was high (44.60%) and follows grade-4 (28.90%), grade-3 (19.16%), grade-2 (6.26%) and grade-1 (1.09%).

In terms of mean grading index in the month of June, 2017, Jassore region showed the high value 4.40 and follows Satkhira region 4.11, Barisal region 3.89, Bagerhat region 3.61 and the South-West region of Bangladesh 4.00.

Table 4.3.12. Damage index of eriophyid mite in different coconut growing districts in June, 2017

Districts	Upazila	G-1 (% infestation)	G-2 (% infestation)	G-3 (% infestation)	G-4 (% infestation)	G-5 (% infestation)	Mean grading index
Jassore	Jassore Sadar	0.00	6.59	46.15	32.97	14.29	4.42
	Bagherpara	0.00	7.79	19.48	35.06	37.67	4.38
District Average		0.00	7.19	32.82	34.02	25.98	4.40
Satkhira	Mongla	0.65	7.24	15.13	26.32	50.66	4.18
	Chitolmari	0.70	0.00	16.20	26.76	56.34	4.03
District Average		0.68	3.62	15.67	26.54	53.50	4.11
Barishal	Barishal Sadar	1.66	4.17	9.17	20.83	64.17	3.92
	Uzirpur	1.77	15.29	17.06	34.12	31.76	3.87
District Average		1.72	9.73	13.12	27.48	47.97	3.89
Bagherhat	Kolaroa	1.77	5.31	13.27	35.40	44.25	3.70
	Kaligonj	2.19	3.65	16.79	19.71	57.66	3.52
District Average		1.98	4.48	15.03	27.56	50.96	3.61
Grand Average		1.09	6.26	19.16	28.90	44.60	4.00

4.3.5. Relationship between weather factors and mean grading index (MGI)

4.3.5.1. Relationship between weather factors and MGI of South-West region of Bangladesh

Relationship between weather factors like average temperature, rainfall and relative humidity and mean grading index of four districts of South-West region of Bangladesh like Jassore, Satkhira, Barishal and Bagerhat is shown in figure 4.3.1. From the figure, it is observed that, the mean grading index was gradually increased from the month September, 2016 to June, 2017. Here it clearly demonstrated that, rainfall had negative effect on mean grading index i.e. when the rainfall became high then mean grading index became low. From the figure, rainfall was increased after the month June, 2017 and decrease at the month of December, 2016. At that time, the mean grading index remained high at the month of June, 2017 and after the rainy season it became low at the month of September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. We can conclud that, the mean grading index became low after rainy season and increased at winter season.

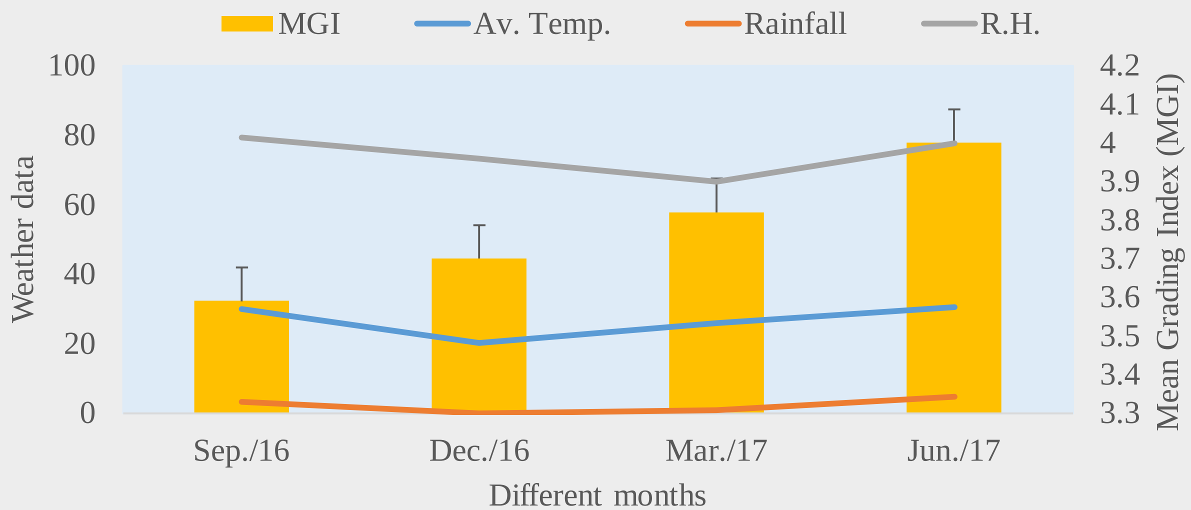

Figure 4.3.1. Relationship between weather factors and MGI of South-West region of Bangladesh

4.3.5.2. Relationship between weather factors and MGI of Jassore region

Relationship between weather factors like average temperature, rainfall and relative humidity and mean grading index of Jassore region is shown in figure 4.3.2. From the figure it is observed that, the mean grading index was gradually increased from the month September, 2016 to June, 2017. Here it clearly demostrated that, rainfall had negative effect on mean grading index i.e. when the rainfall became high then mean grading index became low. From the figure, rainfall was increased after the month June, 2017 and decreased at the month of December, 2016. At that time, the mean grading index remained high at the month June, 2017 and after the rainy season it became low at the month September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. We can conclud that, the mean grading index became low after rainy season and increased at winter season.

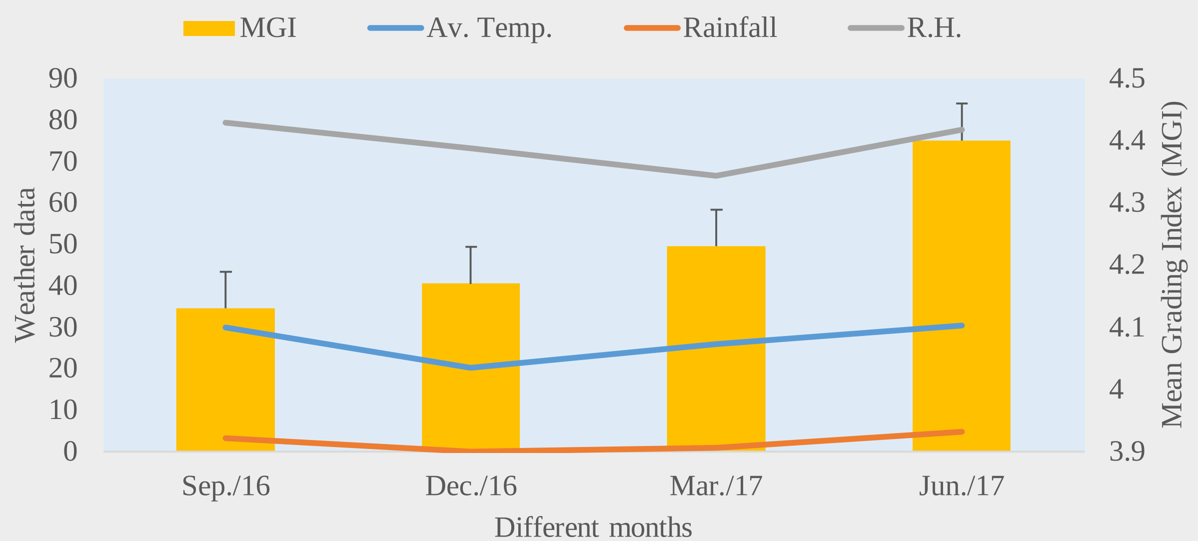

Figure 4.3.2. Relationship between weather factors and MGI of Jeshore region

4.3.5.3. Relationship between weather factors and MGI of Satkhira region

Relationship between weather factors like average temperature, rainfall and relative humidity and mean grading index of Satkhira region is shown in figure 4.3.3. From the figure it is observed that, the mean grading index was gradually increased from the month September, 2016 to June, 2017. Here it clearly revealed that, rainfall had negative effect on mean grading index i.e. when the rainfall became high then mean grading index became low. From the figure, rainfall was increased after the month June, 2017 and decreased at the month of December, 2016. At that time, the mean grading index remained high at the month June, 2017 and after the rainy season it became low at the month September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. We can conclud that, the mean grading index became low after rainy season and increased at winter season.

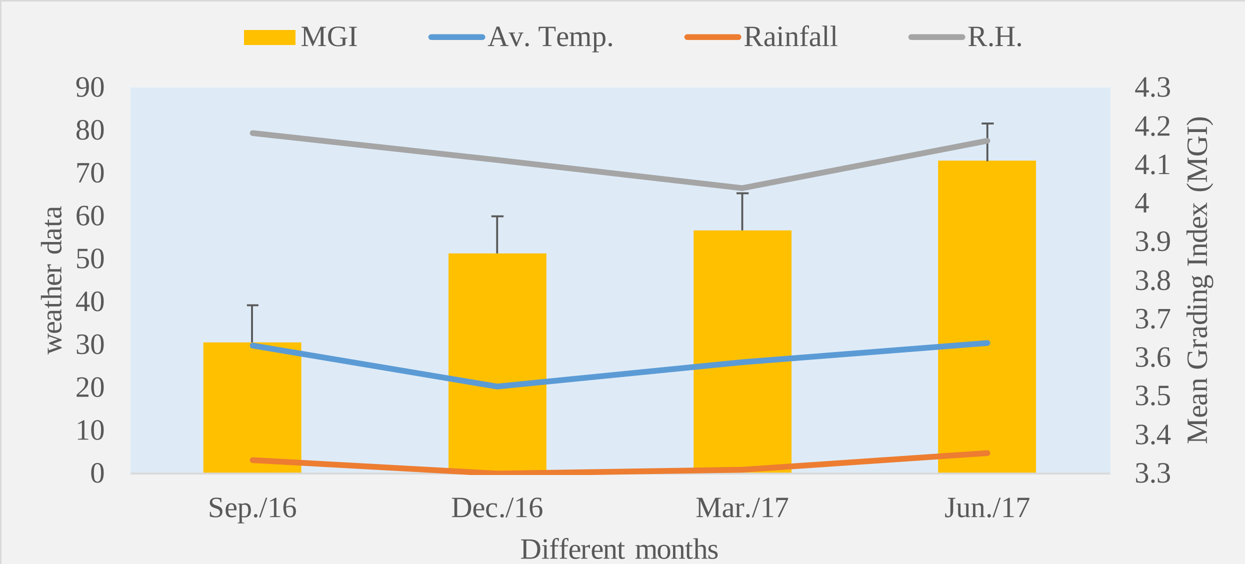

Figure 4.3.3 Relationship between weather factors and MGI of Satkhira region

4.3.5.4. Relationship between weather factors and MGI of Barishal region

Relationship between weather factors like average temperature, rainfall and relative humidity and mean grading index of Barishal region is shown in figure 4.3.4. From the figure it is observed that, the mean grading index was gradually increased from the month September, 2016 to June, 2017. Here it clearly revealed that, rainfall had negative effect on mean grading index i.e. when the rainfall became high then mean grading index became low. From the figure, rainfall was increased after the month June, 2017 and decreased at the month of December, 2016. At that time, the mean grading index remain high at the month June, 2017 and after the rainy season it became low at the month September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. We can conclude that, the mean grading index became low after rainy season and increased at winter season.

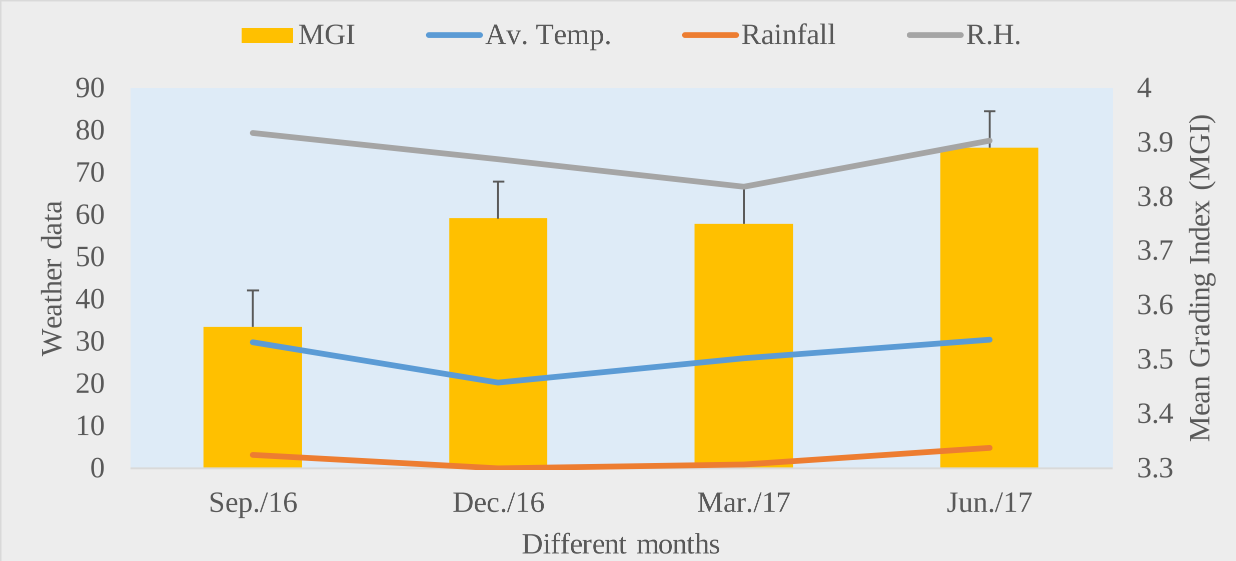

Figure 4.3.4. Relationship between weather factors and MGI of Barisal region

4.3.5.5. Relationship between weather factors and MGI of Bagerhat region

Relationship between weather factors like average temperature, rainfall and relative humidity and mean grading index of Bagerhat region is shown in figure 4.3.5. From the figure it is observed that, the mean grading index was gradually increased from the month September, 2016 to June, 2017. Here it clearly demonstrated that, rainfall had negative effect on mean grading index i.e. when the rainfall became high then mean grading index became low. From the figure, rainfall was increased after the month June, 2017 and decreased at the month of December, 2016. At that time, the mean grading index remained high at the month June, 2017 and after the rainy season it became low at the month September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. We can conclud that, the mean grading index became low after rainy season and increased at winter season.

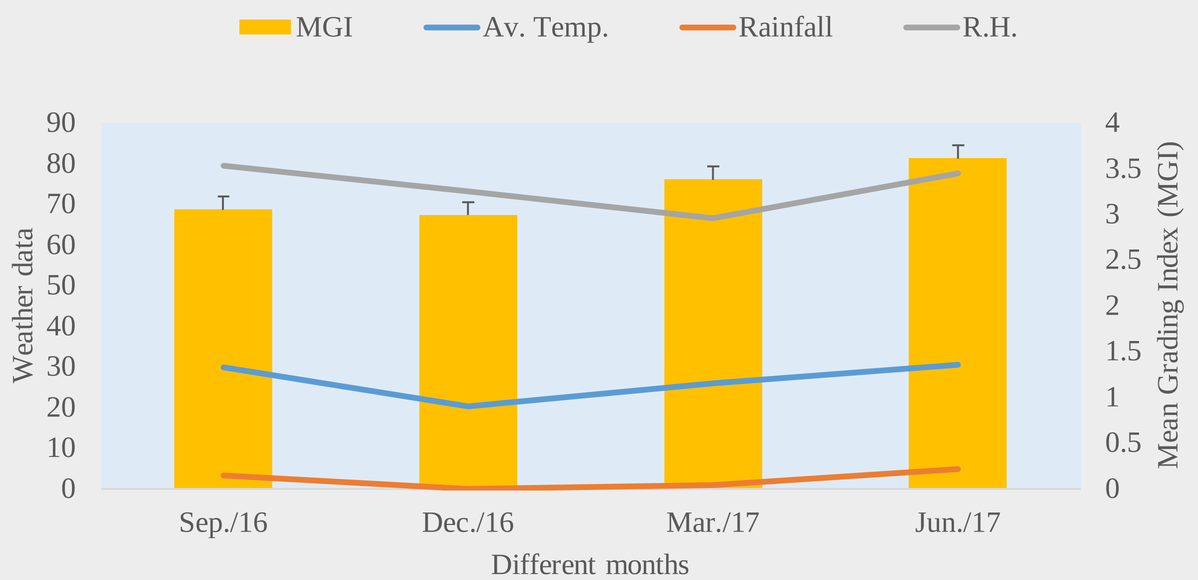

Figure 4.3.5. Relationship between weather factors and MGI of Bagerhat region

Experiment 4: Test on the action of chemical pesticides against coconut mites in laboratory condition

This study was conducted during February to March 2017 in the laboratory under Entomology Division of RARS, BARI, Jassore as well as in the laboratory under the Department of Entomology, SAU, Dhaka to determine the bioassay of chemical pesticides against coconut mites. For this study detail sub-headings are given bellow:

4.4.1. Test of chemical pesticide at laboratory condition

4.4.1.1. Coconut mite mortality rate at 12 hours after treatment application

There was significant variation among the treatments on the percentage of mortality of coconut mite at 12 hours after application, which is shown in table 4.4.1. From the table 4.4.1., it reveals that, the highest mortality percent was 100.00 % at T_3 (comprised of Intrepid 10SC @ 4ml/L of water) which was statistically similar with T_6 (98.24 %) and the neat higher mortality in followed by the mortality decreased in T_9 (88.47 %), T_2 (88.06 %), T_8 (85.36 %), T_5 (84.94 %), T_{20} (74.29 %), T_{15} (74.16 %), T_{12} (65.51 %), T_{21} (63.55 %), T_7 (53.67 %), T_{24} (34.08 %), T_{18} (27.43 %), T_4 (27.07 %), T_{23} (26.49 %), T_{11} (24.75 %), T_{22} (22.49 %), T_{27} (16.62 %), T_{14} (15.20 %), T_1 (14.84 %), T_{30} (13.92 %) and T_{17} (12.50 %), respectively. On the other hand, the lowest mortality percentage was recorded 0.00 % at T_{31} (untreated control) which was statistically similar with T_{25} (0.32 %), T_{16} (1.07 %) and T_{28} (2.23 %) and followed by T_{29} (3.97 %), T_{13} (4.52 %), T_{19} (7.24 %), T_{10} (8.09 %) and T_{26} (11.38 %), respectively.

In case of percent mortality increase over control, T_3 showed the best result (100.00 %), which was higher than all other treatments at 12 hours after treatment application. So from this table 4.4.1, we can conclude that T_3 (Intrepid 10SC @ 4ml/L of water) was the best treatment which can kill mite within 12 hours after application. Sujatha *et al.* 2003; Muthiah *et al.* 2001 and other researchers also agree with this present study by their previous research trail with different pesticides.

Table 4.4.1. Percent mortality of coconut mite at 12 hours after application of pesticides

Treatments	Number of live mite/4mm^2 nut surface	Number of dead mite/4mm^2 nut surface	Number of total mite/4mm^2 nut surface	% mortality	% mortality increases over control
T_1	21	3.75	24.75	14.84 jkl	14.84
T_2	5	38.75	43.75	88.06 bc	88.06
T_3	0	21.75	21.75	100.00 a	100.00
T_4	77	30.75	107.75	27.07 h	27.07
T_5	4	22.75	26.75	84.94 c	84.94
T_6	0.75	32.5	33.25	98.24 a	98.24
T_7	9.75	11.75	21.5	53.67 f	53.67
T_8	6	35.25	41.25	85.36 bc	85.36
T_9	3	23.75	26.75	88.47 b	88.47
T_{10}	98.5	8.5	107	8.09 m	8.09
T_{11}	58.5	19	77.5	24.75 hi	24.75
T_{12}	24.75	49	73.75	65.51 e	65.51
T_{13}	50	2.25	52.25	4.52 no	4.52
T_{14}	31.5	5.75	37.25	15.20 jk	15.20
T_{15}	16.5	47.25	63.75	74.16 d	74.16
T_{16}	56	0.75	56.75	1.07 op	1.07
T_{17}	46	7	53	12.50 kl	12.50
T_{18}	32	12	44	27.43 h	27.43
T_{19}	37	2.75	39.75	7.24 mn	7.24
T_{20}	33	94.5	127.5	74.29 d	74.29
T_{21}	20	34.5	54.5	63.55 e	63.55
T_{22}	41	11.75	52.75	22.49 i	22.49
T_{23}	35.25	12.5	47.75	26.49 h	26.49
T_{24}	60.5	31.25	91.75	34.08 g	34.08
T_{25}	65	0.25	65.25	0.32 p	0.32
T_{26}	42	5.5	47.5	11.38 l	11.38
T_{27}	110.25	22.25	132.5	16.62 j	16.62
T_{28}	18	0.5	18.5	2.23 op	2.23
T_{29}	35.5	1.5	37	3.97 no	3.97
T_{30}	42.25	6.75	49	13.92 jkl	13.92
T_{31}	25	0	25	0.00 p	-
CV	-	-	-	6.29	-
LSD	-	-	-	3.21	-

4.4.1.2. Coconut mite mortality rate at 24 hours after treatment application

There was significant variation among the treatments on the percentage of mortality rate of coconut mite at 24 hours after application, which is shown in table 4.4.2. From the table 4.4.2., it is clear that, the highest mortality percent was 100.00 % at T_3 (comprised on Intrepid 10SC @ 4ml/L of water) which was statistically similar with T_8 (97.21 %), T_9 (96.97 %), T_6 (96.30 %) and T_{12} (95.91 %) and the neat higher mortality in followed by the mortality decreased in T_2 (89.11 %), T_7 (85.42 %), T_{21} (82.79 %), T_{11} (82.31 %), T_5 (81.07 %), T_4 (80.58 %), T_{24} (78.00 %), T_{20} (77.38 %), T_{15} (71.64 %), T_{18} (68.01 %), T_{23} (58.45 %), T_{22} (53.38 %), T_{27} (41.74 %), T_{14} (41.31 %), T_1 (38.62 %), T_{30} (37.59 %), T_{17} (36.76 %), T_{26} (35.11 %) and T_{10} (34.35 %), respectively. On the other hand, the lowest mortality percentage was recorded 0.00 % at T_{31} (untreated control) which was statistically similar with T_{25} (6.82 %) and T_{16} (7.78 %) and followed by T_{28} (9.58 %) T_{29} (13.98 %), T_{13} (31.15 %) and T_{19} (32.00), respectively.

In case of percent mortality increase over control, T_3 showed the best result (100.00 %), which was higher than all other treatments at 24 hours after treatment application. So from this table 4.4.2., we can conclude that T_3 (Intrepid 10SC @ 4ml/L of water) was the best treatment which can kill mite within 24 hours after application. Pushpa and Nandihalli (2010); Muthiah *et al.* (2001) and other researchers also agree with this present study by their previous research trail with different pesticides.

Table 4.4.2. Percent mortality of coconut mite at 24 hours after application of pesticides

Treatments	Number of live mite/4mm^2 nut surface	Number of dead mite/4mm^2 nut surface	Number of total mite/4mm^2 nut surface	% mortality	% mortality increases over control
T_1	59.75	33.75	97.5	38.62 hi	38.62
T_2	4.75	38.25	43	89.11 bc	89.11
T_3	0	74.75	74.75	100.00 a	100.00
T_4	7.25	30	37.25	80.58 d	80.58
T_5	7.75	29.5	37.25	81.07 cd	81.07
T_6	1	39.5	40.5	96.30 ab	96.30
T_7	10.75	62.5	73.25	85.42 cd	85.42
T_8	1	34	35	97.21 ab	97.21
T_9	1.75	53.75	55.5	96.97 ab	96.97
T_{10}	24	12.5	36.5	34.35 hi	34.35
T_{11}	13	42	55	82.31 cd	82.31
T_{12}	2.25	43.5	45.75	95.91 ab	95.91
T_{13}	49.75	22.25	72	31.15 i	31.15
T_{14}	39.5	28.25	67.75	41.31 h	41.31
T_{15}	18.25	46.25	64.5	71.64 ef	71.64
T_{16}	68	5.75	73.75	7.78 jk	7.78
T_{17}	29.5	17.25	46.75	36.76 hi	36.76
T_{18}	34.5	73.75	108.25	68.01 f	68.01
T_{19}	46.5	22	68.5	32.00 i	32.00
T_{20}	32	107.5	139.5	77.38 de	77.38
T_{21}	3.5	26	29.5	82.79 cd	82.79
T_{22}	36	41	77	53.38 g	53.38
T_{23}	15	21.25	36.25	58.45 g	58.45
T_{24}	21.75	76.75	98.5	78.00 de	78.00
T_{25}	48.25	3.75	52	6.82 jk	6.82
T_{26}	43.25	23.25	66.5	35.11 hi	35.11
T_{27}	65.5	48.25	113.75	41.74 h	41.74
T_{28}	76.75	7.75	84.5	9.58 j	9.58
T_{29}	68	10.75	78.75	13.98 j	13.98
T_{30}	56.5	34.25	90.75	37.59 hi	37.59
T_{31}	35.5	0	35.5	0.00 k	0.00
CV	-	-	-	9.66	-
LSD	-	-	-	7.42	-

4.4.1.3. Coconut mite mortality rate at 36 hours after treatment application

There was significant variation among the treatments on the percentage of mortality rate of coconut mite at 36 hours after application, which is shown in table 4.4.3. From the table 4.4.3., it is revealed that, the highest mortality percent was 100.00 % at T_3 (Intrepid 10SC @ 4ml/L of water) which was statistically similar with T_6 (96.53 %) and T_9 (96.01 %), and the neat higher mortality followed by the mortality decreased in T_2 (93.18 %), T_8 (91.65 %), T_5 (88.90 %), T_{20} (86.10 %), T_{15} (85.56 %), T_{12} (83.61 %), T_{21} (81.50 %), T_7 (79.57 %), T_{24} (78.67 %), T_{18} (77.45 %), T_4 (72.40 %), T_{23} (71.29 %), T_{11} (70.24 %), T_{22} (66.55 %), T_{27} (65.37 %), T_{14} (61.67 %) and T_1 (60.87 %), respectively. On the other hand, the lowest mortality percentage was recorded 0.00 % at T_{31} (untreated control) which was statistically different from other treatments and followed by T_{25} (7.65 %), T_{16} (26.40 %), T_{28} (28.36 %), T_{29} (31.59 %), T_{13} (32.67 %), T_{19} (40.81 %), T_{10} (42.38 %), T_{26} (54.40 %), T_{17} (56.80 %) and T_{30} (58.11), respectively.

In case of percent mortality percentage increase over control, T_3 showed the best result (100.00 %), which was higher than all other treatments at 36 hours after treatment application. So from this table 4.4.3., we can concluded that T_3 (Intrepid 10SC @ 4ml/L of water) was the best treatment which can kill mite within 36 hours after application. Pushpa and Nandihalli (2010); Sujatha *et al.* 2003 and other researchers also agree with this present study by their previous research trail with different pesticides.

Table 4.4.3: Percent mortality of coconut mite at 36 hours after application of pesticides

Treatments	Number of live mite/4mm^2 nut surface	Number of dead mite/4mm^2 nut surface	Number of total mite/4mm^2 nut surface	% mortality	% mortality increases over control
T_1	33.25	52.25	85.5	60.87 lmn	60.87
T_2	8.75	115.75	124.5	93.18 bcd	93.18
T_3	0	26.5	26.5	100.00 a	100.00
T_4	28.75	72.25	101	72.40 i	72.40
T_5	5.25	43.25	48.5	88.90 de	88.90
T_6	3.25	91.5	94.75	96.53 ab	96.53
T_7	6.75	31	37.75	79.57 gh	79.57
T_8	8	79.25	87.25	91.65 cd	91.65
T_9	3.75	90	93.75	96.01 abc	96.01
T_{10}	47	34.5	81.5	42.38 p	42.38
T_{11}	14.5	36.5	51	70.24 ij	70.24
T_{12}	4.5	22.75	27.25	83.61 fg	83.61
T_{13}	70.5	34	104.5	32.67 q	32.67
T_{14}	22.5	36.5	59	61.67 lm	61.67
T_{15}	3	17.75	20.75	85.56 ef	85.56
T_{16}	75.75	27.25	103	26.40 r	26.40
T_{17}	46.75	61.75	108.5	56.80 no	56.80
T_{18}	21	66.75	87.75	77.45 h	77.45
T_{19}	70.25	48.75	119	40.81 p	40.81
T_{20}	18.5	97.25	115.75	86.10 ef	86.10
T_{21}	20.25	89	109.25	81.50 fgh	81.50
T_{22}	46.25	91.25	137.5	66.55 jk	66.55
T_{23}	18	43	61	71.29 i	71.29
T_{24}	14.5	52.75	67.25	78.67 h	78.67
T_{25}	70	4.25	74.25	7.65 s	7.65
T_{26}	60.5	72.25	132.75	54.40 o	54.40
T_{27}	35	67.75	102.75	65.37 kl	65.37
T_{28}	75.75	30.25	106	28.36 qr	28.36
T_{29}	115.75	54	169.75	31.59 q	31.59
T_{30}	22.5	31	53.5	58.11 mno	58.11
T_{31}	30.5	0	30.5	0.00 t	0.00
CV	-	-	-	4.85	-
LSD	-	-	-	4.33	-

4.4.2. Comparison of treatment performance after 12, 24 and 36 hours duration of application

Different treatments were applied on coconut for controlling coconut mite and percent mortality was recorded at 12 hours, 24 hours and 36 hours after treatment application. There was significant variation among the treatments. In the figure 4.4.1., all treatments of 12 hours after treatment application showed the lowest performance for controlling of coconut mite. And, all treatments of 36 hours after treatment application showed the best performance for controlling of coconut mite. So, from the figure, we can conclude that if we apply treatments against coconut mite then the best result will come after 36 hours after treatment application.

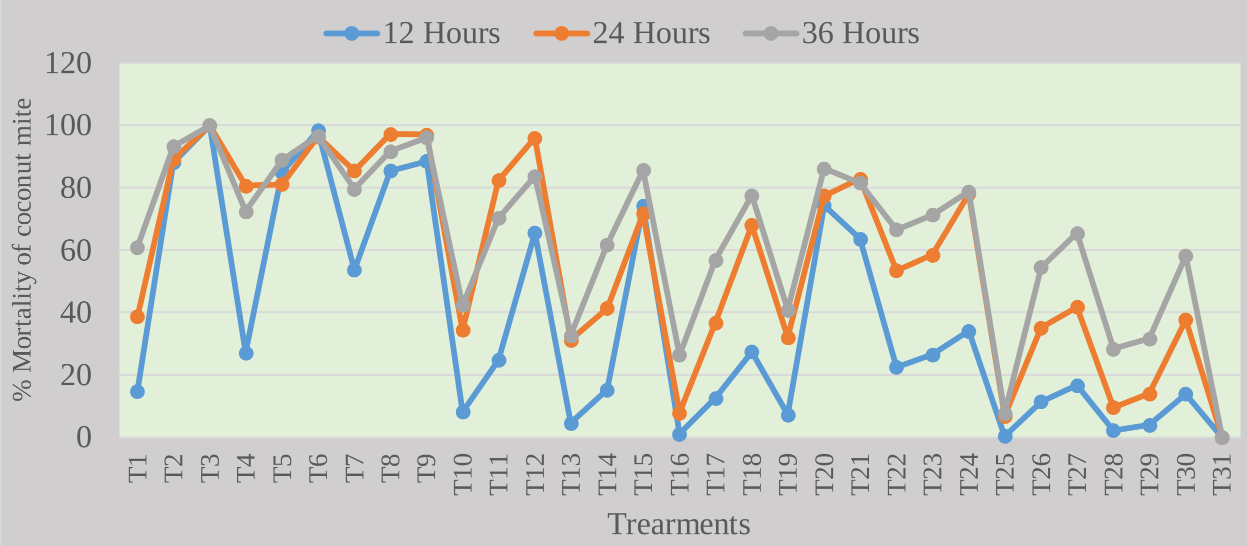

Figure 4.4.1. Percent mortality of coconut mite at 12, 24 and 36 hr after application of pesticides

4.4.3. Yield attributes

4.4.3.1. Size of coconut nut

From the table 4.4.4., the length of coconut nut was 26.82±8.25 cm for Grade-1 infested coconut nut, 24.32±11.39 cm for Grade-2 infested coconut nut, 23.83±9.71 cm for Grade-3 infested coconut nut, 23.32±9.47 cm for Grade-4 infested coconut nut and 22.23±6.91 cm for Grade-5 infested coconut nut.

The width of coconut nut was 50.4±15.53 cm for Grade-1 infested coconut nut, 47.84±22.41 cm for Grade-2 infested coconut nut, 47.39±19.48 cm for Grade-3 infested coconut nut, 44.32±18.81 cm for Grade-4 infested coconut nut and 42.99±14.17 cm for Grade-5 infested coconut nut.

4.4.3.3. Weight of coconut nut

From the table 4.4.4., the weight of coconut nut was 1.51±0.53 Kg for Grade-1 infested coconut nut, 1.25±0.63 Kg for Grade-2 infested coconut nut, 1.24±0.57 Kg for Grade-3 infested coconut nut, 1.17±0.54 Kg for Grade-4 infested coconut nut and 1.01±0.44 Kg for Grade-5 infested coconut nut.

Table 4.4.4. Effect of mite infestation on length, width and weight of coconut nut

Grade	Length of coconut nut (cm)			Width of coconut nut (cm)			Weight of coconut nut (Kg)		
	Max.	Min.	Mean±SD.	Max.	Min.	Mean±SD.	Max.	Min.	Mean±SD.
G-1	30.2	24.4	26.82±8.25	57.4	46.5	50.4±15.53	2.02	1.11	1.51±0.53
G-2	25.8	22.6	24.32±11.39	53.5	45.5	47.84±22.41	1.67	0.94	1.25±0.63
G-3	25.5	22.1	23.83±9.71	51.5	41.7	47.39±19.48	1.57	0.66	1.24±0.57
G-4	24.6	21.5	23.32±9.47	49.7	28.5	44.32±18.81	1.52	0.65	1.17±0.54
G-5	24.5	18.6	22.23±6.91	47.8	27.4	42.99±14.17	1.49	0.61	1.01±0.44

Experiment 5: Development of suitable IPM package for management of coconut mites in Bangladesh

This study was conducted during January to December 2017 in the coconut orchard under the Division of Entomology, RARS, BARI, Jassore to develop an IPM package for the management of coconut mites in field condition. For this study details of sub-headings are given bellow:

4.5.1. Coconut mite infestation in 2 months after treatment

4.5.1.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.1. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments after 2 months.

Table 4.5.1. Tree infestation by eriophyid mite in Jassore district at 2 months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.1.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data are represented in table 4.5.2. From this table 4.5.2., it is revealed that, percentage of coconut nut infestation was low (75.00 %) in P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which is statistically different from other treatment packages and followed by P_2 (79.55

%), P_5 (80.85 %), P_3 (82.50 %), P_7 (84.62 %), P_1 (85.45 %) and P_{10} (85.71 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which is statistically different from others and followed by P_6 (91.30 %), P_8 (90.91 %) and P_9 (86.54 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results were almost similar to this study.

Table 4.5.2. Nut infestation by eriophyid mite in Jassore district at 2 months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	55	38	85.45 d
P_2	44	35	79.55 h
P_3	40	21	82.50 f
P_4	16	12	75.00 i
P_5	47	29	80.85 g
P_6	23	21	91.30 b
P_7	26	22	84.62 e
P_8	33	30	90.91 b
P_9	52	45	86.54 c
P_{10}	14	12	85.71 d
P_{11}	13	13	100.00 a
Grand total	363	278	76.31
CV	-	-	0.35
LSD	-	-	0.50

4.5.1.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.3. From the table 4.5.3., it is demonstrate that all percent mean grading index at 2 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (4.08 %), comprised of untreated control, which was statistically similar with P_6 (4.00 %) and followed by P_8 (3.87 %) and P_9 (3.64 %), respectively. On the other hand, percent mean grading index at 2 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was lowest in P_4 (2.73 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, and followed by P_2 (2.96 %), P_5 (2.85 %), P_3 (3.08 %), P_7 (3.12 %), P_1 (3.19 %) and P_{10} (3.19 %), respectively. This results is related with Rajagopal *et al.* (2003) study, which supports this findings.

Table 4.5.3. Damage index by eriophyid mite in Jassore district at 2 months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	19.15	6.38	29.79	25.53	19.15	3.19 d
P_2	14.55	30.91	14.55	23.64	16.36	2.96 e
P_3	15.38	26.92	19.23	11.54	26.92	3.08 d
P_4	20.45	25.00	29.55	11.36	13.64	2.73 f
P_5	17.50	27.50	20.00	22.50	12.50	2.85 e
P_6	14.29	0.00	0.00	42.86	42.86	4.00 a
P_7	13.46	25.00	21.15	17.31	23.08	3.12 d
P_8	8.70	0.00	21.74	34.78	34.78	3.87 b
P_9	9.09	9.09	33.33	6.06	42.42	3.64 c
P_{10}	25.00	6.25	18.75	25.00	25.00	3.19 d
P_{11}	7.69	0.00	0.00	61.54	30.77	4.08 a
Grand total	15.02	14.28	18.92	25.65	26.13	3.34
CV	-	-	-	-	-	2.06
LSD	-	-	-	-	-	0.12

4.5.2. Coconut mite infestation in 4 months after treatment

4.5.2.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.4. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments.

Table 4.5.4. Tree infestation caused by eriophyid mite in Jassore district at 4 months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.2.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented in table 4.5.5. From this table 4.5.5., it is revealed that, percentage of coconut nut infestation was low (57.78 %) in P_4 (comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which was statistically different from all others and followed by P_2 (73.91 %), P_5 (74.58 %), P_3 (78.79 %), P_7 (81.25 %), P_1 (83.64 %) and P_{10} (84.75 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which was statistically different from others and followed by P_6 (88.89 %), P_8 (88.33 %) and P_9 (85.71 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results was almost same with this study.

Table 4.5.5. Nut infestation by eriophyid mite in Jassore district at 4 months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	55	32	83.64 f
P_2	23	17	73.91 j
P_3	33	26	78.79 h
P_4	45	26	57.78 k
P_5	59	44	74.58 i
P_6	9	8	88.89 b
P_7	32	26	81.25 g
P_8	60	24	88.33 c
P_9	7	6	85.71 d
P_{10}	59	50	84.75 e
P_{11}	29	29	100.00 a
Grand total	411	288	69.59
CV	-	-	0.02
LSD	-	-	0.05

4.5.2.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.6. From the table 4.5.6., percent mean grading index at 4 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (3.90 %), comprised of untreated control, which was statistically different from others and followed by P_6 (3.56 %), P_8 (3.18 %) and P_9 (3.09 %), respectively. On the other hand, percent mean grading index at 4 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was lowest in P_4 (2.16 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, and followed by P_2 (2.73 %), P_5 (2.75 %), P_3 (2.80 %), P_7 (2.86 %), P_1 (2.91 %) and P_{10} (3.00 %), respectively. This study was related with Rajagopal *et al.* (2003), which supports this study.

Table 4.5.6. Damage index by eriophyid mite in Jassore district at 4 months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	21.21	24.24	12.12	27.27	15.15	2.91 ef
P_2	15.25	27.12	32.20	20.34	5.08	2.73 g
P_3	16.36	23.64	34.55	14.55	10.91	2.80 fg
P_4	42.22	24.44	17.78	6.67	8.89	2.16 h
P_5	25.42	22.03	18.64	20.34	13.56	2.75 g
P_6	11.11	22.22	0.00	33.33	33.33	3.56 b
P_7	14.29	42.86	0.00	28.57	14.29	2.86 fg
P_8	11.67	20.00	23.33	28.33	16.67	3.18 c
P_9	18.75	12.50	25.00	28.13	15.63	3.09 cd
P_{10}	26.09	13.04	21.74	13.04	26.09	3.00 de
P_{11}	6.90	3.45	3.45	65.52	20.69	3.90 a
Grand total	19.02	21.41	17.16	26.01	16.39	2.99
CV	-	-	-	-	-	2.56
LSD	-	-	-	-	-	0.13

4.5.3. Coconut mite infestation in 6 months after treatment

4.5.3.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.7. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments.

Table 4.5.7. Tree infestation by eriophyid mite in Jassore district at 6 months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.3.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented in table 4.5.8. From this table 4.5.8., it is revealed that, percentage of coconut nut infestation was low (56.25 %) in P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which was statistically different from others and followed by P_2 (66.67 %), P_5 (73.68 %), P_3 (75.00 %), P_7 (80.00 %), P_1 (82.05 %) and P_{10} (82.14 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which was statistically different from others and followed by P_6 (88.89 %), P_8 (87.10 %) and P_9 (83.67 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results are almost identical with this study.

Table 4.5.8. Nut infestation by eriophyid mite in Jassore district at 6 months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	39	32	82.05 e
P_2	21	14	66.67 i
P_3	36	27	75.00 g
P_4	32	18	56.25 j
P_5	38	28	73.68 h
P_6	18	16	88.89 b
P_7	5	4	80.00 f
P_8	31	27	87.10 c
P_9	49	41	83.67 d
P_{10}	28	23	82.14 e
P_{11}	52	52	100.00 a
Grand total	349	282	74.50
CV	-	-	0.83
LSD	-	-	1.10

4.5.3.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.9. From the table 4.5.9., percent mean grading index at 6 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (3.43 %), comprised of untreated control, which was statistically different from others and followed by P_6 (3.13 %), P_8 (3.00 %), P_9 (3.00 %), P_{10} (3.00 %), P_1 (3.00 %) and P_7 (2.96 %), respectively. On the other hand, percent mean grading index at 6 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was lowest in P_4 (2.13 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, and followed by P_2 (2.53 %), P_5 (2.65 %) and P_3 (2.81 %), respectively. This study was related with Rajagopal *et al.* (2003) study, which is support this study.

Table 4.5.9. Damage index by eriophyid mite in Jassore district at 6 months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	17.95	28.21	12.82	17.95	23.08	3.00 b
P_2	25.00	33.33	11.11	25.00	5.56	2.53 d
P_3	33.33	14.29	9.52	23.81	19.05	2.81 c
P_4	43.75	25.00	12.50	12.50	6.25	2.13 e
P_5	16.33	28.57	34.69	14.29	6.12	2.65 d
P_6	12.90	22.58	16.13	35.48	12.90	3.13 b
P_7	5.77	32.69	30.77	21.15	9.62	2.96 bc
P_8	20.00	20.00	20.00	20.00	20.00	3.00 b
P_9	11.11	27.78	16.67	38.89	5.56	3.00 b
P_{10}	26.32	7.89	21.05	28.95	15.79	3.00 b
P_{11}	17.86	7.14	28.57	7.14	39.29	3.43 a
Grand total	20.94	22.50	19.44	22.29	14.84	2.88
CV	-	-	-	-	-	3.38
LSD	-	-	-	-	-	0.16

4.5.4. Coconut mite infestation 8 months after treatment

4.5.4.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.10. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments.

Table 4.5.10. Tree infestation by eriophyid mite in Jassore district at eight months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.4.2. Coconut nut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented in table 4.5.11. From this table 4.5.11, percentage of coconut nut infestation was low (51.28 %) in P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which was statistically different from others and followed by P_2 (54.76 %), P_5 (66.67 %), P_3 (68.42 %), P_7 (68.97 %), P_1 (69.44 %) and P_{10} (73.47 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which was statistically different from others and followed by P_6 (90.91 %), P_8 (86.49 %) and P_9 (75.68 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results was almost similar with this study.

Table 4.5.11. Nut infestation by eriophyid mite in Jassore district at 8 months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	36	25	69.44 f
P_2	42	23	54.76 j
P_3	38	26	68.42 h
P_4	39	20	51.28 k
P_5	30	20	66.67 i
P_6	33	30	90.91 b
P_7	29	20	68.97 g
P_8	37	32	86.49 c
P_9	37	28	75.68 d
P_{10}	49	36	73.47 e
P_{11}	23	23	100.00 a
Grand total	393	283	72.01
CV	-	-	0.36
LSD	-	-	0.44

4.5.4.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.12. From the table 4.5.12., percent mean grading index at 8 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (4.00 %), comprised of untreated control, which was statistically different from others and followed by P_6 (3.35 %), P_8 (3.21 %) and P_9 (3.16 %), respectively. On the other hand, percent mean grading index at 8 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite is lowest in P_4 (2.14 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, and followed by P_2 (2.36 %), P_5 (2.39 %), P_3 (2.67 %), P_7 (2.69 %), P_1 (2.77 %) and P_{10} (2.86 %), respectively. This findings are related with Rajagopal *et al.* (2003) study, which supports this study.

Table 4.5.12. Damage index by eriophyid mite in Jassore district at 8 months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	33.33	20.00	6.67	16.67	23.33	2.77 df
P_2	48.72	10.26	12.82	12.82	15.38	2.36 g
P_3	26.53	28.57	12.24	16.33	16.33	2.67 f
P_4	45.24	14.29	26.19	9.52	4.76	2.14 h
P_5	31.58	28.95	21.05	5.26	13.16	2.39 g
P_6	13.51	13.51	24.32	21.62	27.03	3.35 b
P_7	31.03	20.69	13.79	17.24	17.24	2.69 ef
P_8	9.09	27.27	12.12	36.36	15.15	3.21 c
P_9	24.32	0.00	24.32	37.84	13.51	3.16 c
P_{10}	30.56	11.11	16.67	25.00	16.67	2.86 d
P_{11}	0.00	0.00	16.67	66.67	16.67	4.00 a
Grand total	26.72	15.88	16.99	24.12	16.29	2.87
CV	-	-	-	-	-	1.77
LSD	-	-	-	-	-	0.09

4.5.5. Coconut mite infestation in 10 months after treatment

4.5.5.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.13. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments.

Table 4.5.13. Tree infestation by eriophyid mite in Jassore district at ten months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.5.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented in table 4.5.14. From this table 4.5.14., it is clear that, percentage of coconut nut infestation was low (50.00 %) in P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which was statistically different from others and followed by P_2 (54.05 %), P_5 (60.00 %), P_3 (62.00 %), P_7 (63.64 %), P_1 (64.71 %) and P_{10} (65.45 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which was statistically similar with P_6 (100.00 %), and followed by P_8 (76.36 %) and P_9 (70.59 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results was almost same with this study.

Table 4.5.14. Nut infestation by eriophyid mite in Jassore district at ten months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	34	22	64.71 d
P_2	37	20	54.05 h
P_3	50	31	62.00 f
P_4	28	14	50.00 i
P_5	25	15	60.00 g
P_6	7	7	100.00 a
P_7	11	7	63.64 e
P_8	55	42	76.36 b
P_9	51	36	70.59 c
P_{10}	55	36	65.45 d
P_{11}	5	5	100.00 a
Grand total	358	235	65.64
CV	-	-	0.74
LSD	-	-	0.85

4.5.5.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.15. From the table 4.5.15., percent mean grading index at 10 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (3.22 %), comprised of untreated control, which was statistically similar with P_6 (3.20 %), and followed by P_8 (2.76 %). On the other hand, percent mean grading index at 10 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was lowest in P_4 (2.45 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, which was statistically similar with P_2 (2.47 %), P_5 (2.47 %), P_3 (2.48 %), P_7 (2.49 %) and P_1 (2.54 %), and followed by P_{10} (2.59 %) and P_9 (2.60 %), respectively. This observation was related with Rajagopal *et al.* (2003) study, which is support this study.

Table 4.5.15. Damage index by eriophyid mite in Jassore district at ten months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	50.00	0.00	14.29	17.86	17.86	2.54 cd
P_2	34.55	21.82	12.73	23.64	7.27	2.47 cd
P_3	38.00	14.00	24.00	10.00	14.00	2.48 cd
P_4	36.36	9.09	27.27	27.27	0.00	2.45 d
P_5	35.29	23.53	11.76	17.65	11.76	2.47 cd
P_6	0.00	60.00	0.00	0.00	40.00	3.20 a
P_7	45.95	10.81	10.81	13.51	18.92	2.49 cd
P_8	40.00	8.00	4.00	32.00	16.00	2.76 b
P_9	23.64	29.09	16.36	25.45	5.45	2.60 c
P_{10}	29.41	27.45	11.76	17.65	13.73	2.59 c
P_{11}	0.00	34.78	21.74	30.43	13.04	3.22 a
Grand total	30.29	21.69	14.07	19.59	14.37	2.66
CV	-	-	-	-	-	2.53
LSD	-	-	-	-	-	0.12

4.5.6. Coconut mite infestation in 12 months after treatment

4.5.6.1. Coconut tree infestation

All observed coconut trees were infested by coconut mite at coconut orchard at Jashore regions which is shown in the table 4.5.16. There was no significant difference among the percent infestation of coconut mite of different IPM packages used as treatments.

Table 4.5.16. Tree infestation by eriophyid mite in Jassore district at twelve months after treatment application

IPM Packages	No. of trees	No. of infested trees	% infested trees
P_1	5	5	100
P_2	5	5	100
P_3	5	5	100
P_4	5	5	100
P_5	5	5	100
P_6	5	5	100
P_7	5	5	100
P_8	5	5	100
P_9	5	5	100
P_{10}	5	5	100
P_{11}	5	5	100
Grand total	55	55	100

4.5.6.2. Coconut infestation

From the observed coconut trees coconut nuts were collected and the nut infestation data is represented in table 4.5.17. From this table 4.5.17., it is revealed that, percentage of coconut nut infestation was low (33.33 %) in P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) which was statistically different from others and followed by P_2 (50.00 %), P_5 (55.56 %), P_3 (57.14 %), P_7 (58.62 %), P_1 (59.32 %) and P_{10} (59.57 %), respectively. On the other hand, percent of coconut nut infestation was high (100.00 %) in P_{11} (untreated control) which was statistically similar with P_6 (100.00 %) and followed by P_8 (66.67 %) and P_9 (59.57 %), respectively. Ramaraju *et al.* (2002); Islam (2008) and many other researcher work on the IPM packages against coconut mite and their results was almost same with this study.

Table 4.5.17. Nut infestation by eriophyid mite in Jassore district at twelve months after treatment application

IPM Packages	No. of nut	No. of infested nut	% infested nut
P_1	59	35	59.32 d
P_2	22	11	50.00 g
P_3	35	20	57.14 e
P_4	9	3	33.33 h
P_5	27	15	55.56 f
P_6	6	6	100.00 a
P_7	29	17	58.62 d
P_8	18	12	66.67 b
P_9	52	32	61.54 c
P_{10}	47	28	59.57 d
P_{11}	5	5	100.00 a
Grand total	309	184	59.55
CV	-	-	1.25
LSD	-	-	1.33

4.5.6.3. Damage index

The infested coconut nuts were classified into five grades (G-1, G-2, G-3, G-4 and G-5) and data is presented into table 4.5.18. From the table 4.5.18., percent mean grading index at 12 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was highest in P_{11} (3.80 %), comprised of untreated control, which was statistically different from others and followed by P_6 (3.71 %), P_8 (2.56 %), P_9 (2.55 %), P_{10} (2.54 %), P_1 (2.52 %) and P_7 (2.48 %), respectively. On the other hand, percent mean grading index at 12 months after treatment application at coconut region in Jassore region, coconut nut infestation by coconut mite was lowest in P_4 (1.67 %), comprised of Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree, and followed by P_2 (2.05 %), P_5 (2.15 %) and P_3 (2.19 %), respectively. This study is related with Rajagopal *et al.* (2003), which supports this study.

Table 4.5.18. Damage index caused by eriophyid mite in Jassore district at twelve months after treatment application

IPM Packages	G-1 (%)	G-2 (%)	G-3 (%)	G-4 (%)	G-5 (%)	MGI (%)
P_1	38.46	7.69	25.00	21.15	7.69	2.52 c
P_2	50.00	13.64	22.73	9.09	4.55	2.05 e
P_3	40.43	27.66	8.51	19.15	4.26	2.19 d
P_4	66.67	0.00	33.33	0.00	0.00	1.67 f
P_5	40.68	28.81	15.25	5.08	10.17	2.15 d
P_6	0.00	28.57	14.29	14.29	42.86	3.71 b
P_7	44.44	7.41	14.81	22.22	11.11	2.48 c
P_8	33.33	22.22	16.67	11.11	16.67	2.56 c
P_9	41.38	13.79	6.90	24.14	13.79	2.55 c
P_{10}	42.86	14.29	11.43	8.57	22.86	2.54 c
P_{11}	0.00	20.00	20.00	20.00	40.00	3.80 a
Grand total	36.20	16.73	17.17	14.07	15.81	2.57
CV	-	-	-	-	-	1.81
LSD	-	-	-	-	-	0.07

CHAPTER V

SUMMARY AND CONCLUSION

This study was conducted in the Southern districts of Bangladesh viz, Jassore, Sathkhira, Barishal and Bagerhat from the year of 2016 to 2017 to determine the level of infestation by coconut mite through farmers' perception, the population dynamics of coconut mite, to identify the severity of coconut mite infestation, to determine the toxic action of chemical pesticides against coconut mite and to develop IPM package for the management of coconut mite.

In case of, coconut growers' response about coconut mite, among the respondents of 10 districts of southern region of Bangladesh 97.20% had home stead orchard and only 2.80% had commercial coconut orchard. The respondents of 96% grew tall shapped coconut and 63.5% grew round shaped coconut in their coconut orchard. Besides this, 98.80% respondents grew green colored coconut, 58.50% yellow and 24% brownish yellow. Among the respondents, 92.3% respondents figure out that insect pests were the main problem to coconut production, where-as, 96.5% of them reported that rhinocerous beetle was the major pest for coconut and 88.8% respondents also reported that mite was one of the major pests for coconut which cause severe damage (63.8% respondents). From the coconut growers' response, 68.5% respondents' confirmed that coconut mite infestation became severe in winter (68.5%) season and low in rainy (57.8%) season. Highest percentage of respondent (41.5%) admitted that coconut mite can damage 50% of coconut and coconut mite can damage exosperm of coconut (99.3%). The respondents used preventive measures against coconut mite infestation, among them, all of them (100%) practised sanitary measures. They got information about coconut mite through AEO (88.5%). As an effective control measure they applied insecticides (30.5%) against coconut mite.

In Jassore region study, the average population of coconut mite on different aged coconut nuts, the highest population of coconut mite (18.44 coconut mite/ 4 sq mm) was observed in April, 2017 and the lowest population of coconut mite (0.85 coconut mite/ 4 sq mm) in August, 2017. The synchronization of the months of the year round in terms of decreasing the population of coconut mite is as follows: April, 2017> May, 2017> March, 2017> February, 2017> January, 2017> December, 2016> October, 2016> November, 2016> September, 2016> June, 2017> July, 2017> August, 2017.

In Satkhira region study, the average population of coconut mite on different aged coconut nuts, the highest population of coconut mite (14.81 coconut mite/ 4 sq mm) was observed in April, 2017 and the lowest population of coconut mite (0.51 coconut mite/ 4 sq mm) in August, 2017. The synchronization of the months of the year round in terms of decreasing the population of coconut mite is as follows: April, 2017> May, 2017> March, 2017> February, 2017> December, 2016> January, 2017> October, 2016> November, 2016> September, 2016> June, 2017> July, 2017> August, 2017.

In Barishal region study, the average population of coconut mite on different aged coconut nuts, the highest population of coconut mite (9.97 coconut mite/ 4 sq mm) was observed in April, 2017 and the lowest population of coconut mite (0.34 coconut mite/ 4 sq mm) in August, 2017. The synchronization of the months of the year round in terms of decreasing the population of coconut mite is as follows: April, 2017> May, 2017> March, 2017> February, 2017> December, 2016> January, 2017> October, 2016> November, 2016> September, 2016> June, 2017> July, 2017> August, 2017.

In Bagerhat region study, the average population of coconut mite on different aged coconut nuts, the highest population of coconut mite (4.02 coconut mite/ 4 sq mm) was observed in April, 2017 and the lowest population of coconut mite (0.46 coconut mite/ 4 sq mm) in August, 2017. The synchronization of the months of the year round in terms of decreasing the population of coconut mite is as follows: April, 2017> March, 2017> February, 2017> May, 2017> December, 2016> January, 2017> October, 2016> November, 2016> September, 2016> June, 2017> July, 2017> August, 2017.

In case of seasonal abundance, there was significant effect of rainfall on the population of coconut mite. When rainfall became high then the population of coconut mite became low.

All coconut trees were infested by the coconut mite from September, 2016 to June, 2017 of two upazila of Jassore, Satkhira, Barishal and Bagerhat districts of Bangladesh.

The nut infestation was 87.46% by coconut mite in the study area during the month of September, 2016, which was 94.35% during the month of December, 2016, 97.95% in March, 2017 and 98.90% during June, 2017 in different coconut growing districts in South-West region of Bangladesh.

In terms of mean grading index in the month of September, 2016, Jassore region showed the high value 4.13 and follows Satkhira region 3.64, Barisal region 3.56, Bagerhat region 3.05 and the South-West region of Bangladesh 3.59. In the month of December, 2016, Jassore region showed the high value 4.17 and follows Satkhira region 3.87, Barisal region 3.76, Bagerhat region 2.99 and the South-West region of Bangladesh 3.70. In the month of March, 2017, Jassore region showed the high value 4.23 and follows Satkhira region 3.93, Barisal region 3.75, Bagerhat region 3.38 and the South-West region of Bangladesh 3.82. In in the month of June, 2017, Jassore region showed the high value 4.40 and follows Satkhira region 4.11, Barisal region 3.89, Bagerhat region 3.61 and the South-West region of Bangladesh 4.00.

The rainfall increased after the month of June, 2017 and decreased in December, 2016. At that time, the mean grading index remained high in June, 2017 and after the rainy season it became low in September, 2016. Again when rainfall decreased i.e. after December, 2016 then the mean grading index increased. It is possible that, the mean grading index became low after rainy season and increased in winter season.

In case of bioassay of chemical treatments against coconut mite at 12, 24 and 36 hours after application, T_3 (Intrepid 10SC @ 4ml/L of water) showed the best performance with 100.00 % mortality and T_{31} (untreated control) showed the lowest performance 0.00 % at 12 hours after application pesticides. The trend line of the result is $T_3 < T_6 < T_9 < T_2 < T_8 < T_5 < T_{20} < T_{15} < T_{12} < T_{21} < T_7 < T_{24} < T_{18} < T_4 < T_{23} < T_{11} < T_{22} < T_{27} < T_{14} < T_1 < T_{30} < T_{17} < T_{26} < T_{10} < T_{19} < T_{13} < T_{29} < T_{28} < T_{16} < T_{25} < T_{31}$.

From the comparison among the treatment performance of 12, 24 and 36 hours duration after application, treatments of 36 hours duration after treatment application showed the best performance as compared to 24 and 12 hours because of residual action of the pesticides.

The length of coconut nut was 26.82±8.25 cm for Grade-1 infested coconut nut, 24.32±11.39 cm for Grade-2 infested coconut nut, 23.83±9.71 cm for Grade-3 infested coconut nut, 23.32±9.47 cm for Grade-4 infested coconut nut and 22.23±6.91 cm for Grade-5 infested coconut nut. It shows that the length of coconut nut is decreased with the increase of coconut mite infestation.

The width of coconut nut was 50.4±15.53 cm for Grade-1 infested coconut nut, 47.84±22.41 cm for Grade-2 infested coconut nut, 47.39±19.48 cm for Grade-3 infested coconut nut, 44.32±18.81 cm for Grade-4 infested coconut nut and 42.99±14.17 cm for Grade-5 infested coconut nut. It shows that the girth of coconut nut is decreased with the increase of coconut mite infestation.

The weight of coconut nut was 1.51±0.53 Kg for Grade-1 infested coconut nut, 1.25±0.63 Kg for Grade-2 infested coconut nut, 1.24±0.57 Kg for Grade-3 infested coconut nut, 1.17±0.54 Kg for Grade-4 infested coconut nut and 1.01±0.44 Kg for Grade-5 infested coconut nut. It shows that the weight of coconut nut is decreased with the increase of coconut mite infestation.

All coconut trees were infested throughout the year from January to December, 2017 in coconut orchard at Jassore region of Bangladesh.

In Jassore region, the infestation of nut at 2, 4, 6, 8, 10 and 12 months after application were low at 75.00%, 57.78%, 56.25%, 51.28%, 50.00% and 33.33%, respectively in IPM package P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree). In Jassore region, the percent mean grading index in these months IPM package P_4 (Intrepid 10SC @ 4ml/L of water and neem oil cake @ 5 kg/tree) showed the best performance nd P_{11} (untreated control) showed the low performance (4.08%, 3.90%, 3.43%, 4.00%, 3.22% and 3.80%, respectively). The trend is $P_4 < P_2 < P_5 < P_3 < P_7 < P_1 < P_{10} < P_9 < P_8 < P_6 < P_{11}$.

Conclusion

From this study it can be concluded that coconut mite is the major pest of coconut plantation. The infestation of coconut mite was observed more or less all over the Bangladesh especially in southern region of Bangladesh, which may cause huge loss in coconut production. Now a days, coconut growers are aware of this pest and its nature of damage. So, they can take necessary measures against it. This pest infestation became low in rainy season and high in winter season, so preventive measures should be taken just after rainy season. Sanitation and IPM are the best management practices against coconut mite.

Considering the above experimental results of the present study further investigations in the following areas may be carried out-

1. More study may be needed for critical/thorough observation of coconut mite incidences in Bangladesh.

2. More experimental study should be conducted to get more accuracy in damage assessment of coconut mite in different regions of Bangladesh.

3. Further study may be needed for ensuring the efficiency of IPM against coconut mite in different agro-ecological zones (AEZ) of Bangladesh for regional management strategy.

CHAPTER VI

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CHAPTER VII

APPENDIXES

Appendix I. The physical and chemical characteristics of soil the experimental site as observed prior to experimentation (0-15 cm depth).

Mechanical composition:

Soil parameters	Observed values
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 mcq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil

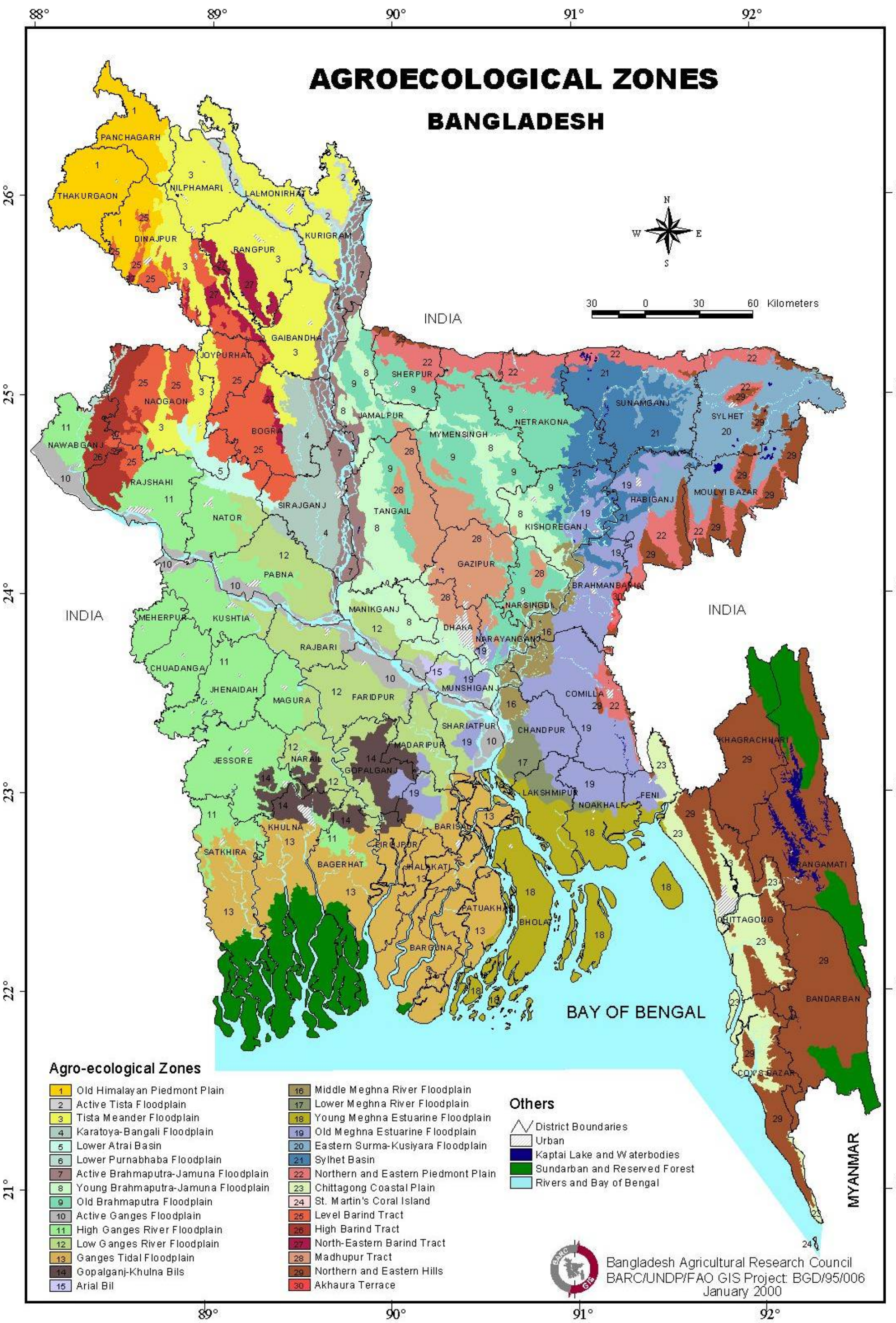
Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka.

Appendix II: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2012 to February 2013

Date/Week	**Temperature**		**Relative humidity (%)**	**Rainfall (mm) (Total)**
	Maximum	**Minimum**		
November	25.1	15.8	73.1	2.08
December	25	13	60.7	0
January	28.2	18.4	60.3	3.50
February	33.8	22.3	52.2	4.53
March	34.5	24.5	51.65	4.87
April	35.8	26	50.05	6.03

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207

Appendix III. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.