HOST PREFERENCE AND MANAGEMENT OF WHITEFLY, *BEMISIA TABACI* GENN. ON OKRA

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Registration No. 01027
Session: July-Dec, 2006

A THESIS

Submitted to

Sher-e-Bangla Agricultural University, Dhaka

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2008

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This is to certify that the thesis entitled, **"HOST PREFERENCE AND MANAGEMENT OF WHITEFLY, *BEMISIA TABACI* GENN. ON OKRA"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **MST. KHURSHIDA NASREEN** bearing Registration No. 01027 under my supervision and guidance. No part of the thesis 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 been duly acknowledged.

Dated: June, 2008
Place: Dhaka, Bangladesh

(Dr. Md. Razzab Ali)
Research Supervisor
Advisory Committee

Dedicated TO

MY

Beloved Parents

ACKNOWLEDGEMENT

All praises and thanks to almighty Allah (SWT), the supreme ruler of the universe who enables the author to complete this study successfully.

The author expresses her deepest sense of gratitude and sincere appreciation to his venerable research supervisor Dr. Md. Razzab Ali, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his continued guidance, support, encouragement and invaluable suggestions throughout the study period and during the preparation of manuscript.

She also wishes to express her sincere thanks, earnest obligation and profound gratitude to honorable co-supervisor Professor Jahanara Begum, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for her valuable suggestions and gratuitous labor in conducting the research work and preparation of the thesis.

The author also humbly expresses her grateful appreciation and thanks to Professor Dr. Mohammed Ali, Associate Professors Dr. Md. Abdul Latif and Dr. Md. Mizanur Rahman, Department of Entomology, SAU and well wishers who prayed for her success.

The author is highly grateful to other teachers and classmates in the Department of Entomology, SAU for their kind co-operation and helps during the study period of MS program. Thanks are extended to Md. Razibul Alam, Mst. Fatema Khatun, Mohammed Assaduzzaman Miah and Md. Aminul Haque Bhuyan for their co-operations in analyzing data and manuscript preparation.

Cordial thanks are also due to all field workers of SAU farm for their co-operation to complete her research work in the field.

Finally, she feels heartiest indebtedness to her beloved parents, brothers, uncles, aunts and other members of the family for their patient inspirations, sacrifices, blessing and never ending encouragement.

June, 2008 **The author**

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HOST PREFERENCE AND MANAGEMENT OF WHITEFLY, *BEMISIA TABACI* GENN. ON OKRA

By

MST. KHURSHIDA NASREEN

ABSTRACT

An experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka during March to July, 2007 to explore the resistance source(s) among four okra varieties/genotypes against whitefly, *Bemisia tabaci* Genn. as well as to evaluate the effectiveness of some selected management practices in controlling whitefly as well as *Okra yellow vein clearing mosaic virus* (O_kYVCMV) on okra. Out of four okra varieties, Hybrid Dherosh performed as highly resistant in respect of incidence of adult whitefly (16.34 adults/5 plants), O_kYVCMV infected leaves (1.20%) and plants (9.60%). The two varieties BU Dherosh 1 (28.93 adults/5 plants, 4.39% leaf infection and 15.20% plant infection, respectively) and BARI Dherosh 1 (31.33 adults/5 plants, 5.69% leaf infection and 21.40% plant infection, respectively) performed as resistant and the variety Choice Dherosh rated as highly susceptible host (67.60 adults/5 plants, 16.96% leaf infection and 74.40% plant infection, respectively). The incidence of adult whitefly was highly significant and positively correlated to the incidence of both O_kYVCMV infected leaves and plants of okra. The resistant variety Hybrid Dherosh produced maximum number of fruit per plant (14.33) and single fruit weight (16.97 gm) as well as the highest yield (7210.3 kg/ha) as compared with the highly susceptible variety Choice Dherosh, which produced minimum number of fruit per plant (8.40) and single fruit weight (12.17 gm) as well as the lowest yield (3380.60 kg/ha). The incidence of O_kYVCMV infected plants was negatively correlated to the yield of okra varieties.

Among five different management practices applied against whitefly on okra, T_1 (spraying of Admire 200 SL [Imidacloprid] @ 0.2 ml/liter of water at 7 days interval) performed as best in reducing 79.63% adult whitefly incidence, 76.65% O_kYVCMV infected leaves and 87.59% plant infection over control. Spraying of Admire 200 SL @ 0.2 ml/liter of water also performed as best in increasing 109.65% yield over control as well as other yield attributes such as height of plant, number of branch per plant, number of fruit per plant. Considering the economic analysis of the different management practices, T_4 (spraying of neem oil @ 3% at 7 days interval) considered as the most profitable treatment in respect of BCR (9.23), which was eco-friendly also. But in terms of national demand, T_1 (spraying of Admire 200 SL @ 0.2 ml/liter of water at 7 days interval) was the most effective treatment, which enhanced to produce maximum yield (7048.83 kg/ha) and contributed reasonable BCR (4.59).

Chapter I
Introduction

CHAPTER I

INTRODUCTION

Okra, *Abelmoschuss esculentus* (L.) Moench is a vegetable crop belongs to the family Malvaceae. It is cultivated almost all over the world. The crop is reported to be originated from tropical Africa and then gradually distributed to the Mediterranean Sea area, East Asia and Indian Subcontinent (Purseglove 1968). However, Chassiar (1984) reported that South and South East Asian countries might be the origin of okra. Okra is popular and specially honored because of its nutritive value and delicacy as a vegetable. The okra fruits are very rich in calcium, vitamin-E, starch and also contain appreciable amount of dry matter, protein, carbohydrate, fiber, carotene, thiamin, riboflavin, niacin, iron etc (Rashid 1999). The area under okra cultivation in Bangladesh during the year 2006 was 295 acres with production of 346 tons. The average yield of okra in Bangladesh is 1.40 ton^{-1}acre (BBS 2006), which is far low as compared to the potential yield of this crop and to the average yield of other okra growing countries.

Main reasons for poor yield of okra are non-availability of improved varieties, lack of quality seeds and susceptibility to a number of diseases and insect pests (Sastry and Singh 1974, Mukhopadhyay *et al.* 1986). Among the insect pests of major importance, mention may be made of whitefly, leaf hopper (jassid), shoot and fruit borer, leaf roller and red cotton bug and minor insects are aphid, leaf eating beetles and weevils, cutworm, semi-looper, fruit borer, sap sucking bug, thrips, mealy bug and scale insect (Butani and Jotwani 1984). Of them, the whitefly, *Bemisia tabaci* Gennadius causes damage okra by feeding cell sap from the plants and plant parts of okra. The damage is caused not only by desapping the plants and exuding honeydew, but also they act as vector of virus diseases transmitting the mosaic, the leaf curl virus diseases (Butani and Jotwani 1984). Incidence and severity of okra mosaic is directly related to availability and abundance of its insect vector, *B. tabaci* Genn. (Nath and Saika 1993). It can be mentioned that *Okra yellow vein clearing mosaic virus* (O_kYVCMV) is a member of Geminivirus group, which is semi–persistently transmitted by whitefly, *B. tabaci* Genn. in the field. (Kumar and Moorthy 2000). O_kYVCMV causes drastic reduction in yield and quality of okra, has been considered to be one of the most important constrain in okra cultivation in India and some other okra growing countries (Harender *et al.* 1993) including Bangladesh. The reasons have been recognized as the virus can attack okra plants in any stage of plant growth, the diseases spreads quickly in the field, adversely affects the growth and yield contributing characters due to remarkable alteration the cellular components of the infected plants (Sarma *et al.* 1995).

The susceptibility of okra to O_kYVCMV transmitted through whitefly makes the situation of okra cultivation non profitable in most of the growing countries. In Bangladesh, the okra is considered to be a very important crop, as it becomes available vegetable in crisis period. But high incidence of O_kYVCMV in okra becomes a great threat to okra cultivation in Bangladesh (Parvin 2004). O_kYVCMV has been reported to be the most important yield limiting factor of okra, which may cause more than 90% yield loss (Sastry and Singh 1974).

Host plant resistance is one of the preferred and effective methods for minimizing the damage caused by whitefly and associated viruses, because it does not require the complete elimination of the pest to be effective. However, different varieties have been developed and released in India as well as in Bangladesh. Two varieties named IPSA Derosh-1 and BARI Dherosh-1 were released as resistant varieties against O_kYVCMV in Bangladesh (Ali 1999, Rashid 1999). Parvin (2004) reported that BARI Dherosh 1 performed at the least preferred and Local -1 as the most preferred host in terms of incidence adult whitefly in the okra field. In India, Joshi *et al.* (1960) recommended the okra variety Pusa Sawani as resistant to O_kYVCMV. Mohapatra *et al.* (1995) reported that among different improved and hybrid varieties of okra, Pusa Sawani was found as the most susceptible variety and recorded 100% infection while varieties like HRB -9-2, DOV-91-4 and Pashupati showed tolerance at least under field conditions. It was reported by Singh (2000) that Perbani Kranti was found to be resistant to *Yellow vein mosaic virus* which transmits by whitefly *B. tabaci.* Parvin (2004) and Begum (2002) reported that the incidence of whitefly population in the field of okra was positively correlated to the incidence of O_kYVCMV infection.

The resistant source of the virus seemed to be either unavailable or proved to be unstable in field performance. Nath and Saika (1993) pointed out that yield loss of okra could be reduced by preventing early spread of the causal virus by controlling the vector, whitefly, *B. tabaci* Genn. Studies were conducted in West Bengal, India during 2000-01 to determine an environmentally safe management of yellow vein mosaic disease of okra through the use of tolerant cultivars (Parbhani Kranti, Arka Abhoy, Arka Pankaj, Sevendhari Green and an F1 hybrid), cost effective scheduling of efficient insecticides (metasystox [demeton-S-methyl], carbofuran and phorate) and plant product-based vector (*Bemisia tabaci*) control measures (Srabani *et al.* 2002). Singh *et al.* (1989) reported that the insecticides reduced numbers of *Bemisia tabaci* per plant and increased yield more effectively than other treatments. Atiri *et al.* (1991) reported that only treatments with the synthetic pyrethroid, lambdacyhalothrin, at 15 g a.i./ha and aqueous neem solution at 467 litres/ha significantly reduced incidence, severity and total damage caused by *Okra mosaic tymovirus* (ONV). Treatments with a cypermethrin + dimethoate mixture (3:25) at 280 g a.i./ha apparently had the same effect on disease incidence and severity, but it had no effect on total damage relative to the untreated control.

The Choice variety of okra is the new introduction in Bangladesh by Lal Teer seed company and other hybrid varieties imported from different countries that are widely cultivated by the farmers in Bangladesh. Until now, a few report is available on the evaluation of okra varieties/genotypes for resistant to okra whitefly in Bangladesh.

OBJECTIVES

Considering the above discussions the present study was undertaken to fulfill the following objectives:

1. To find out the resistant source(s) among four okra varieties/genotypes against whitefly transmitting *Okra yellow vein clearing mosaic virus* (O_kYVCMV);
2. To evaluate the effectiveness of some selected management practices against whitefly transmitting O_kYVCMV on okra;
3. To correlate between the incidence of whitefly population and incidence of O_kYVCMV disease infection;
4. To assess the economics management practices applied against whitefly.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Okra whitefly (*Bemisia tabaci* Genn.) is the most important insect pest of okra in Bangladesh and acts as the vector of *Okra yellow vein clearing mosaic virus* (O_kYVCMV) on okra. Studies on different aspects of the whitefly have been done else where but a few of them is related to the present study. Literature relating to varietal screening or finding of resistant or tolerant varieties/genotypes against this insect pest are scanty in our country. However, the available literature relevant to this study including the target pest, host preference and its management are presented under the following sub-heading.

2.1. Origin and distribution of whitefly

Bemisia tabaci was first described in 1889 as a pest of tobacco in Greece and named as *Aleyrodes tabaci*, the tobacco whitefly (Gennadius 1889). The first whitefly specimen was discovered shortly thereafter (collected in 1887) in the US on sweet potato (Quintance 1900). In 1957, this species and 18 other previously described whitefly species were synonymized into a single taxon, *Bemisia tabaci* (Russel 1957). It is known as various crop-based common names such as tobacco whitefly, cotton whitefly or sweet potato whitefly.

The outbreaks in cotton occurred in the late 1920s and early 1930s in India and subsequently in Sudan and Iran from the 1950s and 1961 in El Salvador (Hirano *et al.* 1993). *B. tabaci* is widespread in the tropics and subtropics and seems to known range of distribution. In South Asia it has been reported from India (Nariani 1960), West Pakistan (Ahmad and Harwood 1973), Srilanka (Shivanathan 1977), Thailand (Thongmeearkom *et* *al.* 1981). The whitefly has been reported as green house pest in several temperate countries in Europe, e.g., Denmark, Finland, Norway, Sweden and Switzerland. Besides, in greenhouses, the species has been reported on outdoor plants in France and Canada (Basu 1995). In the ten years annual report published individually by the Division of Plant Pathology of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur included the viruses in respect of *Okra yellow vein mosaic of Bhendi* (O_kYVMB), which is transmitted by whitefly.

From 1926 to 1981, *B. tabaci* was reported as sporadic pest and was the most important vector of plant viruses in subtropical, tropical and temperate zones where winters are mild enough to permit year round survival (Cock 1986). However, whitefly related problems have historically occurred after the introduction of intensive cropping regimes that require relatively high inputs of fertilizers and pesticides (Brown *et al.* 1995).

The presumably related to its close association with agricultural mono-crop cultivated by human *B. tabaci* was documented in tropical and subtropical localities of all the continents except in equatorial South America (Cock 1986). The inadvertent transport of the B-biotype on ornamental plants beginning in 1985-1986 established *B. tabaci* throughout the Europe, the Mediterranean Basin, Africa, Asia, Central America, North America (Mexico and the US) and South America (Costa *et al.* 1993). Worldwide distribution of whitefly, *B. tabaci* was updated by CAB International Institute of Entomology, London (Table 1)

Table 1. Global distribution of whitefly as updated by CAB International Institute of Entomology, London (Cock 1986)

Continent/Subcontinent	Countries
Europe	Cyprus, Denmark, Finland, Greece, Switzerland, Turkey, UK etc
USSR (Former)	Azerbaijan SSR, Georgian SSR
Africa	Angola, Cape Verde Island, Egypt, Ethiopia, Ivory coast, Sierra Leone, Somalia, South Africa etc.
Asia	Afghanistan, Myanmar, China, India, Indonesia etc
Pacific Islands and Australia	Australia, Hawaii etc
North West Atlantic	Bermuda
America, Northern USA	California, Florida, Texas etc
Canada	British Columbia, Quebec etc
Central America and Caribbean	Barbados, Costa Rica, Puerto Rico etc
South America	Argentina, Brazil, Venezuela, Colombia etc

2.2. Host range of whitefly

A survey of the literature from the early 1900s suggests that the number of host plants colonized by *Bemisia tabaci* has increased over time, probably as agricultural practices have shifted to irrigated monoculture and as different species have been cultivated during the century. Early documentation cited at least 155 plant species as hosts in Egypt alone (Azab *et al.* 1970), whereas by 1986, a worldwide detailed survey yielded an estimate of 420 host plant species (Brown *et al.* 1995). Current records indicate that *B. tabaci* can successfully colonize a multitude of host plant species worldwide (Cock 1986).

Capoor and Verma (1950) also reported that the host range of *yellow vein mosaic virus* of okra is restricted to malvaceous plants although they could be able to transmit the virus in six different plant species out of 34 different plant species tested through vector inoculation.

Bhendi (Okra) yellow vein mosaic, Croton yellow vein mosaic, Dollchos yellow mosaic, Horsegram yellow mosaic, Indian cassava mosaic and *Tomato leaf curl viruses* were transmitted by whiteflies (*B. tabaci*). All these considered as whitefly-transmitted geminiviruses. (Harrison *et al*. 1991).

In a survey during September 1985- May 1986, Verma *et al.* (1989) reported that the adults and mymphs of *Bemisia tabaci* were found on 17 plant species in widely separate families in the Kalyani area. Incidence depended on the plant species and season. In experimental fields the whiteflies were collected from winter crops of Okra tomato and *Phaseolus vulgaris.* Survival on various crops was similar but the periods for completion of life cycles varied. In transmission experiments, the differential transmissibility of *Yellow mosaic virus* diseases on *Vigna radiata*, *Vigna mungo* and *Lablab purpureus* to different hosts was not due to biological diferences in whiteflies but to host-virus-vector interactions.

Burban *et al*. (1992) collected *Bemisia tabaci* from cassava, Okra and other food plats in Cote d'Ivoire, West Africa, were investigated by isoenzyme electrophoresis and experimental host range studies. Two biotypes were identified. One was found only on cassava and aubergines; the other was polyphagous, but did not infest cassava. Differences in esterase patterns matched these host range restrictions exactly. The implications of these finding are discussed in relation to the role of *B. tabaci* as a virus vector.

The recently introduced B-biotype has the broadest host range among whiteflies in the genus *Bemisia;* some estimates range up to 500 species (Brown *et al.* 1995). Basu (1995) reported that *Bemisia tabaci* is highly polyphagous and has been recorded on a very wide range of cultivated and wild plants comprising more than 500 species of plants including numerous field crops, ornamentals and weeds. According to Panwar (1995), the host plants of *Bemisia tabaci* include cotton, tomato, tobacco, okra, sweet potato, cassava, cabbage, cauliflower, melon, brinjal and many cultivated plants.

Ioannou *et al.* (1987) conducted a study on host range of whitefly and it was observed that more than 100 species and varieties belonging to 16 families, 7 species of Solanaceae and 8 in other families became systemically infected following inoculation by *B. tabaci.* In the field, the virus was found from tomato at all growth stages and in all seasons from naturally infected *Datura stramonium,* tobacco, 3 wild *Lycopersicon* spp. and from breeding lines of tomato.

Greathead (1986) also updated the information reported by Mound and Hasley (1978) and listed 540 species of plants belongs to 77 families. It may be pointed out that 50% of the total number of host plants belonging to only 5 families; namely Leguminosae, Compositae, Malvaceae, Solanaceae and Euphorbiaceae. The compilation of the list of Greathead (1986) presented here including 540 plant species belonging to 77 families. Plant families have been ranked in Table 2 according to the number of plants recorded as hosts of *B. tabaci:*

Table 2. Ranking of plant families as hosts of *Bemisia tabaci* as listed by Greathead (1986)

Plant family	Number of host species
Leguminosae	99
Compositae	62
Malvaceae	37
Solanaceae	37
Euphorbiaceae	35
Convolvulaceae	20
Verbenaceae	18
Cucurbitaceae	17
Labiatae	16
Amaranthaceae	15
Cruciferae	15
Rosaceae	12
Moraceae	10
Chenopodiaceae	09
Oleaceae	08
Tiliaceae	05
Umbeliferae	05
5 families, each with 4 species	20
12 families, each with 3 species	36
13 families, each with 2 species	26
29 families, each with 1 species	29
Total 77	**540**

2.3. Biology and life history of whitefly

The majority of whitefly species cannot be identified by the morphological characters of the adults. Genera and species are usually defined according to the structure of the fourth nymphal instar, the so-called "pupal case" (Mound and Hasley 1978). Unfortunately, polyphagous whitefly species such as *Trialeurodes vaporariorum* (Westwood) and *B. tabaci* vary in the appearance (shape and size) of their pupal case, depending on the cuticle of the host plant on when they feed. This host-correlated morphological variation and host plant diversity have led to large number of synonyms of *B. tabaci* (Lopez-Avilla 1986), which have been listed by Mound and Hasley (1978). The adult whitefly, *B. tabaci* is a tiny soft bodied and pale yellow, change to white within a few hours due to deposition of wax on the body and wings (Haider, *et al.* 1999). The different developmental stages of whitefly, *B. tabaci* are described on the following sub-headings:

2.3.1. Egg

White eggs generally are pyriform or ovoid and posses a pedicel that is a peg like extension of the chorion (Byrne and Bellows 1991). Eggs are pear shaped and they are laid indiscriminately almost always on the underside of the young leaves (Hirano *et al.* 1993). Basu (1995) reported that eggs are laid indiscriminately almost always on the under surface of the leaves, anchored by the labium which remains closely apposed to the leaf surface. Lopez-Avila (1986) observed by that the egg dimensions are length 0.211±0.005 mm; width at the broadest part 0.096±0.002 mm and length of pedicel 0.24±0.003 mm. The female can lay 119 eggs in cotton captivity (Hussain and Trehan 1933) 300 eggs on brinjal under field conditions (Avidov 1956). Initially the eggs are translucent, creamy white and turn into pale brown before hatching. The incubation period varies widely mainly due to varying environmental conditions especially temperature. Under outdoor condition the incubation period has been reported to be ranged between 3-5 days in summer and 7-33 days during winter (Azab *et al.* 1970 and, Hussain and Trehan 1933).

2.3.2. Nymphal and Pupal stages

After completion of development, the egg crakes at the apical end along a longitudinal line of dehiscence. As the first instar nymph of *B. tabaci* begins to emerge, it bends in half until its forelegs can clasp the leaf, after which nymph walk away from the spent chorion (Poinar 1965). The first instar nymph is often called crawler (Basu 1995). When the first instar nymphs hatch they only move a very short distance over the leaf surface before settling down again and starting to feed. Once a feeding site is selected the nymphs do not move and they remain sessile until they reach the adult stage, except for brief periods during molts (Hirano *et al.* 1993). The first instar nymphs are pale, translucent white, oval with a convex dorsum and flat ventral side. They measure 0.267±0.007 mm in length and 0.144±0.010 mm in width (Lopez-Avila 1986). They have functional walking legs (with three apparent segments). Legs of second and third nymphal instars appear to have only one segment (Gill 1990).

The second instar nymphs are quite distinct from first instar for its size. These nymphs are 0.218±0.012 mm wide at the broadest part of the thoracic region. The body of third instar nymph is more elongated than the early instars, measuring 0.489±0.022 mm in length and 0.295±0.018 mm in breath.

The fourth instar nymphs have elliptical body measuring 0.662±0.023 mm broad. This fourth instar nymph has red eye-spots, which become eyes at the adult stage, are characteristic of this instar (Hirano *et al.* 1993). This fourth instar is commonly referred to as a pupa (Gill 1990). Hinton (1976) reported that certain whiteflies have pupal stage in the sense that this stage serves as a mold for some of the imaginal muscles. Two distinctive characters of these pupae are the eyes and the caudal furrow. Dorsal surface of the elliptical body is convex and the thoracic and abdominal segments are pronounced. Mound (1983) showed that the pupae from which female emerge are larger than those producing males. Duration of these stages varies and has generally been correlated with temperature or seasonal factor. Under constant conditions of 25°C, 75% RH and light: dark 16:8 hours, the fourth instar nymphs lasted 3.4 days on bean, 201 days on cotton and 2.0 days on tomato. The duration of pupal stage was 4.4 days on bean, 2.4 days on tomato and 1.7 days on cotton (Lopez-Avila 1986).

The total duration of the immature stages of *B. tabaci* varies widely and is correlated with climate and host-plant conditions. The shortest duration of 11 days during summer (Pruthi and Samuel 1942) and the longest of 107 days during winter (Hussain and Trehan 1933) were observed in India.

2.3.3. Adults

The adult (Plate 1) emerges leaving the empty pupal case. Under a constant temperature of 29.5°C±0.6°C and a photoperiod of 14:10 LD, 90% of the *B. tabaci* emerged from their pupal cases between 0600 and 0930 hours (lights occurred at 0600 hours). Adults are tiny, soft bodied and pale yellow, change to white within a few hours due to deposition of wax on the body and wings (Haider *et al.* 1999). Their antennae are long and slender and mouthparts are constructed for piercing and sucking. The forewings are slightly longer than the hind wings. At least, the wings cover the abdomen like a roof (Berlinger 1986). Byrne and Houck (1990) reported that sexual dimorphism in wing forms: the fore and hind wings of females are larger than those of males. The mean wing expanses of females and males are 2.13 mm and 1.81 mm respectively (Byrne and Bellows 1991). Adult longevity of males on tobacco was 4 days 7 days in winter;

corresponding female life span was 8 and 12 days respectively in India (Pruthi and Samuel 1942).

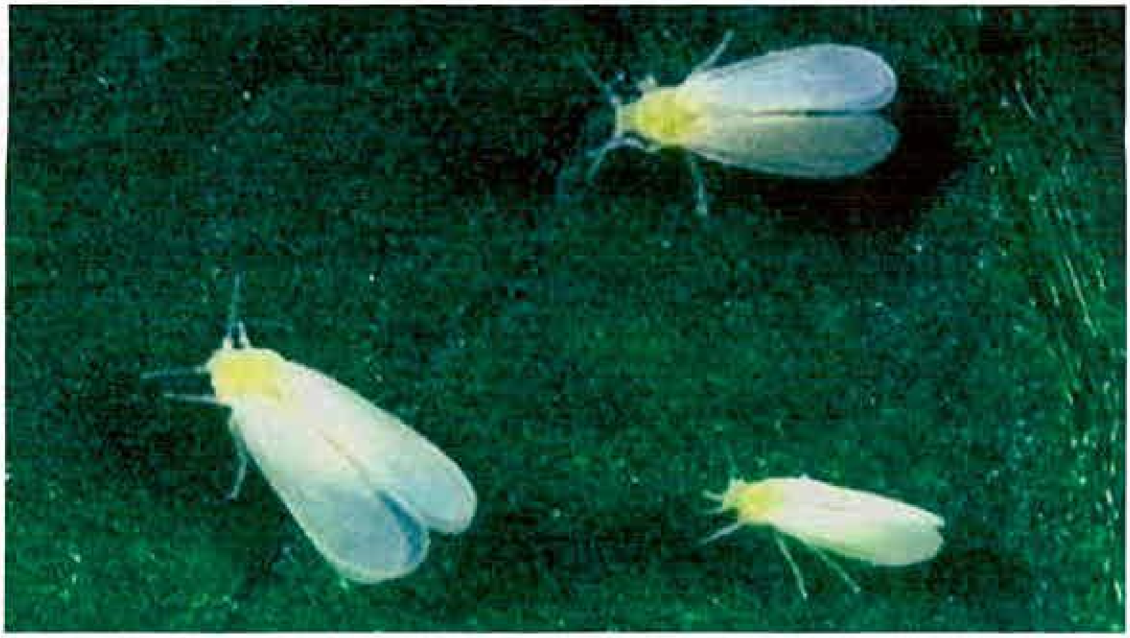

Plate 1. Adult whitefly, *Bemisia tabaci* Genn.
Source: Bedford (2004)

The maximum adult emergence occurs before 0800 and 1200 hours (Musuna 1985, Butler *et al.* 1983, Azab *et al.* 1971, Hussain and Trehan, 1933). *B. tabaci* is arrhenotokous and is known to lay unfertilized eggs which give rise to males only (Sharaf and Batta 1985, Mound 1983, Azab *et al.* 1971, Hussain and Trehan 1933). Unmated female produce male offspring while mated female produce both males and females. Monsef and Kashkooli (1978) recorded 10-11 generations per year on cotton in Iran and Hussain and Trehan (1933) and Pruthi and Samuel (1942) found 12 overlapping generations on cotton in India.

2.4. Nature of damage of whitefly

B. tabaci continues to be an economically important pest of greenhouse and field crops throughout equatorial areas of the world (De Barro 1995). Berlinger (1986) reported that whitefly, *B. tabaci* damaging the plants in three means that were discussed below:

2.4.1. Direct damage

Direct damage is caused by the piercing and sucking of sap from the plant foliage. Both nymphs and adults cause direct damage by feeding sap from the underside of the leaves (Berlinger 1986, Naresh and Nene 1980). This feeding cause weakening and early wilting of the plants and reduces the plant growth rate and yield. It may also cause leaf chlorosis, leaf withering, premature dropping of leaves (Berlinger 1986). Young plants even may be killed in case of severe whitefly infestation (Scalan 1995) in mungbean (Srivastava and Singh 1976).

2.4.2. Indirect damage

It results by the accumulation of honeydew secreted by the whitefly. This honeydew serves as substrate for the growth of black sooty mold fungus on leaves and fruits. The mold reduces photosynthetic capacity of the infested plant parts (Berlinger 1986, Naresh and Nene 1980).

Hossain *et al*. (1989) worked on the metabolism of plastid pigments in virus infected and apparently healthy okra plants. Infection by (unspecified) viruses caused reductions in chlorophylls a, b and a+b, and in beta-carotene in all the organs tested compared with amounts in healthy okra plants. It was concluded that virus infection alters the activity of enzymes involved in chlorophyll and beta-carotene synthesis.

Mandahar and Singh (1972) studied the effect of *Okra Yellow Vein Mosaic Virus* on its host. They reported that infection of *Hibiscus esculentus* induced 62-82% reduction in total chlorophyll and 56.61% reduction in total photosynthesis, while the respiration of infected tissue was increased 8.33%. It was concluded that carbohydrates were transported from healthy to diseased leaves in which they accumulate and this may account in part for infected plants not to bear any fruit.

Ramiah *et al.* (1972) observed that infection by the *Okra Yellow Vein Mosaic Virus* reduced chlorophyll a and b contents of leaves of okra and increased chlorophylls enzyme activity. Carotene and xanthophylls contents were also reduced.

2.4.3. Transmission of virus

The vector of plant viruses causes this type of damage and virus transmission is the main damage caused by the *Bemisia tabaci* (Cohen and Berlinger 1986). A number of reviews of whitefly-transmitted diseases have been published during the last three decades (Brown and Bird 1992, Verma 1992, Duffus 1987, Francki *et al.* 1985, Bock 1982, Muniyappa 1980, Bird and Maramorasch 1978 and Costa 1976)

Whitefly borne viruses of six or seven morphological classes have been demonstrated so far (Cohen 1990 and Duffus 1987). Of these, the geminivirus group is by far the most important, both in terms of number of diseases and their economic impact in various parts of the world (Brown and Bird 1992). Among different virus diseases, *Okra yellow vein clearing mosaic virus* (O_kYVCMV) is recognized as the most destructive disease of okra in all the okra growing areas of the world and this disease is transmitted by *B. tabaci* (Verma 1952, Capoor and Verma 1950 and Kulkarni 1924).

Chakraborty *et al.* (1997) reported that enation leaf curl disease of okra, caused by *Okra enation leaf curl virus* was commonly observed in the fields around Varanasi and Mirzapur Districts of Eastern Utter Pradesh, India. The disease was characterized by the presence of conspicuous enations under the surface of the leaves and leaf curling. The virus was readily transmitted by whiteflies, *Bemisia tabaci*. The disease incidence varied from 2 to 83% in susceptible varieties grown in the field.

Khan and mukhoadhyay (1985) studied on the spread of (*Hibiscus esculentus*) *Yellow Vein Mosaic Virus* and showed a steep rise during the early growth stage of the crop. They reported that the final rate of spread/day was independent of the quantum of initial infection.

According to Basu (1995) batches of five or more whiteflies invariably gave significantly higher percentage of transmission than did single whiteflies. Generally the females retained infectivity for much longer periods and proved to be more efficient than the males, the exception of this generalization is also evident. However, the natural spread of a vector borne virus requires 3 basic components, namely, the virus itself, the host and the vector. Among them, the host plant is the common victim of both the vector and the virus, whereas the virus is the common beneficiary exploiting the host plant as well as the vector (Basu 1995).

2.5. Historical preview of O_kYVCMV disease

Okra yellow vein-clearing mosaic virus (O_kYVCMV) causes the most destructive disease of okra in all okra-growing countries. Kulkarni (1924) first called attention to the disease being responsible for tremendous yield reduction of okra in Bombay, India, Uppal *et al.* (1940) established that the disease is caused by a virus and they also named the virus as

Yellow vein mosaic virus. The same disease was described as Yellow vein banding disease although the disease was characterized by vein clearing symptom and there was no evidence that the veins remained green or were banded by strips of yellow tissues in Ceylon by Fernando and Udurawana (1942).

Verma (1952) also studied the virus-vector relationship of *Okra yellow vein mosaic virus* in India. It was then established that the virus spread by an insect vector whitefly, *Bemisia tabaci* and through bud grafting (Capoor and Verma 1950). Sastry and Singh (1974) demonstrated that in the Indian subcontinent, the Virus is, however, widely distributed in the sub-tropical regions in the rainy season crop and in the tropical regions in the spring-summer crop.

In most Indian literatures, the virus was named as *Yellow Vein Mosaic Virus* (YVMV) of bhindi, *Bhindi/Bhendi yellow vein mosaic virus* (BUVMV), *Hibiscus yellow vein mosaic virus* (HYVMV), *Okra yellow vein mosaic virus* (OYVMV), etc. (Ali *et al.* 2000, Bhagat 2000, Borah and Nath 1995, Handa and Gupta 1993, Singh 1990, Sharma *et al.* 1987). In Bangladesh, a similar disease has been investigated as *Lady's finger mosaic virus, Lady's finger/okra yellow vein mosaic virus, Lady's finger yellow vein clearing mosaic virus, Okra mosaic virus* (Anonymous 1993, Akanda 1991 and Miah, M.A.S 1988). In the recent study, the name of the virus is used as *Okra yellow vein clearing mosaic virus* (O_kYVCMV) to accommodate all as synonyms and also to differentiate the other viruses infecting okra.

The works on *Okra yellow vein clearing mosaic virus* conclusively proved that the disease manifests itself with the vein clearing symptom, which turns into vein mosaic, chlorosis, etc. The virus is non-transmissible mechanically and through seeds of the infected plants. However, it is no persistently transmitted by an insect vector, *B. tabaci* and also transmitted through grafting. The virus is proved to be a member of geninivirus group (Handa and Gupta 1993, Handa 1991, Harrison *et al.* 1991 and Singh 1990)

2.6. Symptoms caused by O_kYVCMV

The vein clearing, vein chlorosis and yellowing having mosaic were noted as common symptoms of *Okra yellow mosaic virus* (OYMV) which transmit by whitefly as noted by the researches worked on the virus at the beginning (Handa 1991, Capoor and Verma 1950 and Fernando and Udurawana 1942). They also included dwarfing of the infected plants those produced distorted small-size fruits as the peculiarity of the symptoms of OYMV (Capoor and Verma 1950).

Capoor and Verma (1950) published a paper on yellow vein mosaic of okra, in which detailed studies on symptomatology, transmission and host range were done. They noted that clearing of small vein appears as the first visible symptom due to infection of *Yellow vein mosaic virus*, which gradually extends to other veins and finally turns into vein chlorosis, vein banding and profuse vein- swellings on the undersides of leaves. The veins of the leaves of infected plants are thick, brittle, dark green and curled downward. The infected plants produce malformed fruits those are pale in color and became though and fibrous. Mechanical inoculation test conducted by them was found to be non-responsive. Seed transmission test using the seeds from infected plants also proved to be negative. Graft transmission using buds of infected plants was positive in their experiment. Insect transmission using jassids (*Empoasca devastans* Distant, *Empoasca sp.*), Aphid (*Aphis gossypii* Glover) and Whitefly (*B. tabaci* Genn) was conducted by the same authors and the result revealed that among the species tested. Only *B. tabaci* could be able to transmit the virus. However, they were unable to transmit the virus using dodder (*Cuscuta reflexa* Roxb).

Handa and Gupta (1993) characterized the *Yellow vein mosaic virus* of bhindi *(Abelmoschus esculentus)* as a geminivirus having 18 x 30 nm in size. They performed ELISA test using polyclonal antiserum of *Indian cassava mosaic bigeminivirus* (ICMV) and found close relationship of *Yellow vein mosaic virus* of okra with ICMV. The results also demonstrated that *Bhindi yellow vein mosaic virus* was more closely related to ICMV than that of *African cassava mosaic bigeminivirus* (ACMV).

Givord *et al.* (1972) examined a disease characterized by mosaic symptoms, vein clearing and vein banding on okra in the Ivory Cosast. They reported that the virus was transmitted mechanically to 40 species of Malvaceae and two plants of other families.

2.6. Yield loss

Nariani and Seth (1958) provided the information from their experiments that *Bemisia tabaci* transmit the disease with which caused by *Yellow vein mosaic virus* of okra inflicts significant reduction in the fruit yield and also impairs the fruit quality.

Atiri (1990) observed the relationships between growth stages, leaf curl symptom development and fruit yield in okra and found the effect of growth stage at which leaf-curl virus disease symptoms developed on fruit yield of some Okra *(Abelmoschus esculentus)* lines. Symptoms developed before flowering and symptoms appeared during flowering, the number, size and weight of fruits were significantly lower in diseased than in healthy plants. The lines in which symptoms appeared only after the commencement of fruiting, the disease did not significantly reduce fruit yield. It is concluded that expensive control measures against its vector (*Bemisia tabaci*) may be unnecessary for the last group and that this trait may be bred into commercial cultivars.

O_kYVCMV has been reported to be the most important yield limiting factor of okra, which may cause more than 90% yield loss (Sastry and Singh 1974).

Pun *et al.* (1999b) reported that the incidence of the *Okra yellow vein clearing mosaic virus* in the field frequently reached even up to 100%, which caused more than 95.5% yield reduction of fresh fruit.

2.7. Seasonal abundance and population dynamics of whitefly

Bhagabati and Goswami (1992) studied on the incidence of O_kYVMV disease of okra in relation to whitefly population and different sowing dates. They counted the highest whitefly population in the crop sown in May to June while the incidence of okra yellow vein mosaic disease was the highest (100%) in crop sown in late October. They observed a high positive correlation between the virus disease incidence and population of whitefly (*B. tabaci*).

Borad *et al.* (1993) conducted field experiment to find out the relationship of *B. tabaci* population density and the incidence of yellow vein mosaic disease of okra in 1988 and 1989 cropping seasons. In both years, the population reached a maximum size during the first week of October. Symptoms of YVMV appeared one week after infestation with *B. tabaci.* The disease percentage increased progressively with the corresponding increase in vector population. Both adults of *B. tabaci* and YVMV were observed 16 and 20 days after seed sowing. The disease incidence was 41% and 90% for the 26 February and 8 April sowing, respectively. Plants sown on 24 April and only 5% infection. Correlation coefficients for all three planting dates indicated highly significant relationship between adult whitefly population density and the incidence of YVMV.

Mazumder *et al.* (1996) conducted an experiment for two consecutive years (1992 and 1993) on the incidence of *Bhendi yellow vein mosaic geminivirus* and its vector *Bemisia tabaci* in the okra cultivars Pusa sawani, Parbhani Kranti and M-31. Lower disease incidence and whitefly populations were revealed in crops sown between February 25 and March 20 compared with sowing dates of April 15 to July 25. The number of whiteflies was lower on Parbhani kranti and M-31 than on Pusa sawani. The total and marketable yields were maximum in early sown crops rather than crops sown after 15 April and number of unmarketable okras increased with delayed sowing. Simple correlation studies revealed a positive significant association between disease incidence and whitefly population, temperature, relative humidity (evening), rainfall and number of rainy days. Marketable fruit yield of okras was negatively correlated with disease incidence and a positive correlation between disease incidence and unmarketable fruit yield was obtained.

Salinas and Sumalde (1994) reported that the whitefly was observed throughout the year and the highest population was noted during the month of September and during April to May and November. He further showed that the high temperature and rainfall appeared to have a descriptive effect on the population of Whitefly (*B. tabaci*).

Sharma *et al.* (1987) worked on the influence of temperature on the incidence of *Yellow vein mosaic virus* of okra. They reported that the effect of temperature on the incidence of [*Hibiscus*] *yellow vein mosaic virus* (HYVMV) on six varieties of okra (*Abelmoschus esculentus*) was assessed over a period of 6 years. HYVMV incidence was found to be increased with the decreased temperature in September compared with August. A significant negative correlation co-efficient between temperature and virus as well as whitefly population incidence was observed.

Whitefly population has the potential for rapid, perhaps exponential increase under favorable conditions of climate and host plant availability. The seasonal migration of whiteflies from one host plant to another has been reported by various authors.

In Sudan, a study was conducted by Kranz *et al.* (1977) and found a sharp increase in whitefly population in September and October, which was directly correlated with higher relative humidity (80-90%) and increasing temperature (36 to 38°C). These conditions favor the development of juvenile stages by shortening the duration of each stage. They also indicated that the population decreases due to high mortality rates at eggs and free juvenile stages in March, April and May, when temperature is high (43 to 45°C) and relative humidity is low (8 to 17%).

Eichelkraut and Cardona (1989) reported that dry conditions were more favourable for whitefly, *B. tabaci*, than those of high precipitation. Salinas (1994) reported that temperature, relative humidity and the number of rainy days had a highly significant correlation with the adult whitefly population. A high significant correlation was also noted between relative humidity and the egg counts. On the other hand, Gerling *et al.* (1986) and Horowitz *et al.* (1984) observed that the extreme RH, both high and low were unfavorable for the survival of immature stages. Thus in Sudan, Horowitz (1986) found significant drop of whitefly population levels at heavy rainy condition.

Gameel (1970) attributed the occasional population whitefly in the Sudan to high temperatures (43 to 45°C) and low humidity levels (8-17%) or to low temperature and low humidity levels.

Lal (1981) found high humidity and stable maximum temperatures (29.4°C to 32.9°C) to be congenial for whitefly development on cassava in Kerala, India. High humidity and rainfall and relatively low temperature during July to October in Southern India were found to be uncongenial to the whitefly population development (Muniyappa 1983).

In Bangladesh, Mahmud (2004) also observed the positive correlation between whitefly (*Bemisia tabaci* Genn.) population (adult and nymphs) with increasing temperature and relative humidity.

2.8. Varietal susceptibility

Ali (1999) worked on *Okra yellow vein mosaic virus* and developed a resistant variety against the virus, which as released in the name of IPSA Derosh (Okra-1).

Joshi *et al*. (1960) reported Pusa Sawani as new okra variety resistant to *yellow vein mosaic virus* and recommended the variety for the farmers to grow commercially in India.

Mohapatra *et al*. (1995) recorded the incidence of *Yellow vein mosaic virus* (*Bhendi yellow vein mosaic bigeminivirus*) in some improved and hybrid varieties of okra were recorded under field conditions. Weekly incidence of the disease was compared with severity index and a minimum variation of the severity index was observed among the varieties. Pusa Sawani was the most susceptible variety and recorded 100% infection while varieties like HRB -9-2, DOV-91-4 and Pashupati showed tolerance at least under field conditions.

Singh (2000) conducted field experiments during the kharif seasons of 1989, 1990 and 1991 in Uttar Pradesh, India to identify varieties of Okra suitable for western Uttar Pradesh condition. Variety Perbani Kranti gave higher yield and pod weight than the other varieties studied for all three years; in addition, Perbani Kranti was also resistant to *Yellow vein mosaic virus* which transmits by whitefly *B. tabaci.*

Sing *et al.* (1993) recorded *Okra yellow vein virus* infection for eight cultivars grown in the Tarai region of Uttar Pradesh during 1987-88. Mean yield over the two years was highest for Prabhani Kranti (9.1 t/ha) followed by Punjab 7 and Punjab Padmini (9 and 8.8 t/ha), respectively. The lowest levels of virus infection were recorded for Punjab 7 and Prabhani Kranti, of which 83.5 and 78.8% of the plants grown, respectively, showed no viral infection.

Bhagabati *et al.* (1998) observed that infection by *Yellow vein mosaic virus* (YVMV) retards the growth and development of susceptible varieties of okra plants in India. The leaf area, fruit length, fruit weight and fruits volume are drastically reduced by virus infection. Moisture content of both diseased leaves and fruits is higher than that of healthy okra plants at all growth stages.

Ahmed and Hossain (1985) made a survey on disease of crops with and view to establish a herbarium at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The survey was conducted for three cropping seasons 1982-83, 1983-84 and 1984-85. Disease severity was worked out on 62 crops in nine districts of Bangladesh. In all 296 diseases were recorded including okra yellow vein clearing disease as and commonly prevalent disease which transmit by whitefly on okra.

The development of a resistant okra variety against O_kYVCMV at Bangladesh Agricultural Research Institute, Joydebpur, Gazipur has been reported by Rashid *et al.* (1999) and released the variety in the name of BARI Okra-1.

2.9. Management of whitefly

2.9.1. Cultural control

Anju and Gupta (1993) worked on the management of *bhendi yellow vein mosaic virus* disease. They reported that agronomic management practices improved the yield to 56-67 g/ha in spring and 56-61 g/ha in the kharif season when plants were spread at 60x30 cm to produce a dense stand.

2.9.1.1. Mulching

Mauromicale *et al.* (1996) carried out an experiment in the greenhouse to determine the effect of mulching with polythene sheets of different colour (black, transparent, white and reflecting aluminium colour) on the spread of *Bemisia tabaci*, infection by *Tomato yellow leaf curl bigemini virus* (TYLCV) and the productive behavior of tomatoes in 2 different cycles. They observed that mulching with the aluminium coloured polythene caused a delay in the infestation rate of *Bemisia tabaci* and as a result infection TYLCV was delayed. They also reported that there was a noticeable increment rate of mature tomato per plant the 2nd half of the productive cycle which resulted increment of yields of tomato. It was concluded that black polythene increased the total yield in both growing cycles whereas, white polythene increased yield only during the spring summer cycle.

2.9.1.2. Sowing Time

Singh (1990) observed that the incidence of the disease increased in the late sowing i.e., sowing on March 10, when the whitefly population was also found to be increased compared to sowing on February 10. The fruit yield was also remarkable reduced in the late sowing.

Sayeed (1988) conducted an experiment in Bangladesh Agricultural University Farm, Mymensingh using a Japanese okra cultivar named pentagreen to find out the effects of date of planting and insecticidal spray on the conducted of yellow vein mosaic virus of Lady's finger. He used three sowing dates viz. 17^{th} April, 2^{nd} May and 17^{th} May. The results demonstrated that the incidence of *Yellow vein mosaic virus* was 25%, 48% and 56% in the first, second and third planting, respectively.

Alegbejo (2001) reported that the effect of sowing date (30 June, 15 July and 30 July) on the incidence of *Okra mosaic virus* (O_KMV) was investigated during 1997 and 1998 at Samaru, Nigeria. Two Okra cultivars were used in the study, the resistant ABK 102 and the highly susceptible JOKOSO. The average number of virus vectors caught per plot decreased with delay in sowing. These vectors were identified as *PoDASrica spp.*, *Syagrus calcaratus* and *Nisotra dilecta.* The percentage of OKMV infected plants increased with delay in sowing, while fruit yield decreased.

Nath and Saikia (1995) conducted an experiment to find out the influence of sowing time on yellow vein mosaic virus of okra. They reported that the incidence of *Yellow vein mosaic bigeminivirus* (BYVMV) on okra cv. Pusa sawani varied from 75 to 91% in plots sown between early April and the end of June. Infection in plots sown during February to the end of March was progressively less. They also found that the lowest yield of okra was obtained from the plots sown in May and June. A strong positive correlation was obtained between present of disease incidence and whitely (*Bemisia tabaci*) population (r=0.085), whereas a strong negative correlation was obtained from disease incidence and fruit yield (r=0.84).

2.9.1.3. Inter cropping

Hossain (198) worked on effect of intercropping on the incidence of okra mosaic disease in the experimental field of Bangladesh Agricultural University, Mymensingh. The results showed that intercropping reduced the incidence of okra mosaic disease in most of the cases.

Idris (1990) found that there are two main types of disease symptoms, small vein thickening and main vein thickening, possible reflecting the existence of two strains of the virus; the disease, transmitted by *Bemisia tabaci,* always spreads in the direction of the wind; the highest disease rate coincides with the period of greatest plant growth and of highest vector population density; cotton intercropped with okra (*Abelmoschus esculentus*) exhibits higher disease incidence than cotton cultivated as a pure crop; and that cv. Barakat has a high level of disease resistance.

El-Serwey *et al*. (1987) conducted the experiment to find out the effect of intercropping of some host plant with tomato on population density of whitefly *Bemisia tabaci* and the incidence of *Leaf curl virus*. They observed that the effect of intercropping aborigines, okra, pepper and cucumber with tomatoes on the incidence of *Tomato yellow leaf curl* and the Aleyrodid *Bemisi tabaci* were studied in Iraq during 1983-84 and 1984-85. They reported that the population density of immature stage of the *Bemisia tabaci* were significantly lower on tomato seedling planted alone and the density of adults were significantly higher on tomato planted with aubergine or okra than on tomato with capsicum or cucumber. Adult preferred to oviposit on aubergines than on tomatoes. They observed that the incidence of *Tomato yellow leaf curl virus* was reduced by about 10-26% on tomato planted with capsicum during the first 3 months after transplanting.

Sing (1993) studied the production potential and economics of vegetables intercropped with rain fed okra. An experiment was conducted in 1987-88 on a study to determine the feasibility of intercropping rainy season okra (cv. Pusa sawani) with French bean (*Phaseolus vulgaris* cv. *contender*), cowpea (*Vigna unguiculatas*) tomato and brinjal (aubergine). He reported that intercropping with cowpea gave a 60% reduced okra yield. But the okra yield was the highest in all combination (24.98 t/ha) treatment to compared 16.31 t/ha for okra cultivation single. They reported that this combination raised the productively by 31-53% compared with the other intercropping combinations.

Fondong *et al*. (2002) stated that the spread of cassava mosaic disease (CMD) and population of the whitefly vector (*Bemisia tabaci*) were recorded in cassava when grown alone and when intercropped with maize and /or cowpea. The trials were conducted under conditions of high inoculums pressure in 1995 and 1996 at a site in the lowland rainforest zone of southern Cameroon. In the 1995 experiment, the maize and cowpea intercrops reduced the incidence of CMD in the cassava cultivars Dschang white and Dschang violet, but not in the more resistant cultivars improved. In the 1996 experiment with the cultivar Dschang violet, the maize and cowpea intercrops grown alone or together decreased adult whitefly population of cassava by 50% and CMD incidence by 20%.

Amma *et al*. (1991) studied on raising amaranthus as mixed crop on the yield of bhindi. There were 4 treatments, viz. (i) sowing Amaranthus sp. cv. Co. 1 seven days before okra cv. Parbhani kranti (ii) sowing Co. 1 three days before okra, (iii) sowing Co. 1 together with okra and (iv) okra alone. they observed that the amaranthus was successfully reduced vector population especially in treatment (iii) which gave the higher yield of 10.358 t/ha due to low incidence of okra mosaic compared with 9.664 t/ha in (iv). They also suggested that the net income for both crops was also highest in (iii) and lowest in (iv).

2.9.2. Botanical insecticide

Chowdhury *et al.* (1992) evaluated the inhibition of *Bhendi (Okra) yellow vein mosaic virus* (BYVMV) by different plant extracts and found that alcohol extracts were superior to aqueous ones in preventing infection by *Okra (Bhendi) yellow vein mosaic geminivirus* and those from Callistemon, Datura, Agave and ginger (*Zingiber officinale*) gave a good degree of suppression of symptoms on okra sprayed in the field. A lower rate of disease dissemination was recorded in treated plants than in the controls sprayed with water only. Mortality of the victors (*Bemisia tabaci*) was 20-80% when they were confined for 30 minute in a cage with plants treated with the extracts.

Singh *et al.* (1999) reported that the spraying of asafoetida plant extract to an okra crop in the rainy season was tested for the control of the viral vector, *Empoasca devastans* (*Amrasca biguttula biguttula*). The asafoetida formulation at 1-3% conc. in vitro and in field trials in Allahabad, Uttar Pradesh, India, showed strong insect repellent activity against *A. biguttula biguttula*, leading to reduced yellow vein mosaic viral infection levels.

In a laboratory study Butler and Rao (1990) of India reported that 0.5% sprays of 3 commercial neem oil formulations, namely, Neemguard, Newark and Neempon to single eggplant leaves against Whitefly resulted 97% fewer eggs and 87% fewer immature compared to those on untreated leaves.

The efficacy of Phorate, Endosulfan, Phosphamidon, Dimethoate, Methyl demeton [demeton-methyl], Monocrotophos, Phosalone, Acephate, Fenvalerate, Neem seed extract and Neem oil for the control of *Bemisia tabaci* on cotton was studied by Nimbalkar *et al.* (1993) in the field in Maharashtra, India. Monocrotophos, Fenvalerte and Phorate applied at a depth of10 cm at sowing were the most effective.

The plots treated with seed bed netting and two spray of Imidacloprid 200 SL had lowest number of Whitefly and it was statistically similar with the treatment seed bed netting with the spraying Neembicidine and seed treatment only (Anon 2005).

2.9.3. Chemical insecticide

Miah *et al.* (1988) evaluated the effects of insecticides and data of planting on *Yellow Vein Mosaic Virus* of Lady's Finger. They planted okra variety pentagree (Japanese variety) in three different dates viz. 17 April, 2 May and 17 May in 1986 and applied tree insecticides namely Bidrin, Ripcord and Sumithlon in their experiment in Bangladesh Agricultural University Farm, Mymensigh. Among the insecticides, Bidrin was found to be the most effective followed by Ripcord in controlling the yellow vein mosaic of Lady's finger disease incidence. Sumithion used in their experiment was found ineffective. The authors recorded and pronounced effect of planting dates on the disease incidence as well as grown and yield of the crop. The lowest disease incidence was obtained in the first planting while it was the highest in the third planting.

Keshwal and Khatri (1999) reported that a spray of insecticide and tricontanol growth regulator controlled *Tomato yellow leaf curl virus* in tomato and *Bhindi yellow vein mosaic virus* in Okra in India. Hybrid tomato and okra varieties were more susceptible to these virus diseases than the local cultivars.

Sastry and Singh (1973) studied the field evaluation of insecticides for the control of whitefly in relation to the incidence of YVM of okra. They worked with different insecticides on whitefly *Bemisia tabaci* Genn and found that the spraying in the initial stages of the crop just after germination was most important to reduce the population in relation to the incidence of yellow vein mosaic virus. If the crop was not sprayed within 20 days after sowing, the incidence of the yellow vein mosaic would be 45-100 percent resulting in low yield. They also reported that four to six applications of systemic insecticides such as Ekatox, Rogor, Metasystox and Dimecron as foliar sprays and one or two applications of granular forms. Thimet and Disyston to the soil not only reduced the whitefly population but also reduced the incidence of yellow vein mosaic to a greater extent when compared to the untreated control.

Sastry and Singh (1974) conducted another experiment to find out the control for the spread of the *Tomato leaf curl virus* by controlling the whitefly population (*Bemisia tabaci* Genn.). This experiments revealed that four foliar sprays of Dimethioate (0.05%), Methyl parathion (0.02%) and Oxydemeto-Methyl (0.02%) and only one application of Phorate 10 g (15 kg/ha) at the time of planting not only reduced the whitefly population but also resulted in less spread of *Tomato leaf curl virus*.

Lana (1976) studied mosaic virus and leaf curl diseases of lady's finger in Nigeria. He coined that under natural condition use of pesticides was adequate for the control leaf curl and okra mosaic virus disease. Further, the reported that application of Dieldrin (0.12%), DDT + Lindane (0.18%) and Monocrotophos (0.12%) at weekly intervals as foliar sprays starting on week after emergence of okra in the field resulted generally in a low incidence of both diseases.

Iqbal (1979) used Diazinon 60 EC for controlling YMV of okra. He sprayed Diazinion at 15 days intervals in the field and successfully controlled this disease.

Khan and Mukhopadhyay (1985b) tested pesticides against (*Hibiscus esculentus*) *Yellow Vein Mosaic Virus* and its vector *Bemisia tabaci*. Soil application of methyl phosphorodithioate (Furtox 10G) at 15 kg/ha followed by 4 foliar sprays of Metasystox (Demeton-s-smethyl) 25 EC at 0.03% at 15 days intervals from the sowing date. They reported that it reduced disease incidence up to 23.26% (control 81.22%) and average whitefly population to 59.66 (from 231) per plant and enhanced yield to 59.45 kg/ha (from 23.8).

From the early period of control against whitefly with resin soda (Thomas 1932) and fish-oil resin soap sprays (Pruthi 1946, Husain *et al.* 1939), the chemical control has come a long way. The advent of DDT after the second world was ushered in revolution in the sphere of insect control.

The Effectiveness of 19 insecticides and insecticide combinations against the Aleyrodid, *Bemisia tabaci* were evaluated in Venezuela by Marcano *et al.* (1993) and they observed that the most effective insecticides against eggs and nymphs of the pest were: Imidacloprid (91.67 and 78.61 litres/ha); Mineral oil + Lmidacloprid (88.85 and 71.33) litres/ha); Cyfluthrin+ Methamidophos (87.85 and 69.08 litres/ha); Buprofezin (86.1 and 53.19 litres/ha); Lambda-cyhalothrin (86.1 and 47.47 litres/ha); Profenofos + Cypermethrin (85.93 and 70.18 litres/ha); and Bifenthrin (85.82 and 70.21 litres/ha).

The efficacy of Phorate, Endosulfan, Phosphamidon, Dimethoate, Methyl demeton [demeton-methyl], Monocrotophos, Phosalone, Acephate, Fenvalerate, Neem seed extract and Neem oil for the control of *Bemisia tabaci* on cotton was studied by

Nimbalkar *et al.* (1993) in the field in Maharashtra, India. Monocrotophos, Fenvalerte and Phorate applied at a depth of10 cm at sowing were the most effective.

Singh *et al.* (1994) found that Cotton leaf curl bigeminivirus (CLCuV) occurred widely in parts of north western India on *Gossypium hirsutum* during 1994, its incidence varying from 1 to 97% on different varieties. A greater build-up of the vector population was observed in cotton during October. A greater build-up of the vector population was observed in cotton during October. Ethion 50 EC at 800 ml and Triazophos 40 EC at 600 m. /acre were both effective against the vector.

The efficacy of Imidacloprid (Bay NTN 33893), applied on *P. ixocarpa* seeds, roots (before transplanting) and /or on the neck of the plant (a few days after transplanting), in controlling *Bemisia tabaci* was evaluated in fieldexperiment conducted in Totolapan, Morelos, Mexico by Alatorre *et al.* (1995). The treatments which proved to be efficient in controlling *B. tabaci* were: seed applications+ root applications and a combination of all the application methods. Imidacloprid (applied every 7-10 days) was more effective in controlling the pests than metamifidos.

Increase of trap catches with the increase of day temperature indicates the thermophilic nature of Whiteflies. Unlike Cotton, insecticidal control of *B. tabaci* has generally been aimed at curbing the spread of viral diseases rather than the direct injury by whitefly (Basu 1995).

Imidachloprid (a systemic chloronicotinyl insecticide) gained major importance for control of *B. tabaci* in both field and protected crops, in view of extensive resistance to Organophosphorus, Pyrethroid and Cyclodiene insecticides (Cahil *et al.* 1995).

Cahil *et al*. (1996) cautioned that the application of Imidacloprid must be carefully handled to avoid rapid resistance selection since *B. tabaci* has the genetic potential to become resistant to this insecticide.

Haider (1996) found that grafted Tomato plants sprayed with Ripcord was the very effective in managing the virus disseminating whitefly.

Kabir *et al*. (1996) observed that Chess, Nogos and Fenom as effective on the reduction of blackfly, *Aleurocanthus woglumi* Ashby after 7 days of application.

It is recommended that an action threshold of damage level 1-3 (i.e. presence of adults and eggs to appearance of nymphs and 500-1000 individuals/leaf) should be adopted (Rodriguez *et al*. 1996)

Rushtapakornchai *et al*. (1996) investigated three granular insecticides (Fipronil 0.3% G, Carbosulfan 5.0% G and Carbofuran 3.0% G) and 10 foliar insecticides (Bifenthrin 2.5% EC, Fenpropathrin 10.0% EC, Acephate 75.0% SP, Pyriproxyfen 10.0% EC., Fipronil 5.0% SC, Imidacloprid 10.0% SL, Carbosulfan 20.0% e.c., Methamidophos 60.0% SL, Cypermethrin/ Phosalone 28.8% e.c. and Beauveria bassiana). The effectiveness of these insecticides to control *Bemisia tabaci* on tomato (cv. VF-134-1-2) was tested in petchaburi province (Thailand) between November and December, 1995. At 18 days after transplanting (DAT) the occurrence of yellow leaf curl symptoms on tomato plants was 5.0, 3.3 and 6.7% in treatments of the 3 granular insecticides, respectively, and between 1.7 and 15.0% in foliar insecticide treatments. At 32 and 45 DAT, the abundance of yellow leaf curl symptoms ranged from 21.7 to 55.0% and 36.7 to 71.7%, respectively, in Bifenthrin, Imidacloprid, Fenpropathrin, Fipronil and Cypermethrin/ Phosalone treatments. The abundance of symptoms in untreated plots was 65.0 and 91.7%, respectively.

Azam *et al*. (1997) conducted an experiment during 1993-95 with some insecticides (Carbofuran, Endosulfan, Dimethoate, Buprofezin and Triazophos) for the control of *B. tabaci* and yellow leaf curl bigeminivirus (TYLCV) and found that Endosulfan had the most affect to control *Bemisia tabaci*.

In the Dominican Republic, several applications of Imidachloprid starting after transplantation were used to control TYLCV (Polston & Anderson 1997).

Naimatullah *et al*. (1998) tested (Endosulfan, Methamidophos, Talstar [Bifenthrin], M-pede [an organic insecticide based on potassium salts of fatty acids], Incegar (insect growth regulator) and Surfactan (Surf+cotton seed oil) individually and in various combinations in a field experiment in Faisalabad, Punjab, Pakistan, to determine the most effective control of *B. tabaci* infesting cotton cultivars CIM-1100 and S-12. The combination of Methamidophos+ Talastar proved to be the most effective in decreasing the egg hatchability (32.41 and 37.40%), adult emergence (50.30 and 54.50%), adult population (2.34 and 2.15/leaf) and *Cotton Leaf Curl Virus* (2.4 and 1.11 mean number of scoring) on S-12 and CIM-1100, respectively, as against 97.47 and 94.34%egg hatching, 96.39 and 96.37 adult emergence and 10.99 and 9.93 per leaf adult population on the two cultivars in the untreated control.

The Chloronicotinyl insecticide imidacloprid is widely used in soil application, seed treatment and as a foliar spray. Its systemic properties are well known, it is more or less completely metabolised, depending on the method of application, plant species and time. In the present work, Nauen *et al*. (1999) demonstrate that the olefine metabolite and two hydroxy metabolites of Imidacloprid are active against the cotton Whitefly, *Bemisia tabaci*, in oral ingestion bioassays (sachet test). The 4-hydroxy metabolite is as active as Imidacloprid and the Olefine compound C 10 times more active. The tow hydroxy metabolites wee also active against biotypes from Almeria, Spain and a B-type strain from California.

Mason *et al.* (2000) observed that proportion of viruliferous Whiteflies surviving the acquisition on treated plants appeared similar to that of insects fed on untreated plants, suggesting that Thiamethoxam activity in preventing TYLCV transmission by *B. tabaci* was simply due to its killing activity and anti-feeding or repellent actions can be excluded. Viruliferous whiteflies exposed to Thiamethoxam-treated plants stopped feeding before acquiring enough viruses to subsequently inoculate plants.

Nuvacron 40SL (Monocrotophos) and Cymbush 10 EC had significant effect on lower incidence of Whitefly as well as viral infection (Anon. 2001).

Zabel *et al.* (2001) investigated the efficacy of a new class of insecticide (Chloronicotinyl) Mospilan 20 SP (a.i. Acetamiprid), compared with Lannate 90 SL (a.i. Methomyl) and Applaud WP 25 (a.i. Buprofezin), in glasshouse control of Whitefly (Trialeurodes vaporariorum). All investigated insecticides significantly decreased the number of whitefly larvae, compared with untreated plots where population density grew during the trial. Based on statistical analysis, efficacy of all insecticides on Whitefly larvae were in the same category. Some differences occurred 7 days after the third treatment. Deposited egg number was significantly different between controls and each insecticide plot. Efficacy of investigated insectiides, evaluated according to deposited egg number, was also good and in the same cataegory. Aneja *et al.* (2002) reported that

Bemisia tabaci population reduced when treated with Nuvacron 36 SL (monocrotophos, 500 ml/10 L of water).

Berlinger *et al.* (2002) found that *Tomato Yellow Leaf Curl Virus* (TYLCV) is the most frequently occurring virus in the Middle East, and the most harmful. It is transmitted solely by the whitefly, *Bemisia tabaci*. Within 4-6 h of inoculative feeding, a whitefly can transmit TYLCV to a healthy plant with 80% probability. The symptoms are apparent after two to three weeks where upon fruit set is effectively terminated.

A study was conducted by Abdullah *et al.* (2004) as a part of a research work on insecticide hormoligosis in *B. tabaci* to investigate the changes in biological parameter of this pest in response to repeated application of insecticides. Five commonly used insecticides on cotton in Punjab (India), i.e. Quinalphos (250, 375 and 500 g), Carbaryl (625, 938 and 1250g), Acephate (750, 1125 and 1500 g), Endosulfan (438, 656 and 875 g) and Fenvalerte (25, 38 and 50 g a.i. /ha), were repeatedly sprayed on potted plants of cotton. The maximum reduction was recorded in all doses of Endosulfan, followed by higher doses of other insecticides. In general, low doses of insecticides caused lower reduction in longevity compared with higher doses. The results indicated that no hormoligosis was induced in longevity of the Whitefly by the tested insecticides.

Torres *et al.* (2004) studied the toxicity of Thiamethoxam and Imidacloprid and their efficacy against Whitefly. Thiamethoxam and Imidacloprid showed significant control of Whitefly in comparison with untreated plant up to 40 days after treatment in potted plants. Whitefly population had low density over time in the field with no differences between treatments and only at day 64 higher whitefly population was observed on untreated plants and plants treated with 0.5 mg a.i. of Thiamethoxam per plant.

Untreated and treated plants with 0.5 mg of Thiamethoxam showed infestation of 68.7 and 31.2%, respectively, at this time, Thiamethoxam and Imidacloprid used in cotton for whitefly control can be more successful when they are used at doses bellow 1 mg (a.i.) per plant due to shorter residual effect.

Significantly the lowest whitefly infestation was occurred when seed bed netting and Imidacloprid was applied simultaneously (Anon 2005).

The plots treated with seed bed netting and two spray of Imidacloprid 200 SL had lowest number of Whitefly and it was statistically similar with the treatment seed bed netting with the spraying Neembicidine and seed treatment only (Anonnymous 2005).

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present study comprising two sets of experiments have been conducted during March to July, 2007 in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh.

Experiment 1: Field screening of four okra varieties/genotypes for resistance against whitefly, *Bemisia tabaci* Genn.

Experiment 2: Evaluation of some selected management practices against whitefly, *Bemisia tabaci* Genn. on okra

On details, each of the experiment is furnished below:

Experiment 1: Field screening of some selected okra varieties/genotypes for resistance against whitefly, *Bemisia tabaci* Gennadius

The present study was conducted on screening of four selected okra varieties/genotypes against whitefly, *Bemisia tabaci* Genn. at the experimental field of the SAU, Dhaka, during March to July, 2007.

3.1.1. Treatments

The four varieties/genotypes of okra, *Abelmoschuss esculentus* L. collected from different sources are presented in Table 1. Each variety of which was considered as an individual treatment.

Table 3. Particulars of four okra varieties/genotypes used under the present trial

Treatment	Variety	Source of availability
V_1	BU Dherosh-1	Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur.
V_2	BARI Dherosh-1	Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.
V_3	Hybrid Dherosh (Indian)	Local market, Siddique Bajar, Dhaka.
V_4	Choice Dherosh (LalTeer)	East West Seed (Bangladesh) Ltd.

3.1.2. Location of the experiment

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh.

3.1.3. Climate of the experimental area

The experimental site is situated in the sub-tropical climatic zone characterized by heavy rainfall during March to July and sporadic during the rest of the year. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm. The data recorded and calculated as monthly average temperature, relative humidity and rainfall for the crop-growing period of experiment were noted from the Bangladesh Meteorological Department (climate division), Agargaon, Dhaka-1207 and have been presented in Appendix I.

3.1.4. Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series (Appendix II). The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.* 1991).

3.1.5. Land preparation

The soil was well prepared and ensured good tilth for commercial crop production. The land of the experimental field was ploughed with a power tiller. Later on, the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and finally the land was ready. The field layout and design of the experiment were followed immediately after land preparation. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.1.6. Manure and fertilizer

Manures and fertilizers with their doses and their methods of application followed in study were recommended by Haque (1993) and are shown in Table 4.

Table 4. Doses of manures and fertilizers and their methods of application used for this experiment

Manures and fertilizers	Dose per ha (kg)	Basal dose (kg/ha)	Top dressing (kg/ha)	
			First*	Second**
Cowdung	5000	Entire amount	-	-
Urea	150	-	75	75
TSP	120	Entire amount	-	-
MP	110	Entire amount	-	-

*25 Days after sowing, **45 Days after sowing.

3.1.7. Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 4 unit plots. The size of the unit plot was 3.0 m×2.0 m. The block-to-block and plot-to-plot distance was 0.75 m and 0.50 m, respectively.

3.1.8. Collection of seed and seed sowing

The seeds of four selected okra varieties BU Dherosh-1, BARI Dherosh-1, Hybrid Dherosh (Indian), Choice Dherosh (Lal Teer) were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur and Local market, Siddique Bajar, Dhaka and Lal Teer Seed Company Ltd. Before sowing seeds, the germination test was done and approximately 90% germination was found in all varieties. Seeds were then directly sown on the main field on the 5th April, 2007.

3.1.9. Intercultural operations

After sowing seeds light irrigation was given to each plot. Supplement irrigation was applied at an interval of 2-3 days. Dead or damaged seedlings were replaced by healthy one from stock immediately. Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. Stagnant water was effectively drained out at the time of heavy rainfall. The total amount of recommended dose of urea was top dressed in 2 splits at 15 days after establishment of the seedlings.

3.1.10. Data collection and calculation

For data collection five plants per plot were randomly selected and tagged. Data collection was started from the first initiation of the whitefly attack (after 19 days of seed sowing). Data were collected once in a week. The data were collected on number of whitefly; number of O_kYVCMV infected leaves; weight and number of okra per 5 tagged plant; yield and single fruit length of different okra varieties. All the data were calculated as where needed as follows:

3.1.10.1. Percent O_kYVCMV infected plant in number

Number of infected plant was counted from total plants per plot and percent plant infection by O_kYVCMV was calculated by using the following formula:

$$\% \; O_kYVCMV \text{ infected plant} = \frac{\text{No. of } O_kYVCMV \text{ infected plant}}{\text{Total no. of plants per plot}} \times 100$$

3.1.10.2. Percent O_kYVCMV infected leaf in number

Number of infected leaves was counted from total leaves per five tagged plants per plot and percent leaf infection by O_kYVCMV was calculated by using the following formula:

$$\% \; O_kYVCMV \text{ infected leaf} = \frac{\text{No. of } O_kYVCMV \text{ infected leaf}}{\text{Total no. of leaves}} \times 100$$

3.1.11. Statistical analysis

Data were statistically through MSTAT-C software (Anonymous 1989) and Duncan's multiple range test (DMRT) (Duncan 1955) was used to determine the levels of significant differences for separating the means of different parameters. Correlations studies were also done to make relationships between different parameters.

Experiment 2: Evaluation of some selected management practices against whitefly, *Bemisia tabaci* Genn. on okra.

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, during March to July, 2007 to evaluate some management practices against whitefly, *Bemisia tabaci* transmitting *Okra yellow vein clearing mosaic virus* (O_kYVCMV) on okra.

3.2.1. Land preparation and design of the experiment

The land was well prepared for ensuring good tilth. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.The plots (3m x 2m) were made ready as per treatment design with marking rows maintaining spacing (30 cm x 10 cm) for commercial okra cultivation.

3.2.2. Materials used in the experiment

Choice Dherosh (Lal Teer), the most susceptible variety of okra was used in the present study.

3.2.3. Treatments of the experiment

The experiment was comprised of five treatments including a untreated control plot. The treatments of the experiment were assigned as follows:

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval

T_2= Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval

T_3= Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval

T_4= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval

T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval

T_6= Untreated control

3.2.4. Seed sowing and cultural practices

Seeds of okra variety Choice Dherosh (Lal Teer) were directly sown on the 5th April, 2007 in thee main field as mentioned in the earlier experiment and proper intercultural operations were done for proper growth of the plants.

3.2.5. Procedure of spray application

Insecticides were procured from local market. The spray solutions at the pre-fixed concentration of the respective treatments were prepared in Knapsack sprayer by mixing with water as required just before spraying in the afternoon. The spray solutions thus prepared and sprayed in the assigned plots as per the treatment design. The spraying was always done in the afternoon to avoid bright sunlight. The spray materials were applied uniformly to obtain complete coverage of whole plants of the assigned plots. Caution was taken to avoid any drift of the spray mixture to the adjacent plots at the time of the spray.

3.2.6. Data collection and calculation

The data were recorded at 7 days interval during different growth stages of the crop. Five plants were randomly selected in each replication for each of six treatments for recording the data, in which one plants were selected from each row.

3.2.6.1. Treatment effects on whitefly population and O_kYVCMV infection

The population of adult whitefly per 5 plants was recorded by counting through direct turn method at very early in the morning and the average values were calculated. Percent O_kYVCMV infected plants and leaves were sorted on the basis of number of O_kYVCMV infected plants and leaves, respectively. The percent whitefly population reduction over control was calculated by using the following formula (Khosla 1997):

$$\text{Percent population reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of treated plots

X_2 = the mean value of untreated plots

3.2.6.2. Treatment effects on plant growth parameters of okra

For plant yield contributing characters, the data on plant height, number of branch and leaf per plant number of fruit per plant, length of individual fruit and weight of the fruits were recorded. The yield data were also recorded. The percent increase or decrease in yield over control was also calculated as follows (Khosla 1997):

$$\text{Percent yield increase/decrease over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of treated plots

X_2 = the mean value of untreated plots

3.2.7. Economic analysis of the treatments

Economic analysis in terms of benefit cost ratio (BCR) was analyzed on the basis of total expenditure of the respective management practice along with the total return from that particular treatment for a hectare of land:

3.2.7.1. Treatment wise management cost/variable Cost: The cost was calculated by adding all costs incurred for labours and inputs for each management treatment including untreated control during the entire cropping season. The plot yield (kg/plot) of each treatment was converted into kg/ha.

3.2.7.2. Gross Return (GR): The yield in terms of money that was measured by multiplying the total yield by the unit price of okra (Tk 14/kg).

3.2.7.3. Net return (NR):

The net return was calculated by subtracting treatment wise management cost from gross return.

3.2.7.4. Adjusted net return (ANR):

The adjusted net return was determined by subtracting the net return for a particular management treatment from the net return with control plot. Finally, BCR for each management treatment was calculated by using the following formula described by Elias and Karim (1984):

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}}$$

3.2.8. Statistical analysis

The collected data were analyzed through MSTAT-C software in single factor RCBD, and DMRT was used to separate means. Correlations were also performed to see the relationship among different parameters.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present study comprising two sets of experiments were conducted to evaluate different okra varieties/genotypes against whitefly, *Bemisia tabaci* for resistance source(s) as well as to find out the most effective treatments among some selected management practices against the pest during March to July, 2007 in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

Experiment 1: Field screening of four okra varieties/genotypes for resistance against whitefly, *Bemisia tabaci* Genn.

4.1.1 Incidence of whitefly at different days after sowing

Statistically significant differences were found in respect of incidence of adult whitefly among different okra varieties at different days after sowing of the okra seeds (Table 5).

At 19 days after sowing (DAS), the highest number (17.33) of whitefly adult per 5 plants was recorded in the okra variety Choice Dherosh. This was statistically different from all other varieties followed by BARI Dherosh 1 (11.33 adults/5 plants) and BU Dherosh 1 (11.00 adults/5 plants), where both are statistically similar with each other. But the lowest number (6.00) of adult whitefly was recorded in Hybrid Dherosh. As a result, the order of trends of prefence by adult whitefly among four okra varieties was Choice Dherosh > BARI Dherosh 1 > BU Dherosh > Hybrid Dherosh.

More or less similar trends of the results regarding the incidence of adult whitefly by number were also observed at 26, 33, 40 and 47 DAS, where the highest number (35, 86.67, 111.67 and 87.33, respectively) of whitefly adults per 5 plants were observed in the variety Choice Derosh followed by BARI Derosh-1 (24.33, 53.67, 42.00 and 25.33 adult/5 plants, respectively) and BU Dherosh 1 (22.33, 48.00, 38.00 and 25.33 adult/5 plants, respectively). But the lowest number (15.67, 27.67, 17.67 and 14.67 adult/5 plants, respectively) of whitefly adult was observed in the variety Hybrid Derosh.

On an average, the highest number of whitefly adult per 5 plants was also recorded in the variety Choice Derosh (67.60), which was significantly different from other varieties and the lowest number (16.34) of whitefly adult per 5 plants was observed on Hybrid Derosh followed by BARI Dherosh 1 (31.33 adults/5 plants), which was also statistically similar with BU Dherosh 1 (28.93 adults/5 plants). As a results, the order of trends of resistance among four okra varieties in terms of adult whitefly incidence was Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh.

Table 5. Incidence of whitefly adult on four okra varieties throughout the cropping season during Kharif season, 2007

Varieties	Whitefly adult (No./5 plants)					
	19 DAS	**26 DAS**	**33 DAS**	**40 DAS**	**47 DAS**	**Mean**
BU Dherosh-1	11.00 b	22.33b	48.00b	38.0b	25.33b	28.93 b
BARI Dherosh-1	11.33 b	24.33b	53.67b	42.0b	25.33b	31.33 b
Hybrid Dherosh	6.00 c	15.67c	27.67c	17.67c	14.67c	16.34 c
Choice Dherosh	17.33 a	35.00a	86.67a	111.67a	87.33a	67.60 a
CV (%)	21.53	10.51	7.71	15.02	19.73	14.75
$LSD_{(0.05)}$	4.48	4.744	7.928	2.725	2.234	4.72

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

From the above findings it is revealed that among four okra varieties, Hybrid Dherosh performed as the least preferred host in respect of incidence of adult whitefly (6.00 to 14.67 adults /5 plants) followed by BU Dherosh 1 (11.00 to 25.33 adults/5 plants) and BARI Dherosh 1 (11.33 to 25.33 adults/ 5 plants) throughout the cropping season (Table 5). But the okra variety Choice Dherosh performed as the most preferred host (17.33 to 87.33 adults/5 plants). As a result, the order of trends of susceptibility of different okra varieties/genotypes tested in this observation in respect of incidence of adult whitefly is Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh. More or less similar work was done by Parvin (2004) and she reported that BARI Dherosh 1 performed at the least preferred and Local -1 as the most preferred host in terms of incidence adult whitefly in the okra field.

4.1.2. Incidence of O_kYVCMV infection

Statistically significant variations were observed in respect of O_kYVCMV infected leaves (Table 6) and plants (Table 7) among different okra varieties.

4.1.2.1. Incidence of O_kYVCMV infected leaves at different days after sowing

At 19 days after sowing (DAS) seeds, the highest percent (2.50) O_kYVCMV infected leaves per 5 plants was recorded in the okra variety Choice Dherosh (Plate 2). This was statistically different from all other varieties followed by BARI Dherosh 1 (1.00%) and BU Dherosh 1 (0.80%), where both are statistically similar with each other. But no incidence (0.00%) of O_kYVCMV infected leaves was observed in Hybrid Dherosh (Plate 3). As a result, the order of trends of susceptibility among four okra varieties in terms of incidence of O_kYVCMV infected leaves was Choice Dherosh > BARI Dherosh 1 > BU Dherosh > Hybrid Dherosh.

Plate 2. Severely infected okra variety Choice Dherosh by O_kYVCMV

Plate 3. Highly resistant okra variety Hybrid Dherosh to whitefly as well as O_kYVCMV

More or less similar trends of the results regarding the percent incidence of O_kYVCMV infected leaves were also observed at 26, 33, 40 and 47 DAS, where the highest percent (8.57%, 16.35%, 24.30% and 33.08%, respectively) of incidence of O_kYVCMV infected leaves per 5 plants were observed in the variety Choice Derosh. This was statistically different from all other varieties and followed by BARI Derosh-1 (3.5%, 6.78%, 8.40% and 11.47%, respectively). This was also followed by BU Dherosh 1 (1.60%, 4.01%, 6.89% and 8.67%, respectively). But the lowest percentages (0.50%, 1.00%, 2.00% and 2.50%, respectively) of incidence of O_kYVCMV infected leaves were observed in the variety Hybrid Derosh.

Considering the average incidence of O_kYVCMV infected leaves throughout the cropping season, more or less similar trend of incidence of O_kYVCMV was also observed and the highest percentage (16.96%) of incidence of O_kYVCMV infected leaves was recorded in the variety Choice Derosh. This was significantly different from other varieties followed by BARI Dherosh 1 (5.69%) and BU Dherosh 1 (4.39%). But the lowest percentage (1.20%) of incidence of O_kYVCMV infected leaves recorded in Hybrid Derosh. So, the order of trends of resistance among four okra varieties in terms of incidence of O_kYVCMV infected leaves was Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh.

Table 6. Incidence of O_kYVCMV infected leaves among four okra varieties throughout the cropping season during Kharif, 2007

Varieties	% O_kYVCMV infected leaf					
	19 DAS	26 DAS	33 DAS	40 DAS	47 DAS	Mean
BU Dherosh-1	0.80b	1.60 c	4.01 c	6.89 b	8.67 c	4.39 b
BARI Dherosh-1	1.00b	3.5 b	6.78 b	8.4b b	11.47 b	5.69 b
Hybrid Dherosh	0.00 c	0.50 d	1.00 d	2.00 c	2.50 d	1.20 c
Choice Dherosh	2.50 a	8.57a	16.35 a	24.3 a	33.08 a	16.96 a
CV (%)	20	21.66	18.46	22.65	12.89	16.07
$LSD_{(.05)}$	0.75	0.95	1.12	3.38	1.88	1.66 a

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

4.1.2.1. Incidence of O_kYVCMV infected plants at different days after sowing

At 19 days after sowing (DAS) seeds, the highest percent (35.00 %) O_kYVCMV infected plants per 5 plants was recorded in the okra variety Choice Dherosh which was statistically different from all other varieties. This was followed by BARI Dherosh 1 (5.00 %) and BU Dherosh 1 (3.00 %), where both are statistically similar with each other. But no incidence (0.00%) of O_kYVCMV infected plants was observed in Hybrid Dherosh. So, the order of trends of results regarding the susceptibility of different okra varieties in terms of percent incidence of O_kYVCMV infected plants is Choice Dherosh > BARI Dherosh 1 > BU Dherosh 1> Hybrid Dherosh.

More or less similar trends of the results regarding the percent incidence of O_kYVCMV infected plants were also observed at 26, 33, 40 and 47 DAS, where the highest percent (65.00%, 82.00%, 90.00% and 100.00%, respectively) of incidence of O_kYVCMV infected plants per/plot were observed in the variety Choice Dherosh. This was statistically different from all other varieties and followed by BARI Dherosh-1 (14.00%, 23.00%, 30.00% and 35.00%, respectively) and also followed by BU Dherosh 1 (10.00%, 15.00%, 18.00% and 30.00%, respectively). But the lowest percentages (5.00%, 9.50%, 14.60% and 19.00%, respectively) of incidence of O_kYVCMV infected plants were observed in the variety Hybrid Dherosh.

Considering the average incidence of O_kYVCMV infected plants throughout the cropping season, apparently similar trend of results was observed.The highest percentage (74.40%) of incidence of O_kYVCMV infected plants was recorded in the variety Choice Dherosh. This was significantly different from other varieties and followed by BARI Dherosh 1 (21.40%) and BU Dherosh 1 (15.20%). But the lowest percentage (8.36%) of incidence of O_kYVCMV infected plants recorded in Hybrid Dherosh. As a result, the order of trends of results regarding resistance or susceptibility of different okra varieties in terms of incidence of percentage of incidence of O_kYVCMV infected plants per/plot is Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh.

Table 7. Incidence of O_kYVCMV infected plants/plot among four okra varieties throughout the cropping season during Kharif, 2007

Varieties	% O_kYVCMV infected plants/plot					
	19 DAS	26 DAS	33 DAS	40 DAS	47 DAS	Mean
BU Dherosh 1	3.00 b	10.00 bc	15.00 c	18.00 c	30.00 b	15.2 bc
BARI Dherosh 1	5.00 b	14.00 b	23.00 b	30.00 b	35.00 b	21.4 b
Hybrid Dherosh	0.00 c	5.00 c	9.50 c	14.6.0 c	19.00 c	8.36 c
Choice Dherosh	35.00 a	65.00 a	82.00 a	90.00 a	100.00 a	74.4 a
CV (%)	22	21	20	21	19	20
$LSD_{(.05)}$	2.5	8	7.5	11	10	10.5

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

4.1.3. Relationship between incidence of adult whitefly and %OkYVCMV infected leaf among different okra varieties

Correlation study was done to establish the relationship between the incidence of adult whitefly and %OkYVCMV infected leaf among different okra varieties.

From the study it was revealed that positive correlation was observed between the parameters (Figure 1). It was evident from the Figure 1 that the equation y = 1.0487x - 4.4 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9986) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that %OkYVCMV infected leaf was strongly as well as positively correlated with the incidence of adult whitefly, i.e., the incidence of OkYVCMV infected leaf increased with the increase of incidence of adult whitefly among different okra varieties.

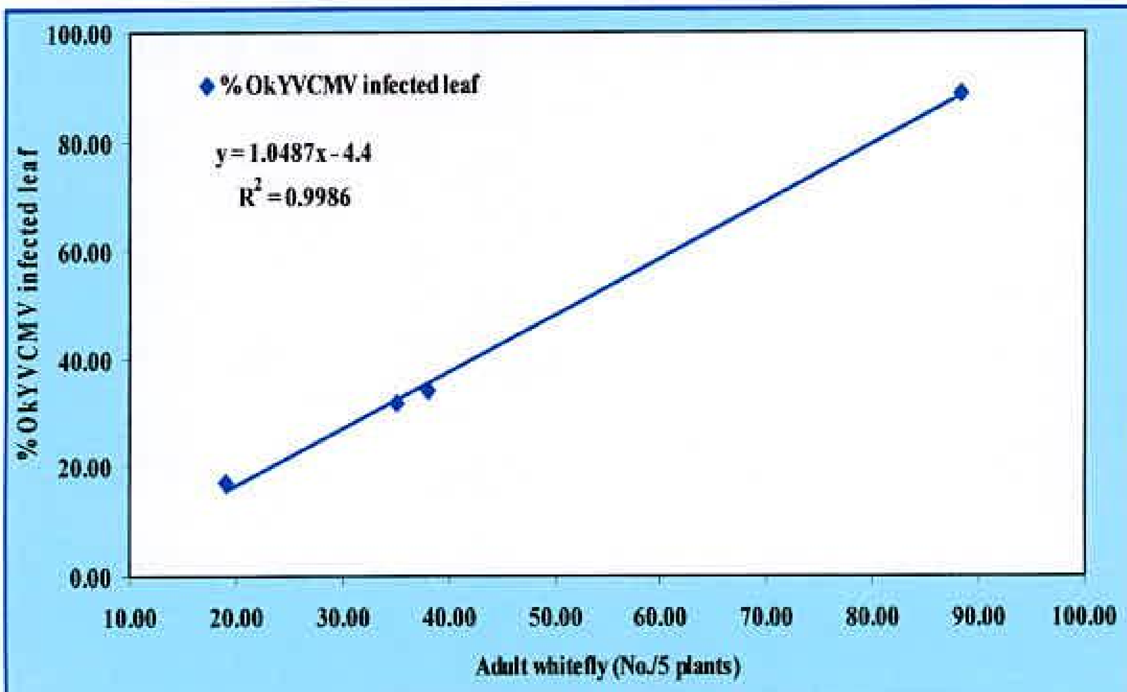

Figure 1. Relationship between incidence of adult whitefly and % OkYVCMV infected leaf among different okra varieties

4.1.4. Relationship between incidence of adult whitefly and %OkYVCMV infected plant among different okra varieties

Correlation study was done to establish the relationship be tween the incidence of adult whitefly and %OkYVCMV infected plant among different okra varieties.

From the study it was revealed that significant correlation was observed between the parameters (Figure 2). It was evident from the Figure 2 that the equation $y = 0.9693x - 3.17$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9981$) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that %OkYVCMV infected plant was strongly as well as positively correlated with the incidence of adult whitefly, i.e., the incidence of OkYVCMV infected plant increased with the increase of incidence of adult whitefly among different okra varieties.

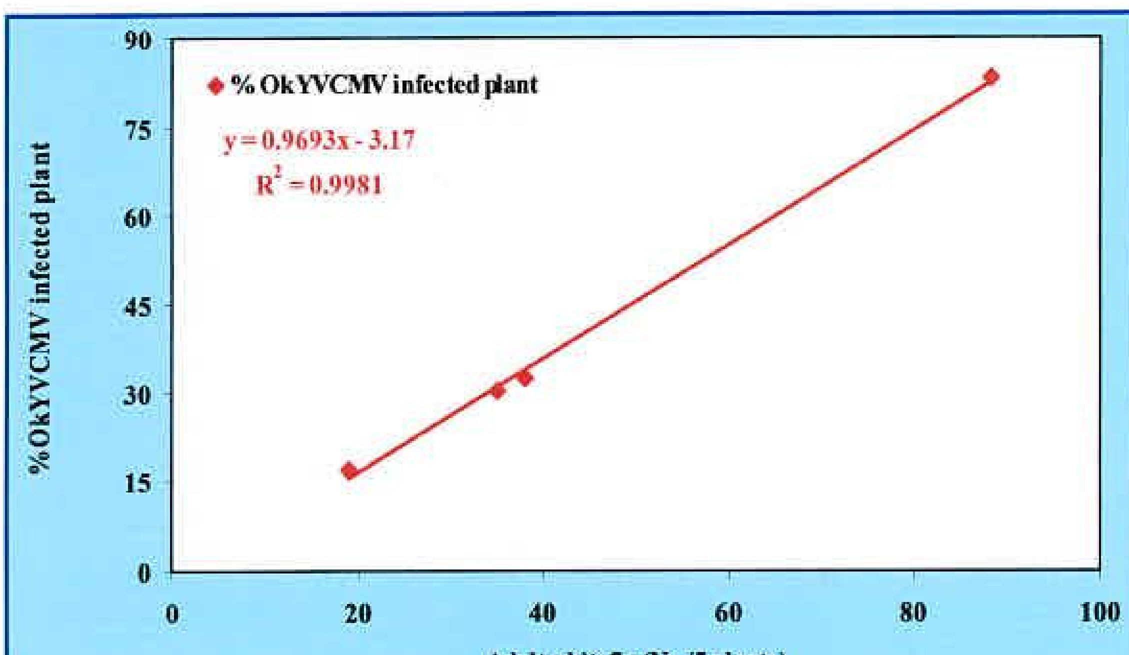

Figure 2. Relationship between incidence of adult whitefly and % OkYVCMV infected plant among different okra varieties

From figure 1 and 2 it is revealed that among four okra varieties, Hybrid Dherosh performed as the least susceptible host in respect of incidence of O_kYVCMV infected leaves (0.00 to 2.50%) followed by BU Dherosh 1 (0.80 to 8.67%) and BARI Dherosh 1 (1.00 to 11.47%) throughout the cropping season. But the okra variety Choice Dherosh performed as the most preferred host (2.50 to 33.08%). Considering the incidence of O_kYVCMV infected plants among four okra varieties, Hybrid Dherosh performed as the least susceptible host (0.00 to 19.00%) followed by BU Dherosh 1 (3.00 to 30.00%) and BARI Dherosh 1 (5.00 to 35.00%) throughout the cropping season. But the okra variety Choice Dherosh performed as the most preferred host (35.00 to 100.00%). As a result, the order of trends of susceptibility of different okra varieties/genotypes tested in the present study in respect of incidence of both O_kYVCMV infected leaves and plants is Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh. The incidence of adult whitefly is strongly as well as positively correlated to the incidence of both O_kYVCMV infected leaves ($r = 0.9986$) and plants ($r = 0.9981$). About similar works had been done by several workers. Ali (1999) reported that BU Dherosh (Okra-1) showed resistant against *Okra yellow vein clearing mosaic virus.* In India, Joshi *et al.* (1960) recommended the okra variety Pusa Sawani as resistant to O_kYVCMV. Mohapatra *et al.* (1995) reported that among different improved varieties of okra, Pusa Sawani was found as the most susceptible variety and recorded 100% infection while varieties like HRB -9-2, DOV-91-4 and Pashupati showed tolerance at least under field conditions.

It was reported by Singh (2000) that Perbani Kranti was found to be resistant to *Yellow vein mosaic virus* which transmits by whitefly *B. tabaci.* Parvin (2004) and Begum

(2002) reported that the incidence of whitefly population in the field of okra was positively correlated to the incidence of O_kYVCMV infection.

4.1.4 Yield attributes of different okra varieties/genotypes

Significant variations were observed in terms of number of fruit/plant, number of fruit/plot, weight of single fruit (gm), single fruit length (cm) of different okra varieties/genotypes under the present trial represented in Table 8.

Considering the number of fruit per plant, the largest number (14.333) of fruit per plant was recorded in the variety Hybrid Dherosh, which was statistically similar with the variety BU Dherosh-1 (13.73) and the lowest number (8.4) of fruit per plant was recorded in the variety Choice Dherosh. This was statistically similar with the variety BARI Dherosh-1 (9.6). Similarly, the highest number (401.7) of fruit per plot was recorded in the variety Hybrid Dherosh, which was statistically similar with the variety BU Dherosh-1 (384.0). But the lowest number (213.3) of fruit per plot was recorded in the variety Choice Dherosh, which was statistically similar with the variety BARI Dherosh-1 (249.7). In case of single fruit weight (gm), the highest single fruit weight was recorded in Hybrid Dherosh (16.97 gm), which was statistically identical with the variety of BU Dherosh-1 (15.85 gm) and BARI Dherosh-1 (14.497 gm). On the other hand, the lowest single fruit weight was recorded in Choice Dherosh (12.17 gm). In terms of single fruit length (cm) no significant difference was observed among different okra varieties (Table 8).

Table 8. Yield attributes of four okra varieties throughout the cropping season during Kharif, 2007

Varieties	No. of fruit/plant	No. of fruit/plot	Single fruit weight (gm)	Single fruit length (cm)
BU Dherosh 1	13.73 a	384.0a	15.85 ab	12.54 a
BARI Dherosh 1	9.60 b	249.7b	14.50 ab	12.23 a
Hybrid Dherosh	14.33 a	401.7a	16.97 a	13.55 a
Choice Dherosh	8.40 b	213.3b	12.17 b	11.99 a
CV (%)	10.2	10.06	12.78	6.75
$LSD_{(.05)}$	2.348	62.76	3.797	1.695

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

4.1.5 Yield of different okra varieties/genotypes

As depicted in Table 9, at early fruiting stage, the highest weight (588.5 gm) of fruit per plot was recorded in the variety Hybrid Dherosh, which was statistically different from all other varieties. This was followed by BARI Dherosh-1 (436.8 gm), BU Dherosh-1 (347.2 gm) respectively. But the lowest weight (330.2 gm) of fruit per plot was recorded in Choice Dherosh. More or less similar trends of fruit weight per plot were also observed at mid and late fruiting stage and also total fruit weight throughout the cropping season. The highest yield was recorded in the variety Hybrid Dherosh (7210.3 kg/ha), which was statistically different from all other varieties. This was followed by BU Dherosh-1 (5735.6 kg/ha), the variety BARI Dherosh-1 (3949.3 kg/ha) respectively. On the other hand, the lowest fruit yield was recorded in the variety Choice Dherosh (3380.6 kg/ha). As a result, the order of yield performance of four okra varieties was Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh.

Table 9. Yield of four okra varieties throughout the cropping season during Kharif, 2007

Varieties	Weight of fruit/plot (gm)				Yield (kg/ha)
	Early fruiting	Mid fruiting	Late fruiting	Total fruit (kg)	
BU Dherosh 1	347.2 c	1579.0 b	1515.0 b	3.44 b	5735.6 b
BARI Dherosh 1	436.8 b	862.5 c	1064.0 c	2.367 c	3949.3 c
Hybrid Dherosh	588.5 a	2002.0 a	1743.0 a	4.32 a	7210.3 a
Choice Dherosh	330.2 c	757.8 d	946.1 d	2.03 d	3380.6 d
CV (%)	3.33	1.32	1.41	1.12	1.15
$LSD_{(0.05)}$	28.36	34.3	36.99	0.06318	116.1

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different ($P>0.05$) from each other by DMRT

4.1.4. Relationship between incidences of O_kYVCMV infected plants and yield of four okra varieties

Correlation study was done to establish the relationship between the incidences of OkYVCMV infected plants and yield of different okra varieties. From the study it was revealed that significant correlation was observed between the parameters (Figure 3). It was evident from the Figure 3 that the equation $y = -47.231x + 6984.6$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.6216$) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that %O_kYVCMV infected plant was negatively correlated to the yield of different okra varieties, i.e., the yield decreased with the increase of the incidence of O_kYVCMV infected plant.

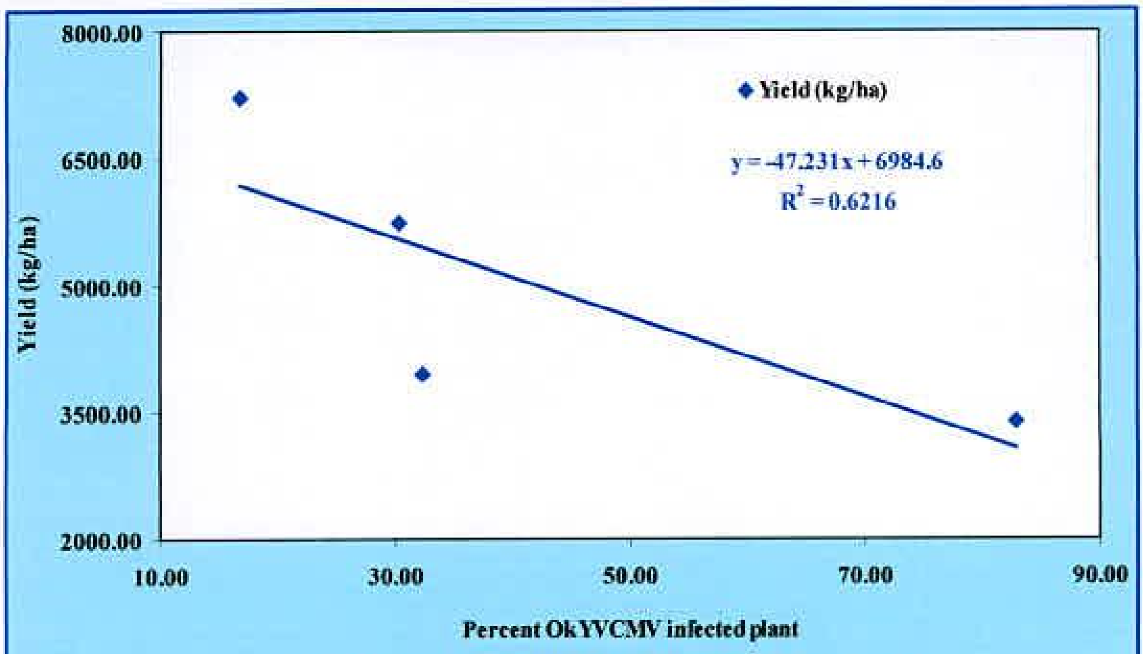

Figure 3. Relationship between incidence O_kYVCMV infected plants and yield of different okra varieties

From the above findings it is revealed that among four okra varieties, the maximum number of fruit per plant (14.33) and single fruit weight (16.97 gm) as well as the highest yield (7210.3 kg/ha) were produced by the whitefly and O_kYVCMV resistant variety Hybrid Dherosh, while the minimum number of fruit per plant (8.40) and single fruit weight (12.17 gm) as well as the lowest yield (3380.60 kg/ha) were produced by the susceptible variety Choice Dherosh. As a result, the order of trends of performance of four okra varieties in relation to yield and yield attributes was Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh. The incidence of O_kYVCMV infected plants was negatively (r = 0.6216) correlated to the yield of different okra varieties. Parvin (2004) reported about similar results and she stated that the percent reduction of selected growth, yield and yield contributing characters were found to be varied depending on different okra varieties.

Experiment 2: Evaluation of some selected management practices against whitefly, *Bemisia tabaci* Genn. on okra

The experiment was conducted to evaluate the efficacy of some selected insecticides against whitefly, *Bemisia tabaci* Genn. on okra during March to July, 2007 in the experimental field of the SAU, Dhaka. The results of the study have been presented and discussed with interpretations under the following sub-headings:

4.2.1 Effect of different management practices on the incidence of adult whitefly and O_kYVCMV infection on okra

Significant differences were observed on the effects of different treatments applied against whitefly, *Bemisia tabaci* infesting okra variety Choice Dherosh (Table 10).

4.2.1.1 Effect on the incidence of adult whitefly

As depicted in Table 10, the highest number (55.33) of adult whitefly per 5 plants was observed in T_6 (untreated control), which was statistically different from all other treatments and followed (42.00 adults/5 plants) by T_3 (spraying of Marshal 100 EC @ 1.5 ml/liter of water). This was also followed (30.67 adults/5 plants) by T_5 (spraying of Malathion 57 EC @ 2.0 ml/liter of water). On the other hand, the lowest number (12.27) of whitefly adult per 5 plants was recorded in T_1 (spraying of Admire 200 SL @ 0.2 ml/liter of water) followed (16.20 adults/5 plants) by T_4 (spraying of Neem oil @ 3.0 ml/liter of water) and T_2 (spraying of Ripcord 10 EC @ 1.5 ml/liter of water). Considering the percent reduction of incidence of adult whitefly over control, the maximum reduction (79.63%) was recorded in T_1 and the minimum reduction (24.09%) over control was recorded in T_3. As a result, the order of trends of effectiveness of different management practices in respect of incidence of adult whitefly infesting okra was $T_1 > T_4 > T_2 > T_5 > T_3 > T_6$.

Table 10. Effect of different management practices on the incidence of adult whitefly infesting on okra

Treatments	Mean incidence of adult whitefly	
	Adult whitefly (No./5 plants)	% reduction over control
T_1	11.27 de	79.63
T_2	18.87 d	65.90
T_3	42.00 b	24.09
T_4	16.20 d	70.72
T_5	30.67c	44.57
T_6	55.33 a	79.63
CV (%)	7.24	-
$LSD_{(0.05)}$	6.553	-

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval
T_2 = Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval
T_3 = Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval
T_4 = Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval
T_5 = Spraying of Malathion @ 2.0 ml/L of water at 7 days interval
T_6 = Untreated control

From the above findings it is revealed that T_1 (spraying of Admire 200 SL [Imidacloprid] @ 0.2 ml/liter of water) performed as the best treatment in reducing the incidence of adult whitefly infesting okra and T_3 performed as the least effective treatment. Similar works were done by Khan and Mukhopadhyay (1985b) and they reported that the soil application of methyl phosphorodithioate (Furtox 10G) reduced average whitefly population to 59.66 (from 231) per plant and enhanced yield to 59.45 kg/ha (from 23.8). Alatorre *et al*. (1995) and Marcano *et al*. (1993) also reported the Imidacloprid performed as the most effective insecticide in reducing the incidence of *Bemisia tabaci* on okra.

Miah *et al.* (1988) reported that among 19 insecticides, Bidrin, Ripcord performed as effective against whitefly on okra.

4.2.1.2 Effect on the incidence of O_kYVCMV infection

Significant differences were also observed on the effects of different management practices in respect of incidence of O_kYVCMV infected leaves and plants of okra (Table 11).

4.2.1.2.1 Effect on the incidence of O_kYVCMV infected leaf

In case of the incidence of O_kYVCMV infected leaves, the highest percentage (27.80%) of the incidence of O_kYVCMV infected leaves was recorded in T_6 (untreated control), which was followed by T_3 (21.10%) and the treatment T_5 (17.80%) and T_2 respectively. On the other hand, the lowest percentage (6.49%) of the incidence of O_kYVCMV infected leaves was recorded in T_1 followed by T_4 (12.77%). Considering the percent reduction of the incidence of O_kYVCMV infected leaves over control, the maximum reduction (76.65%) was recorded in T_1 and the minimum reduction (24.10%) over control was recorded in T_3. As a result, the order of trends of effectiveness of different management practices in respect of the incidence of O_kYVCMV infected leaves is $T_1 > T_4 > T_2 > T_5 > T_3 > T_6$.

4.2.1.2.2 Effect on the incidence of O_kYVCMV infected plant

In case of the incidence of O_kYVCMV infected plant, the highest percentage (80.60%) of the incidence of O_kYVCMV infected plants was recorded in T_6 (untreated control), which was statistically different from all other treatments. This was followed by T_3 (71.00%). This was also followed by T_5 (55.00%). This was also followed by T_2 (40.00%). On the other hand, the lowest percentage (10.00%) of the incidence of O_kYVCMV infected plants was recorded in T_1 followed by T_4 (19.00%). Considering the percent reduction of the incidence of O_kYVCMV infected plants over control, the maximum reduction (87.59%) was recorded in T_1 and the minimum reduction (11.91%) over control was recorded in T_3. As a result, the order of trends of effectiveness of different management practices in respect of the incidence of O_kYVCMV infected plants is $T_1 > T_4 > T_2 > T_5 > T_3 > T_6$.

Table 11. Effect of different management practices on the incidence O_kYVCMV infection on okra

Treatments	Mean O_kYVCMV infected leaf (%)		Mean O_kYVCMV infected plant (%)	
	O_kYVCMV infected leaf (%)	% reduction over control	O_kYVCMV infected plant (%)	% reduction over control
T_1	6.49 e	76.65	10.00 f	87.59
T_2	15.68 c	43.60	40.00 d	50.37
T_3	21.1 b	24.10	71.00 b	11.91
T_4	12.77 d	54.06	19.00 e	76.43
T_5	17.86 c	35.76	55.00 c	31.76
T_6	27.8 a	76.65	80.60 a	87.59
CV (%)	8.61	-	18.5	-
$LSD_{(0.05)}$	2.55	-	8.5	-

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval
T_2= Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval
T_3= Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval
T_4= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval
T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval
T_6= Untreated control

From the above findings it is revealed that T_1 (spraying of Admire 200 SL [Imidacloprid] @ 0.2 ml/liter of water) performed as the best treatment in reducing (76.65% and 87.59%) the incidence of O_kYVCMV infected leaves and plants, respectively and T_3 performed as the least (24.10% and 11.91%, respectively) effective treatment. About similar works were also done by Khan and Mukhopadhyay (1985b) they reported that the soil application of methyl phosphorodithioate (Furtox 10G) reduced *Okra yellow clearing mosaic virus* disease incidence up to 23.26% (control 81.22%) and enhanced yield to 59.45 kg/ha (from 23.8).

4.2.1.3 Effect on yield attributes of okra

As depicted in Table 12, the highest height (59.63 cm) of the plant was recorded in T_1, which was statistically different from all the treatments. This treatment was followed by T_4 (55.63 cm) and T_2 (55.57 cm) respectively. On the other hand, the lowest height of the plant was recorded in T_6 (45.7 cm), which was statistically similar with T_3 (46.63 cm) and T_5 (47.63 cm) respectively. Considering the number of branch per plant, the maximum number of branch per plant was recorded in T_1 (2.04), which was statistically different from all of the treatments. But the minimum number (1.27) of branch per plant was recorded in T_6, which was statistically similar with T_3, T_5, T_2 and T_4. In terms of number of fruit per plant, maximum number (18.07) of fruit per plant was recorded in T_1, which was statistically different from the other treatments and followed by T_4 (15.53) and T_2 (14.73) respectively. On the other hand, the minimum number (10.27) of fruit per plant was recorded in T_6 (untreated control) followed by T_3 (12.93) and T_5 (13.60) respectively. Considering the single fruit length in centimeter, there was no significant difference was observed on different treatments.

Table 12. Effect of different management practices on yield attributes of okra during the management of whitefly

Treatments	Height of plant (cm)	Branch/plant (No.)	Fruit/plant (No.)	Single fruit length (cm)
T_1	59.63 a	2.04 a	18.07 a	12.23 a
T_2	55.57 b	1.45 b	14.73 bc	11.90 a
T_3	46.63 c	1.28 b	12.93 d	11.60 a
T_4	55.63 b	1.48 b	15.53 b	12.10 a
T_5	47.63 c	1.44 b	13.60 cd	11.77 a
T_6	45.70 c	1.27 b	10.27 e	11.33 a
CV (%)	2.31	18.39	5.45	4.23
$LSD_{(.05)}$	2.175	0.4982	1.406	0.9096

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval
T_2= Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval
T_3= Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval
T_4= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval
T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval
T_6= Untreated control

4.2.1.4 Effect on the yield of okra

Significantly differences on the effects of different management practices in terms of yield of okra were observed during the management of whitefly. The results depicted in table 13, at early fruiting stage, the highest weight (452.1 gm) of fruit per plot were observed in $T_{1,\ \text{which}}$ was statistically different from all other treatments. This was followed by T_4 (364.1 gm) and T_2 (347.2 gm) respectively. On the other hand, the lowest weight (174.2 gm) of fruit per plot was observed in T_6 (untreated control treatment). This was followed by T_3 (259 gm) and T_5 (289.7 gm) respectively. Again at mid fruiting stage, the highest weight (2067 gm) of fruit per plot was observed in $T_{1,}$ which was statistically different from all other treatments followed by T_4 (1579 gm), T_2 (1169 gm) and T_5 (1116 gm) respectively. On the other hand, the lowest weight (871.9 gm) of fruit per plot was observed in T_6 (untreated control treatment) followed by T_3 (980.1 gm). More or less similar trend was results was also observed at late fruiting stage in respect of weight of fruit per plot, the highest weight (1710 gm) was observed in T_1 which was statistically different from all other treatments. This was followed by T_4 (1607 gm), (1518 gm) and T_5 (1508 gm) respectively. On the other hand, the lowest weight (971.3 gm) was observed in T_6 (untreated control treatment) followed by T_3 (1173 gm).

In terms of total weight of fruit per plot, the highest weight was recorded in T_1 (4.23 kg) which was statistically different from all other treatments. This was followed by T_4 (3.44 kg) and T_2 (3.03 kg). On the other hand, the lowest weight (1.68 kg) was observed in T_6 (untreated control treatment) followed by T_3 (2.75 kg) and T_5 (2.82 kg) respectively. Considering the yield (kg/ha), the highest yield was recorded in T_1 (7048.83 gm), which was statistically different from all other treatments. This was followed by T_4 (5735.61 gm). On the other hand, the lowest yield (3362.22 gm) was recorded in T_6 (untreated control treatment) followed by T_3 (4628.94 gm), T_5 (4701.22 gm) and T_2 (5057.89 gm) respectively. In terms of percent increase of the yield over control, the highest percent yield increase (109.65%) over control was recorded in T_1 and followed by T_4 (70.59%), whereas the lowest percent yield increase (37.68%) over control in T_3 followed by T_5 (39.82%). As a result, the order of trends of effectiveness of different management practices in increasing yield of okra is $T_1 > T_4 > T_2 > T_5 > T_3 > T_6$.

Table 13. Effect of different management practices on the yield of okra by weight

Treat ment	Weight of fruit (gm/plot)				Yield (g/ha)	Yield increase over control (%)
	Early fruiting	Mid fruiting	Late fruiting	Total wt. of fruit (kg/plot)		
T_1	452.1 a	2067 a	1710 a	4.23 a	7048.83 a	109.65
T_2	347.2 b	1169 c	1518 c	3.03b c	5057.89 c	50.43
T_3	259 d	980.1 d	1173 d	2.75 c	4628.94 c	37.68
T_4	364.1 b	1579 b	1607 b	3.44 b	5735.61 b	70.59
T_5	289.7 c	1116 c	1508 c	2.82 c	4701.22 c	39.82
T_6	174.2 e	871.9 e	971.3 e	1.68 d	3362.22 d	-
CV (%)	3.55	4.3	2.32	8.52	5.12	-
$LSD_{(.05)}$	20.31	101.5	59.7	0.4456	474.0	-

Figures indicate original means of three replications
Means followed by same letter(s) are not significantly different (P>0.05) from each other by DMRT

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval
T_2= Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval
T_3= Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval
T_4= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval
T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval
T_6= Untreated control

From the above findings it is revealed that T_1 (spraying of Admire 200 SL [Imidacloprid] @ 0.2 ml/liter of water) performed as the best treatment in respect of yield increase (109.65%), whereas T_3 (spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval) performed as the least (37.68% yield increase over control) effective treatment. About similar works were also done by Khan and Mukhopadhyay (1985b) and they reported that the soil application of methyl phosphorodithioate (Furtox 10G) enhanced yield to 59.45 kg/ha (from 23.8) by reducing the incidence of *Okra yellow clearing mosaic virus* disease up to 23.26% (control 81.22%).

4.2.2 Economic analysis of different management practices

In the present study the plot of untreated control (T_6) did not require any pest management cost, but rest of the treatments needed different amount of management costs for controlling whitefly infesting okra. All these costs were calculated per hectare basis. The labor costs were involved in T_1, T_2, T_3, T_4 and T_5 for spraying insecticides. The cost of chemicals involved in different management practices has been shown in Appendix III.

Table 14. Economic analysis of different management practices applied against whitefly on okra during Kharif season, 2007

Treatments	Spray required (No.)	Cost of pest management (Tk.)	Yield (kg/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted return net (Tk.)	BCR
T_1	5.00	9238.89	7048.83	98683.62	89444.73	42373.65	4.59
T_2	5.00	12850.00	5057.89	70810.46	57960.46	57960.46	4.51
T_3	5.00	12850.00	4628.94	64805.16	51955.16	51955.16	4.04
T_4	5.00	7850.00	5735.61	80298.54	72448.54	72448.54	9.23
T_5	5.00	12016.67	4701.22	65817.08	53800.41	53800.41	4.48
T_6	5.00	0.00	3362.22	47071.08	47071.08		

T_1= Spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval; T_2= Spraying of Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval; T_3= Spraying of Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval; T_4= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval; T_6= Untreated control; Market price of okra, 1.0 kg = 14 Tk.

The economic analysis was done in order to find out the most profitable management practices based on cost and benefit of various components. Thus the highest BCR (9.23) was calculated in T_4 (spraying of neem oil @ 3% at 7 days interval). This was followed (4.59) by treatment T_1 (spraying of Admire 200 SL @ 0.2 ml/L of water at 7 days interval), whereas the lowest BCR was calculated in T_3 (spraying of Marshal 100 EC @ 1.5 ml/liter of water at 7 days interval). But considering the national demand regarding the total yield, T_1 is the most effective treatment which enhanced to produce maximum yield of okra by reducing the incidence of adult whitefly as well as O_kYVCMV infection.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted to find out the resistance sourc(s) among four okra varieties against whitefly, *Bemisia tabaci*. Evaluation was also made with of different management practices to suppress the whitefly infestation as well as whitefly transmitted *Okra yellow vein clearing mosaic virus* (O_kYVCMV) on okra in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during March to July 2007. Four insecticides and one Neem products were considered as management practices including one untreated control. Data were collected on the incidence of adult whitefly, O_kYVCMV infected leaves and plants; yield and yield attributes of okra varieties as well as benefil cost ratio (BCR) of different management practices applied against whitefly on okra.

Considering the performance of four okra varieties against whitefly, variety Hybrid Dherosh performed as the least preferred host in respect of incidence of adult whitefly (16.34 adults/5 plants) followed by BU Dherosh 1 (28.93 adults/5 plants) and BARI Dherosh 1 (31.33 adults/ 5 plants). But the okra variety Choice Dherosh performed as the most preferred host (67.60 adults/5 plants).

Response of incidence to O_kYVCMV infection among four okra varieties, Hybrid Dherosh was also performed as the least susceptible host in respect of incidence of O_kYVCMV infected leaves (1.20%) and plants (9.60%) followed by BU Dherosh 1 (4.39% and 15.20%, respectively) and BARI Dherosh 1 (5.69% and 21.40%, respectively) throughout the cropping season. But the okra variety Choice Dherosh performed as the most preferred host (16.96% and 74.40%, respectively).

As a result, it may be concluded that the order of trends of susceptibility of different okra varieties/genotypes tested in the present study in respect of resistance to the incidence of adult whitefly and O_kYVCMV infected leaves and plants is Hybrid Dherosh > BU Dherosh 1 > BARI Dherosh 1 > Choice Dherosh. The incidence of adult whitefly is strongly as well as positively correlated to the incidence of both O_kYVCMV infected leaves and plants.

Considering the yield and yield attributes of different okra varieties, the highest number of fruit per plant (14.33) and single fruit weight (16.97 gm) as well as the highest yield (7210.3 kg/ha) were produced by the whitefly and O_kYVCMV resistant variety Hybrid Dherosh, while the lowest number of fruit per plant (8.40) and single fruit weight (12.17 gm) as well as the lowest yield (3380.60 kg/ha) were produced by the susceptible variety Choice Dherosh. The incidence of O_kYVCMV infected plants was negatively correlated to the yield of different okra varieties.

Considering the efficacy of the different management practices against whitefly on okra, T_1 (spraying of Admire 200 SL [Imidacloprid] @ 0.2 ml/liter of water at 7 days interval) performed as the best treatment in reducing the incidence of adult whitefly (79.63%) as well as O_kYVCMV infected leaves (76.65%) and plants (87.59%) over control followed (70.72%, 54.06% and 76.43%, respectively) by T_4 (spraying of neem oil @ 3% at 7 days interval), whereas T_3 (spraying of Marshal 100 EC @ 1.5 ml/liter of water at 7 days interval) performed as the least (24.09%, 24.10% and 11.91%, respectivrely reduction over control) effective treatment. enhanced yield to 59.45 kg/ha (from 23.8).

In case of yield and yield attributes T_1 also performed as the best treatment in respect of yield (7048.83 kg/ha from 3362.22 kg/ha in control and 109.65% yield increase over control) of okra as well as other yield attributes such as height of plant, number of branch per plant, number of fruit per plant and T_3 performed as the least (3362.22 kg/ha) effective treatment.

In terms of economic analysis of the different management practices, T_4 (spraying of neem oil @ 3% at 7 days interval) may be considered as the most profitable treatment in respect of BCR (9.23) followed (4.59) by T_1 (spraying of Admire 200 SL @ 0.2 ml/liter of water at 7 days interval), whereas the least profitable (4.04 BCR) treatment is T_3 (spraying of Marshal 100 EC @ 1.5 ml/liter of water at 7 days interval). But considering the national demand, T_1 is the most effective treatment, which enhanced to produce maximum yield (7048.83 kg/ha) and contributed reasonable BCR (4.59).

Chapter VI

References

CHAPTER VI

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Chapter VII

Appendices

CHAPTER VII

APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from March to July 2007

Month	Air temperature (^0C)		R.H. (%)	Total rainfall (mm)
	Maximum	Minimum		
March	31.5	16.9	47	160
April	33.74	23.87	69.41	185
May	34.7	25.9	70	185
June	32.4	25.5	81	628
July	31.4	25.7	84	753

Source : Dhaka Meteorological Center

Appendix II. Results of mechanical and chemical analysis of soil of the experimental plot Mechanical analysis

Constituents	Percent
Sand	33.45
Silt	60.25
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.12
Organic carbon (%)	1.32
Total nitrogen (%)	0.08
Available P (ppm)	20
Exchangeable K (%)	0.2

Source: Soil Resource Development Institute (SRDI)

Appendix III. Cost incurred per hectare in different management practices applied against whitefly on okra during Kharif season, 2007

Treatments	Items of expenditure	Cost (Tk)
	Total no. of labors for spraying insecticides 5x70.00[a]	350.00
	Admire 1666.67 ml (for 5 sprays) x 5.33[b]	8888.89
T_1	**Total Cost**	**9238.89**
	Total no. of labors for spraying insecticides 5x70.00[a]	350.00
	Ripcord 12500 ml (for 5 sprays)x 0.7[c]	12500.00
T_2	**Total Cost**	**12850.00**
	Total no. of labors for spraying insecticides 5x70.00[a]	350.00
	Marshal 12500 ml (for 5 sprays)x 0.7[d]	12500.00
T_3	**Total Cost**	**12850.00**
	Total no. of labors for spraying insecticides 5x70.00[a]	350.00
	Neem oil 25000 ml (for 5 sprays)x 0.3[e]	7500.00
T_4	**Total Cost**	**7850.00**
	Total no. of labors for spraying insecticides 5x70.00[a]	350.00
	Malathion 16666.67 ml (for 5 sprays)x 0.7[f]	16666.67
T_5	**Total Cost**	**11666.67**
T_6 (Untreated Control)	No management cost	00.00

T_1= Admire 200 SL @ 0.2 ml/L of water at 7 days interval; T_2 = Ripcord 10 EC @ 1.5 ml/L of water at 7 days interval; T_3 = Marshal 100 EC @ 1.5 ml / liter of water at 7 days interval; T_4 = Neem oil @ 30.0 ml/L of water at 7 days interval; T_5 = Malathion @ 2.0 ml/L of water at 7 days interval; T_6 = Untreated control

[a]= Labor cost @ 70.00 Tk/day;
[b]= Admire (200 SL) 15 ml=80.00 Tk;
[c]= Ripcord (10 EC) 100 ml=100.00 Tk;
[d]= Marshal (100 EC) 100 ml=70.00 Tk;
[e]= Neem oil 1000 ml=300.00 Tk;
[f]= Malathion (57 EC) 100 ml=70.00 Tk.