DEVELOPMENT OF RED SPIDER MITE *Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae) ON DIFFERENT CUCURBITS

Thesis

Submitted to the Punjab Agricultural University in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE
in
ENTOMOLOGY
(Minor Subject : Plant Pathology)

By

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2002

DEDICATED

TO

MY RESPECTED AND

BELOVED MOTHER

SMT. SAMPURAN KAUR

CERTIFICATE I

This is to certify that the thesis entitled, **"Development of red spider mite, *Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae) on different cucurbits"** submitted for the degree of M.Sc., in the subject of Entomology (Minor subject: Plant Pathology) to the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Mr. Subash Singh (L-2000-A-36-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled, **"Development of red spider mite, *Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae) on different cucurbits"** submitted by **Mr. Subash Singh (L-2000-A-36-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of M.Sc., in the subject of Entomology (Minor subject: Plant Pathology) has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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Ludhiana,
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CHAPTER I

INTRODUCTION

Cucurbits are important group of summer vegetable crops. They belong to family Cucurbitaceae. Their fruits are a vital source of human nutrition as they provide carbohydrates, vitamins and minerals (Whittaker and Davis 1962). Cucurbits are consumed as salad, sweets, served as vegetables and also consumed as seeds. The fruits and seeds of cucurbits also have medicinal value and are used for the treatment of rheumatic pains, eczema and urinary problems (Dutta and Lal 1979). Vegetable crops occupy an area of 29937 thousand hectares in the world while in India they are cultivated in over 3615 thousand hectares. In Punjab vegetable crops are grown in an area of 110347 hectares out of which cucurbits are grown in an area of 9331 hectares which comes to about 8.45% of total area under vegetable crops in Punjab (Arya and Prakash 2002).

In Punjab, cucurbitaceous crops are mainly attacked by insect-pests such as red pumpkin beetle (*Raphidopalpa foveicollis* Linn.), red spider mite [*Tetranychus cinnabarinus* (Boisd.)] and fruit flies (*Dacus cucurbitae* Linn.) (Anonymous 2002). Red spider mites are very serious pest on different cucurbitaceous crops during hot and dry months of April, May and June in Punjab (Gupta *et al* 1972). Mites cause severe damage by piercing their styliform chelicerae into epidermis of leaf and feed upon the liquid contents of the cells. In case of severe infestation on cucurbits, leaves exhibit yellowish-white symptoms leading to their wilting, burning and shedding. Mites also attack floral buds and tender fruits of cucurbits (Dhooria and Sandhu 1974). Upto 50% defoliation of leaves in case of cucumber and melons by feeding of red spider mite alone have been reported (Parr and Hussey 1964; Mansour and Karchi 1991). Dhooria (1985) conducted preliminary studies on the differential susceptibility

of different cucurbits to *T. cinnabarinus* and found musk melon to be the most suitable among cucurbits. Davis (1952) and Dhooria and Mann (1989) reported that the application of certain insecticides or fungicides resulted in rapid increase of spider mite population on vegetable crops and other economic hosts probably due to reduction of natural enemies of mites, favourable influence of pesticides on mites and effect on mite behaviour. Moreover the mites seems to have developed resistance to most of the pesticides recommended against them, so the use of resistant species/varieties can be suitably included for their management and long lasting solution.

Keeping in view the seriousness of red spider mites on different cucurbits in Punjab, the present study "Development of red spider mite, *Tetranychus cinnabarinus* (Boisd.) on different cucurbits" was planned with the following objectives :

i) To study the development of *T.cinnabarinus* on different cucurbit species.

ii) To study the preference of different cucurbit species for feeding by *T.cinnabarinus.*

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Spider mites (300-650μ) are important pests of agricultural crop plants. They have long been considered potentially serious pests of a wide variety of our major food and fibre crops and of our ornamentals (Pritchard and Baker 1955); and the full realization of this potential has become increasingly evident since the introduction of broad-spectrum synthetic organic insecticides of different chemical groups for the control of insect-pests on different crops. A consequence of their increased use was that rare and innocuous species of mites became abundant and very injurious. A well known example of this dramatic change in pest status is the red spider mite, *Tetranychus cinnabarinus* (Boisd.). Reason it did so is that its natural enemies were destroyed by chlorinated and organophosphate insecticides and these spider mites are capable of developing resistance to groups of pesticides. Spider mites are cosmopolitan in distribution and cause damage by penetrating their styliform chelicerae into the leaf tissues and thereby sucking the exuding fluids. The removal of chlorophyll and plant pigments from the leaves result in characteristic yellowish white areas which later turn brown and fall off from the plants. Spider mites may cause severe injury resulting in heavy losses in case of different vegetable crops, citrus, beans, cotton, apples and pears. Effects have commonly been so obvious to the extent of a complete "burning" or leaf abscission that only a limited effort has been made to document the nature of losses or to determine under precisely what conditions, what levels of density, and in relation to what species these losses actually occur. The literature reviewed regarding the common name, recent systematic position, general mite morphology, detailed biology, feeding preference and varietal

resistance of red spider mite, *Tetranychus cinnabarinus* on different cucurbits and various other vegetable crops as reported in literature from India and abroad is given below.

2.1 Common name

Red spider mite, *Tetranychus cinnabarinus* (Boisd.) has been mentioned in literature under different common names by different workers. Janjua (1942) reported it as red spider mite while Rahman and Sapra (1945) mentioned it under the common name **vegetable mite**. The same mite was reported as **castor mite** by Srivastava and Mathur (1962). Subsequently this mite was mentioned in literature as **carmine spider mite** by different workers (Mansour and Karchi 1990, and Mukherjee *et al* 1992).

2.2 Systematic position

Phylum : Arthropoda
Class : Arachnida
Subclass : Acari
Order : Acariformes
Suborder : Prostigmata
Superfamily : Tetranychoidea
Family : Tetranychidae
Subfamily : Tetranychinae
Genus : *Tetranychus*
Species : *cinnabarinus*

The red spider mite was earlier reported by Boisduval (1867) under manuscript name *Acarus cinnabarinus*. Then Wood-Mason (1884) and subsequently Misra (1913) reported the same species as *Tetranychus biomaculatus* Harvey. Cherian (1931) reported this species as *Tetranychus telarius* (Linn.). Subsequently this species was also reported as *T. telarius* by several workers in their publications [Ayyar 1940; Janjua 1942; ChannaBasavanna and Puttarudriah 1957; Lall *et al* 1965; Bindra and Goyal 1966; Goyal and Bath 1967; Basu and

Pramanik 1968; Bindra *et al* 1970; Gupta 1970; Saini *et al* 1970; Singh and Saini 1971; and Somchoudhury and Mukherjee 1971]. Sohi (1964) seems to have given this species wrongly as *Eriophyes telarius* (Linn.) in the list of insect and mite pests of cotton in India. Boudreaux (1956) named this mite species under manuscript name *Tetranychus cinnabarinus*. Subsequently Manson (1963) also reported this species as *T. cinnabarinus*. Later on from India, Prasad (1974) reported about the exact identity of this species as *T.cinnabarinus*.

2.3 Host-range

T.cinnabarinus has a worldwide distribution in warmer parts of the world and has a very broad host-range. From India this mite has been recorded feeding on more than 150 host plants which included cultivated crops, weeds and wild crops (Janjua 1942; Saini *et al* 1970 and Dhooria 1977). Among vegetables this mite has been reported as a serious pest of different cucurbits, brinjal, okra, beans, pulses, potato and tomato. Among cucurbits musk melon, water melon, cucumber and squash melon are the most infested and damaged by red spider mite. Besides vegetable crops this mite has also been reported on many ornamentals (marigold, holly-hock and rose), fruits (grapevines, guava, papaya and pear) and weeds.

2.4 Seasonal incidence

T.cinnabarinus (Boisd.) has been made a separate species from the two-spotted spider mite, *T.urticae* Koch, because of differences in morphology, habits, host preferences, geographic distribution, and cross breeding results. It is a pest of low growing plants in semi-tropical areas of the world. It does not appear to be a pest outside the green house in continental climates. This species remains on its host plant and does not enter into diapause under glasshouse conditions during the winter, as does *T. urticae*. Throughout the winter, warm weather periods may stimulate activity, feeding, and egg production. Although

immature stages of these two species appear similar, summer population of red spider mite may appear more brick-red or ferruginous red, than those of *T. urticae.* But colour varies with the host. Eggs of *T.cinnabarinus* are deposited singly on the under surface of leaves of their host or are attached to fibrils of their webbing. The duration of life stages and fecundity compare with the *T.urticae*. Because the *T.cinnabarinus* reproduces throughout the year, there may be nearly 20 generations per year under field conditions. The optimum temperature for development of mite is around 32°C, but mites are able to reproduce well at above 35°C if exposed for limited period of time. Conditions of extremely high relative humidity cause larval and nymphal stages to go into extended period of quiescence, which may last upto 10 days beyond the normal period required for development; but any time after normal quiescent period, mites exposed to dry environment moult within a few minutes (Jeppson *et al* 1975).

T.cinnabarinus is found throughout the year on different host plants in Punjab. But maximum population of mite is found from end February to June mostly on brinjal, cucurbits, ornamentals and weeds. Mite population again reaches its peak during September-October mainly on brinjal and okra. Monsoon rainfall drastically reduces the mite population during July-August. Lall (1964) reported this mite to cause damage to vegetables which may vary between 30-83%. The mite dispersal occurs by crawling from plant to plant or they may be carried by wind to a distance.

2.5 General mite morphology

One of the most characteristic morphological features of mites is the presence of forcep like feeding organs - the chelicerate mouth parts, and absence of antennae and wings. Body of the mite comprises 3 distinct parts - front part or gnathosoma, followed by

propodosoma or the region bearing first two pairs of legs; metapodosoma or the region bearing last two pairs of legs; and opisthosoma or the posterior part of the body. Propodosoma and metapodosoma together are also known as podosoma.

Spider mites belong to family Tetranychidae, the representatives of which spin fine silken webs on the leaves with the help of silk glands situated in the palp region. Type and shape of tarsal claws and empodia, the peretremes, the dorsal setal patterns, the type of striation pattern in the dorsum of the female hysterosoma, and the number and position of leg setae are important characters for the identification of different species. The eggs of red spider mite are smooth, round, transparent and crystal white when freshly laid and later on change into light yellow colour. Prior to hatching the colour becomes opaque and pinkish. An egg measures 131.3μ in diameter. Eggs are laid singly on the undersurface of the leaf or attached to the silken webs made by mite. The newly hatched larvae are slender in shape and are straw-coloured. Their colour later changes to light green. They possess three pairs of legs. A larva measures 180.3μ in length and 129.6μ in breadth. Larvae after being full-fed are changed into first stage nymphs i.e., protonymphs which are oval in shape, slightly pinkish in colour and possess four pairs of legs. Protonymph measures 290.8μ in length and 158.7μ in breadth. The deutonymphs or second stage nymphs are elongated in shape, reddish in colour, and like the protonymphs have four pairs of legs. The body of deutonymph measures 455.8μ in length and 217.4μ in breadth. The larvae, protonymphs and deutonymphs, all enter into quiescence before transforming to the next stage. Adults emerge later as a result of casting off of skin of quiescent deutonymph. Adult males are easily distinguished from females by their annulated or wedge-shaped body, shorter size, pointed abdomen and pinkish body colour whereas females are having rounded abdomen with light yellow to red colour of body.

Male adult measures 345.1μ in length and 163.6μ in breadth while adult female measures 565.0μ in length and 297.8μ in breadth (Lall *et al* 1965).

2.6 Detailed biology on cucurbits and other host plants

Perusal of literature revealed a little information on the biology of red spider mite, *T. cinnabarinus,* on cucurbits but sufficient information was available on other vegetable crops. Literature reviewed regarding biology of mite is presented below for the cucurbits and other vegetable crops.

2.6.1 Cucurbits

Gupta *et al* (1972) studied rate of development of *Tetranychus cucurbitae* Rahman and Sapra (now *T. neocaledonicus* Andre) at four constant temperatures, viz., 20°, 25°, 30° and 35°C on four different vegetable hosts, i.e., horse gram, okra, brinjal and musk melon, and found musk melon to be the most suitable for the development of mite. They found incubation, larval, protonymphal, deutonymphal and adult period of 3.07±0.33, 1.83± 0.39, 1.54± 0.28, 1.44±0.50 and 16.72±7.88 days, respectively with a fecundity of 56.33±12.03 and 67.04±31.19 eggs, respectively in case of fertilized and unfertilized females. Among different temperatures on which biology of mite was studied, 30 °C was found as the most favourable temperature considering minimum time taken to complete the life cycle and higher fecundity of mite at this combination of food and temperature. Nair (1975) reported that *T. cucurbitae* is a common pest of cucurbits in Punjab. The fertilized female lays 61-93 eggs and unfertilized female lays 39-59 eggs. Dhooria (1985) conducted preliminary studies on the development of *T. cinnabarinus* under laboratory conditions on seven different cucurbit species, namely long melon, ash gourd, squash melon, bitter gourd, musk melon, bottle gourd and sponge gourd and reported developmental period of 3.4 days on long melon

and squash melon, 6.0 days on ash gourd, 3.0 days on musk melon and bottle gourd and 3.75 days on sponge gourd. On bitter gourd, all the larvae released died in that stage excepting two larvae which transformed into protonymphs. The above author reported 46.67, 66.67, 13.33, 26.67 and 60.0 per cent mortality during development respectively on long melon, ash gourd, musk melon, bottle gourd and sponge gourd. Dhooria (1985) reported fecundity per female on long melon, ash gourd, squash melon, musk melon, bottle gourd and sponge gourd, respectively as 33, 7, 37, 250, 31 and 43 eggs, and recorded sex-ratio (female: male) in favour of females on all cucurbits tested except on long melon (1:1.33). The above author concluded musk melon to be the most suitable considering the faster development rate and higher fecundity of mite on it, bitter gourd was observed as unsuitable which may be due to presence of certain alkaloids in high quantity responsible for its bitterness. Pande and Reddy (1985) also studied biology of closely related mite, *T. neocaledonicus* on some cucurbits and reported mean developmental period of 5.51, 7.94 and 8.49 days, respectively with a mean percent mortality of 17.33, 21.33 and 32.44 on pumpkin, ridge gourd and bottle gourd at 30±1°C. The pre-oviposition (1.22 to 1.59 days), oviposition (1.98 to 2.66 days) and post-oviposition (0.70 to 0.81 days) periods were very low on these hosts. Above authors reported mean fecundity per female as 54.83, 44.74 and 35.90 eggs, respectively on pumpkin, ridge gourd and bottle gourd. The above authors concluded pumpkin to be the most suitable due to lower mortality, shorter development period and higher fecundity of mite. Ridge gourd was found as second best as regards development and fecundity of the mite.

Davis (1961) while conducting biological studies on *T. cinnabarinus* on cucurbits reported *T. multisetis* McGregor - a polychaetous form of above species which infests cucurbits and other plants. He revealed no outstanding differences between both the species

regarding the effect of temperature on duration of developmental stages or sizes of various stages, but found that host-range preferences were differing than those of *T. telarius* (now *T. cinnabarinus*). Soans *et al* (1973) studied longevity of *T. cinnabarinus* on five varieties of cucumber. On Marketmore (bitter), Marketmore (non-bitter), Tablegreen (bitter), Tablegreen (non-bitter) and Hawaiian (bitter) mean female longevity was 15.0, 17.8, 14.1, 17.4 and 22.2 days respectively, and mean fecundity per female was 13.8, 21.6, 9.6, 21.1 and 28.9 eggs respectively on these varieties. Above authors found Tablegreen (bitter) to be the least suitable variety for the development of mite.

2.6.2 Other host plants

Srivastava and Mathur (1962) studied biology of *T.cinnabarinus* on castor and reported an average life cycle to complete in 14.3 days during January. Egg stage was completed in 5-8 days, protonymphal stage in 3-4 days, and deutonymphal stage in 3-5 days. Adult male longevity during active season varied from 3-9 days, while female lived for 8-14 days. Almost similar results were reported by Basu and Pramanik (1968). Gupta *et al* (1972) studied rate of development of *T.cucurbitae* on horse gram, okra, brinjal and musk melon at 4 constant temperatures, viz., 20°, 25°, 30° and 35°C and found horse gram to be the second best after musk melon for the development of mite due to minimum life period of 6.39±1.57 days and higher fecundity, i.e., 45.67±12.97 and 54.83±29.34 eggs, respectively in case of fertilized and unfertilized females and 30°C was the most favoured temperature for the development of mite.

Many workers studied biology of *T. cinnabarinus* on okra from time to time and reported incubation, larval, protonymphal, deutonymphal, total immature development and adult longevity respectively as 3.05, 2.35, 2.47, 2.78, 10.65 and 14.25-17.75 days.The average

fecundity per female in fertilized and unfertilized females has been reported respectively as 67.5 and 25.8 eggs. Considering the high fecundity and short life period, okra has also been reported to be the most suitable host for development of the red spider mite (Janjua 1942; Williams 1954; and Lall *et al* 1965).

Meyer (1981) reported that optimum temperature for development of *T. cinnabarinus* lies between 29-32°C. The mite flourished under relatively low humidities. Under optimum conditions eggs hatch in 3-5 days. The 6-legged larva is initially orange but becomes green after feeding, when 2-3 days old it undergoes a short quiescent period and then moults, after which 8-legged protonymph emerges which is also green. Protonymphal period was 2-3 days, while deutonymphal period took 2 days. Life cycle from egg to adult takes 10-14 days under optimum temperature conditions. Extremely high humidities and low temperatures can cause mite to go into diapause. In relatively warm conditions mites multiply throughout the winter and upto 20 generations per year may occur in the field. The female begins to lay eggs after 24 hours and lays from 100-150 eggs over a period of 20-30 days. Unfertilized female produces only males. This mite is more numerous in warm weather, so that population explosion may occur at such times. On the other hand, heavy rains result in high humidities over a large area and this cause decline in mite populations. Gupta *et al* (1982) studied the effect of three different foods, viz., horse gram, castor and brinjal, and three temperatures, viz., 25°, 30° and 35°C on the rate of development, longevity and fecundity of vegetable mite, *T. cinnabarinus*. Their studies revealed that life cycle of mite was shorter at 35°C and longer at 25°C. Among the foods, life cycle was completed in a shorter time on brinjal but fecundity on brinjal was poor. They found castor as the best food and 30°C was the most favoured temperature considering shorter duration of life cycle and higher fecundity

of mite. Horse gram was found as the second best host. Banerjee (1989) reported that *T. cinnabarinus* reproduces both sexually and asexually. A female lays 40-70 eggs on under-surface of leaves. Egg to adult stage lasted for 15-22 days depending on the prevailing season. Mukherjee *et al* (1992) in their studies on the development of *T. cinnabarinus* on green gram reported incubation, larval, larval plus nymphal development, male and female longevity as 3-4, 2.18, 7.03, 4.75 and 10.25 days respectively under laboratory conditions. They also reported fecundity per female of 41.25 eggs and revealed green gram to be the most suitable for the development of mite due to higher fecundity and shortest life cycle.

Vander Bund and Helle (1960) reported that on bean, *T. urticae* had an average fecundity of 107.4 eggs/female with a maximum of 158 eggs per female. Jeppson *et al* (1975) reported that red spider mite reproduces throughout the year, optimum temperature for development of mite was 32°C but they reported that it reproduces at temperatures above 35°C if exposed for a limited period of time. Above authors reported relatively shorter egg to adult period, i.e., 5.8-11.2 days (average 8.3 days). Average duration of egg stage throughout the year was 3.3 days. In summer egg duration was 2 days while it was 4-5 days in winter. Each development stage requires 1.0 to 1.5 days in summer and 1.6 to 6.0 days in February and March.

2.7 Nature and extent of damage

Janjua (1942) and Gupta (1970) reported *T. cinnabarinus* as a serious pest on vegetable crops including cucurbits and found that its serious infestation on water melon and musk melon resulting in profuse webbing on leaves in which dust particles are entrapped and as a result of initial feeding by these mites, whitish specks were produced which later coalesced to form yellowish-white patches. Severely infested leaves lost their vigour and fell

from the plants. Heavy infestation on the fruits also reported and in general the population build-up becomes more pronounced towards crop maturity and mainly after the fruit set. Lall and Singh (1968) in their studies on the variability of resistance to different varieties of okra, brinjal and cucumber against *T. cinnabarinus* reported one cucumber variety to be highly resistant against the mite. Sandhu *et al* (1974) reported serious infestation of *T. cinnabarinus* and *T. cucurbitae* on vegetable marrow, water melon and musk melon and found *T. cucurbitae* to be more abundant as compared to *T. cinnabarinus* on these crops. Dhooria and Sagar (1975) reported an outbreak of *T. cinnabarinus* on squash melon during June in some of the fields. Most of the leaves were found completely webbed by the mite, even most of the flowers and fruits had dense webbing and mite population on them. Singh *et al* (2000) reported *T. cinnabarinus* as a serious pest of cucurbits from different parts of India. Michelbaker *et al* (1952) in their studies on mite pests of melons in Northern California reported red spider mite as the serious pest on melons. Parr and Hussey (1964) reported removal of upto 50% leaf area of cucumber plants and also reported as much as 25% decrease in fruit formation because of infestation of mite, *T. cinnabarinus*. Haaranger (1965) reported that the leaves of cucumber were more susceptible to *T. cinnabarinus* and were damaged more under glasshouse conditions than those grown outdoors. Mansour and Karchi (1991) conducted studies on extent of damage caused by *T. cinnabarinus* and reported this mite as a major pest of cucurbitaceous crops including melons and caused serious damage resulting in reduced yield and quality of the fruits. Tulisalo (1970) reported that a stable population of 3-4 females of *T. urticae* per 10 cm^2 area of the cucumber leaves reduced the yield of cucumber by 15 per cent. Tulisalo (1972) reported infestation with *T. urticae* resulted in economic losses upto 30% defoliation in melons, and found musk melon to be the

most suitable host for the mite infestation. Nair (1975) reported that infestation of *T. cucurbitae* on pumpkin, cucumbers and gourds resulted in desapping and covering the leaves with thick webs on which soil particles were collected in windy weather badly affecting the plant growth and preventing flowering and fruit formation.

2.8 Varietal resistance in cucurbits and other host plants

The literature available regarding the variable susceptibility of different cucurbits and other vegetables to the red spider mite from India and abroad is given below.

2.8.1 Cucurbits

Rahman and Sapra (1940) reported that squash melon was too much susceptible to *T. cinnabarinus* in Baluchistan (Janjua 1942), and to both *T. cinnabarinus* and *T. cucurbitae* in different districts of Punjab. They revealed squash melon to be least resistant and highly preferred for infestation by these mites. Saini *et al* (1970) in their laboratory studies on host-range of *T. cinnabarinus* found musk melon, round gourd, sponge gourd, green gram, pea, onion, okra, tomato and potato as suitable for feeding and breeding of mite whereas *bathu*, *palak*, Bengal gram and cluster bean as unsuitable. Dhooria and Sandhu (1974) conducted experiments on variable susceptibility in water melon and musk melon to *T. cinnabarinus* in Punjab and reported 3288 to 4723 mites per 10 leaves of watermelon and an average population of 40.3 (Planter's Jumbo) to 424.0 (MS 2) per 3 leaves of musk melon, in different varieties. Fotedar (1987) proved experimentally that population growth of red spider mite was rapid in those parts of plants having high nitrogen content. Dhooria and Sukhija (1986) reported that six varieties/selections of musk melon namely Ajmer Singh collection – 2, Haler's Best, HA-2-12-14-13, Led-1-9-1-15-2, MH-6-2-1 and Lucknow were highly infested with *T. cinnabarinus* with >400 mites per 2 leaves. Another six varieties namely

Durgapur selection-1, Kocha-4, Punjab Sunehri, Planter's Jumbo, Pusa Sharbati and Raciod Mill were less infested with mites (100-200 mites per 2 leaves) while Ajmer Singh Collection-1, Hara Madhu, Punjab Hybrid No. 445 and Rakha Singh Collection-1 were moderately infested and had less than 100 mites per 2 leaves.

DaCosta and Jones (1971) conducted studies on resistance of cucumber to two-spotted spider mite *T. urticae* and found that on bitter cucumbers the mite had a high mortality (99%) due to the presence of cucurbitacin which attracted the cucumber beetle and resulted in their feeding whereas it had adverse effect on two-spotted spider mite. On non-bitter cucumbers, the mortality of mites was only 5%. The above authors reported that antibiosis and non-preference characters were related in cucumber through action of the bitter gene (bi-gene).

Soans *et al* (1973) studied resistance in cucumber to *T. urticae* and reported cucumber varieties – Marketmore (bitter) and Tablegreen (bitter) to be significantly resistant having less preference, least damage index, lower fecundity, shortest female longevity, and high mortality in immature stages that kept the population of mite under check. The above authors revealed cucurbitacins to be involved in resistance of cucumber to *T. urticae*.

Ponti (1977a, 1977b, 1978a, 1978b, 1979, 1980a, 1980b) screened 800 cucumber varieties in laboratory and on the basis of a practical test in a series of experiments on resistance in cucumber to *T. urticae* and selected PI-220860; Hybrid Long Green Pickle; PI-178885; Ohio MR200; Taipei No. 1; Robin 50; Aodai; PI-163222 and PI-218036 for their distinguishable level of resistance. Of these resistant varieties, PI-163222 was of Indian origin. He found that besides resistance, tolerance for the mite also appears to occur. He stated that related *Cucumis* species do not seem to possess higher levels of resistance than the

most resistant cucumber varieties. The resistance parameters – acceptance and reproduction appear to be positively correlated in these studies. On resistant varieties the metabolism of spider mites is clearly disturbed but seems that to be caused mainly by bitter principles, i.e., cucurbitacin. The author in his studies also reported that on many resistant varieties the shape and markings of the mites changed within a few days of transferring to these varieties. They grew thicker, became more or less bloated and turned completely black instead of showing the two common black spots which indicated that the metabolism of the mite is disturbed. The disturbance of the metabolism may be caused by a relatively large number of indigestible substances such as abundant chlorophyll, in the sap of resistant varieties or by the presence of substances which disturb the normal progress of metabolism.

Gould (1978) in his studies on resistance in cucumber varieties found that out of varieties Marketmore 72 (non-bitter), Marketmore 70 (bitter), Tablegreen 65 (bitter), Hawaiian (bitter) and Marketeer (bitter) - Hawaiian (bitter) exhibited more resistance to *T. urticae*. He also reported that water stress caused a significant increase in the resistance of bitter varieties but did not affect resistance of non-bitter variety. He revealed that resistance was not attributable to behavioural avoidance of bitter leaves. Mansour *et al* (1987), Mansour and Karchi (1991), and Mansour et al (1994) studied resistance of 32 melon lines to *T. cinnabarinus* in Israel under laboratory conditions through leaf-disc technique. Their studies suggested that there is a definite variation among melon lines in resistance to mite population. The most resistant lines namely CHI-8, BUS-7 and BUS-3 reduced the daily mite fecundity by 49%, 40% and 33%, respectively as compared to the susceptible one NY. These authors stated that resistance did not relate to growth habits of the plant. The authors also reported that selfing

resistant melon parents resulted in significant increase in number of plants on which female mites produced less than 1 egg per day.

2.8.2 Other host plants

Lall *et al* (1965) stated that *T. cinnabarinus* remained active in field throughout the year and preferred those varieties of okra which had low carbohydrate to nitrogen ratio. It preferred high concentration of carbohydrates and low concentration of nitrogen. The high percentage of aspergine, asparatic and glutamic acid enhances egg production. The varieties having high concentration of auxin are also preferred as it accelerates rate of their multiplication. The author also reported that the highest mite infestation from the plants of the fields is more on vegetable crops whose soil samples showed higher levels of nitrogen and low levels of potash with slightly acidic pH reaction. Gupta (1991) reported that the okra varieties RIIHR-10, IIHR-4 and Pusa Sawni are relatively less susceptible to the mite attack in Punjab. The author also reported that earlier sown okra varieties showed lesser attack while April sown varieties showed maximum mite attack in Tamil Nadu.

2.9 Phytophagous mites and their predators reported on cucurbits

Perusal of literature revealed many phytophagous mites belonging to different families reported feeding on different cucurbit crops from India and other parts of the world.

2.9.1 Phytophagous mites reported from India

Phytophagous mites reported from different parts of India on different cucurbitaceous crops belonged to families Tetranychidae (spider mites) and Tenuipalpidae (false spider mites). Records of mites from different cucurbitaceous crops from India are given in Table 1, and in Table 2 information about records of mites from the world (other than India) is given.

2.9.2 Predaceous mites and predaceous insects

Information about predaceous mites and insects from India and other parts of the world reported feeding on different phytophagous mites infesting cucurbits is given in Table 3.

Table 1. Phytophagous mites reported on different cucurbitaceous crops from India

Mite species	Cucurbit species	Reference(s)
Family: Tenuipalpidae		
1. *Aegyptobia hymenocleae* Baker and Tuttle	*Cucurbita digita*	Ghai and Shenhmar (1984)
2. *A. annekei* Meyer	Bottle gourd	Nassar and Ghai (1981)
	Ridge gourd	Singh and Mukherjee (1989)
3. *Brevipalpus amicus* Chaudhry	Ridge gourd	Ghai and Shenhmar (1984)
4. *B. californicus* Banks	Bottle gourd	Singh and Mukherjee (1989)
5. *B. cucurbitae* Mohanasundaram	Ash gourd	Sadana (1997)
6. *B. essigi* Baker	Cloth gourd (*Luffa aegyptiaca*)	Sadana (1997)
7. *B. phoenicis* (Geijsks)	Ridge gourd	Nassar and Ghai (1981) Singh and Mukherjee (1989)
8. *Tenuipalpus pernicis* Chaudhry, Akbar and Rasool	Colocynth (*Citrullus colocynthis*)	Sadana (1997)
Family: Tetranychidae		
9. *Bryobia praetiosa* Koch	Pumpkin	Gupta and Gupta (1994)
10. *B. rica* Chaudhry	Bitter gourd	Ghai and Shenhmar (1984)
11. *Eutetranychus maxima* Nassar and Ghai	Red pumpkin (*Cucurbita maxima*)	Gupta and Gupta (1994)

(Contd.)

Table 1. (contd.)

Mite species	Cucurbit species	Reference(s)
12. *E. orientalis* (Klein)	Bottle gourd, *chibber*, pumpkin, sponge gourd, squash melon and water melon	Dhooria (1987) Singh and Mukherjee (1989) Gupta and Gupta (1994)
13. *Tetranychus angloensis* Meyer	Red pumpkin	Gupta and Gupta (1994)
14. *T. cinnabarinus* (Boisd.) (=*T. telarius* Linn.)	Ash gourd, cloth gourd, cucumber, long melon, musk melon, red pumpkin, sponge gourd, squash melon, vegetable marrow and water melon	Rahman and Sapra (1940) Janjua (1942) Saini *et al* (1970) Gupta *et al* (1971) Banerjee (1989) Singh and Mukherjee (1989) Dhooria (1990)
15. *T. lombardinii* Baker and Pritchard	African horned cucumber, cucumber and pumpkin	Banerjee (1989) Singh and Mukherjee (1989) Gupta and Gupta (1994)
16. *T. macfarlanei* Baker and Pritchard	Red pumpkin, bottle gourd and pumpkin	Moutia (1958) Singh and Mukherjee (1989) Gupta and Gupta (1994)
17. *T. neocaledonicus* Andre (=*T. cucurbitae*)	Ash gourd, cloth gourd, cucumber, gourds, pumpkin, red pumpkin and squash melon	Rahman and Sapra (1940, 1945) Gupta *et al* (1971) Nair (1975) Gupta (1976) Singh and Mukherjee (1989) Gupta and Gupta (1994)
18. *T. urticae* Koch	Cucumber, musk melon and pumpkin	Singh and Mukherjee (1989) Gupta and Gupta (1994)

Table 2. Phytophagous mites reported on different cucurbitaceous crops from the world (other than India)

Mite species	Cucurbit species	Refefrence(s)
Family: Tetranychidae		
1. *Bryobia filifoliae* Tuttle and Baker	*Cucurbita palmata*	Tuttle and Baker (1968)
2. *B. praetiosa* Koch	Cucumber, *Cucurbita sp.*	Tuttle and Baker (1968)
3. *Eutetranychus sudanicus* Elbadry	Water melon	Jeppson *et al* (1975)
4. *Oligonychus pratensis* (Banks)	*Cucurbita palmata*	Tuttle and Baker (1968)
5. *Tetranychus atlanticus* McGregor	Cucumber and musk melon	Tuttle and Baker (1968)
6. *T. cinnabarinus* (Boisd.)	Water melon	Tuttle and Baker (1968)
7. *T. desertorum* Banks	*Cucurbita digita*, musk melon,pumpkin and water melon	Tuttle and Baker (1968)
8. *T. macfarlanei* Baker and Pritchard	Cucumber, gourds and pumpkin	Jeppson *et al* (1975)
9. *T. neocaledonicus* Andre (=*T. cucurbitae*)	Cucurbits	Jeppson *et al* (1975)
10. *T. pacificus* McGregor	Melons	Jeppson *et al* (1975)
11. *T. turkestani* (Ugarog and Nikolski)	Cucumber and melons	Jeppson *et al* (1975)
12. *T. urticae* Koch	Cucumber	Trenkman (1967) DaCosta and Jones (1971) Soans *et al* (1973)

Table 3. Predatory mites and predaceous insects reported feeding on phytophagous mites feeding on different cucurbitaceous crops from India and other parts of the world.

Sr.No.	Predator species	Family	Prey species	Region	Reference(s)
1.	*Amblyseius sp.*	Phytoseiidae	Tetranychid mite	India	Chatterjee *et al* (1987)
2.	*Oligota insidious* (Say).	Anthocoridae	*T. urticae*	N. America	McMurtry *et al* (1970)
3.	*Oligota sp.*	Staphyllinidae	Tetranychid mite	India	Chatterjee *et al* (1987)
4.	*Scolothrips sp.*	Thysanoptera	Tetranychid mite	India	Chatterjee *et al* (1987)
5.	*Stethorus sp.*	Coccinellidae	Tetranychid mite	India	Chatterjee *et al* (1987)

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present investigations on "Development of red spider mite, *Tetranychus cinnabarinus* (Boisd.) on different cucurbits" were carried out under laboratory and screen house conditions in the Department of Entomology, Punjab Agricultural University, Ludhiana. Different techniques used for these studies are given below.

3.1 Raising of nursery plants

Nursery plants of 12 different cucurbit species (Table 4) required for different experiments were raised by sowing seeds in earthen pots containing mixture of well-dried soil and well rotten Farm Yard Manure (1:1), and kept in the screen house at the Entomological Research Farm, Punjab Agricultural University, Ludhiana. Before sowing, seeds of different cucurbit species were treated with Captan as per university recommendations. The potted plants were watered daily.

Before raising the plants, screen house was properly cleaned and thoroughly sprayed with **Metasystox 25 EC** @ 2 ml/litre of spray material to kill the existing insect-pests and mites. Before using the leaves for different experiments, the healthy green leaves selected from different species were thoroughly washed with tap water, dried and examined under the stereoscopic binocular microscope to remove or kill any insect or mite stages found on them.

3.2 Raising of mite culture

Pure culture of *T. cinnabarinus* was raised on potted plants of french bean (*Phaseolus vulgaris* Linn.) under screen house conditions at Entomological Research Farm, Punjab Agricultural University, Ludhiana. The field collected females and males of red spider mite were released on leaves of french bean kept on moist cotton in Petri dishes, and leaves bearing mites were pinned with entomological pins on young leaves of french bean

Table 4. Different cucurbit species used for biological studies, feeding preference and damage index

Sr. No.	English Name	Vernacular Name	Technical Name
1.	Musk melon	**Kharbooza**	*Cucumis melo* var. *reticulata* (Linn.)
2.	Water melon	**Tarbooz**	*Citrullus lanatus* (Thunb.)
3.	Summer squash	**Chappan Kaddu**	*Cucurbita pepo* (Linn.)
4.	Bottle gourd	**Ghia Kaddu**	*Lagenaria siceraria* (Mohxa)
5.	Bitter gourd	**Karela**	*Momordica charantia* (Linn.)
6.	Ash gourd	**Petha**	*Benincasa hispida* (Thunb.)
7.	Ridge gourd	**Ghia tori**	*Luffa cylinderica* (Linn.) M Roem
8.	Squash melon	**Tinda**	*Citrullus vulgaris* (Schrad) var. *fistulosus*. Duth. and Full.
9.	Cucumber	**Khira**	*Cucumis sativa* Linn.
10.	Long melon	**Tar**	*Cucumis melo* var. *utilissimus*. Duth and Full.
11.	Wanga	**Wanga**	*Cucumis melo* sub sp. *melo* Linn.
12.	Wild melon	**Chibber**	*Cucumis melo* var. *callosus* Linn.

plants used for raising mite culture. Before releasing, the identity of mites was confirmed. After completion of 3 generations, the mite culture was utilized for different studies. Regular inspection of cultured plants was made so as to avoid any cross infestation of other phytophagous, predatory mites and insect-pests.

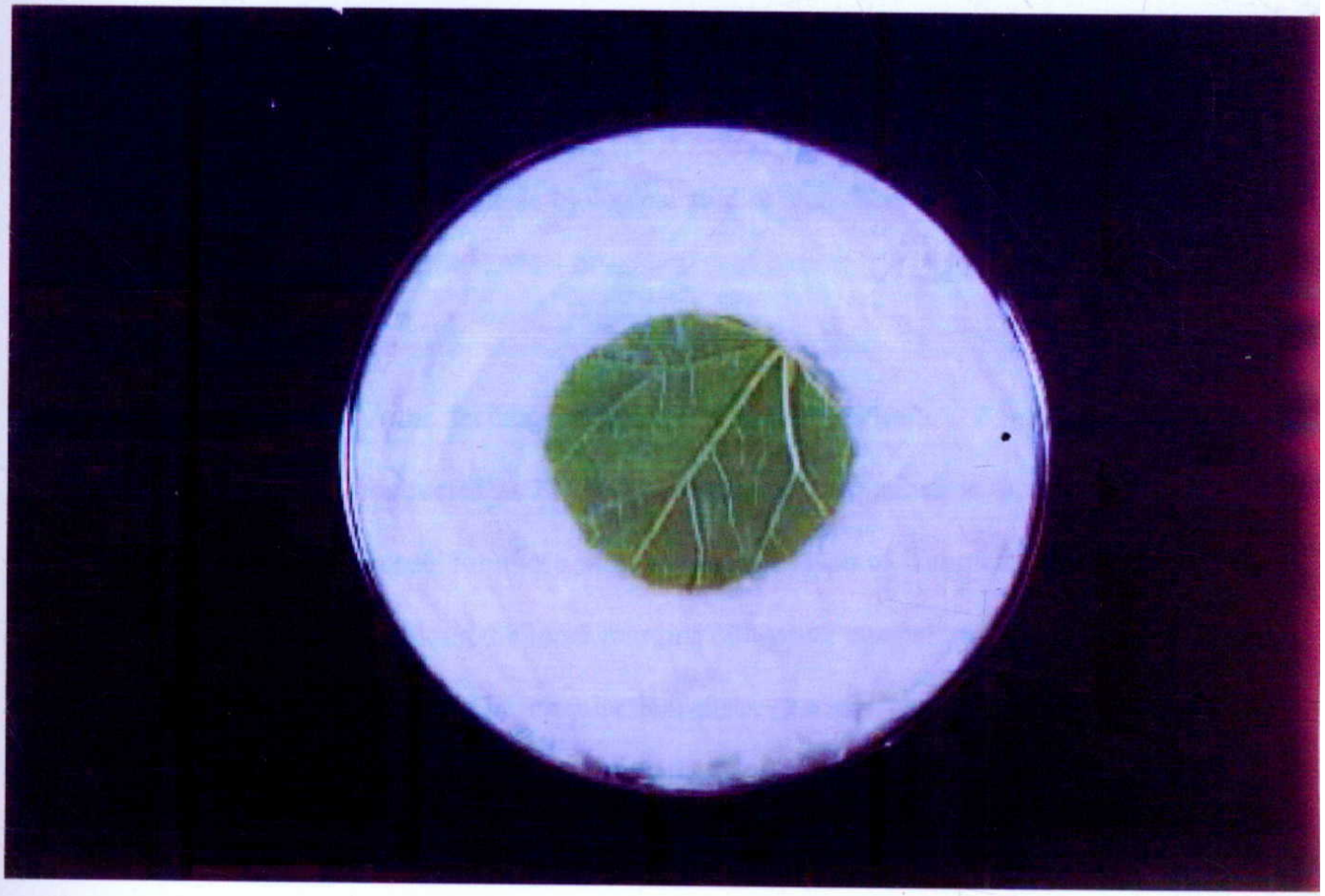
3.3 Biological studies

Leaf-disc technique was used for studying the biology of *T. cinnabarinus* (Plate 1). The female mites were released with the help of 00 series sable hair brush on ventral surface of mite free leaves of different cucurbits kept upwards and placed over moist cotton swabs in Petri dishes (10 cm dia). The cotton swabs were kept supersaturated with water from time to time so that the leaves may remain in turgid condition for longer time. The old leaf-discs were replaced periodically with fresh ones so as to ensure their good quality.

The rate of development of red spider mite was studied at 27±1°C temperature maintained in biological oxygen demand (B.O.D.) incubator. For recording the incubation period more than 10 gravid females were taken from mite culture and released on leaf- discs of different cucurbits to obtain sufficient number of eggs. After 24 hours of releasing, females were removed and eggs were counted and observed daily for hatching. Number of eggs hatched at different observations were counted for calculating the average incubation period. For studying different parameters of development of mite on different cucurbits, one newly emerged larva per leaf disc was released and in this way 50 leaf discs were made for each cucurbit species. The observations regarding larval, proto- and deutonymphal periods were recorded twice daily at 6 a.m. and 6 p.m. The per cent mortality during development of each stage was also observed. Observations regarding pre-, ovi-, and post-oviposition periods, egg laying and longevity were recorded daily on all the cucurbits. Fecundity was

PLATE 1

LEAF DISC TECHNIQUE



Leaf disc technique

calculated by counting the total number of eggs laid by a female during her life span while longevity was observed by counting period between emergence of adult from quiescent deutonymph till last day of its survival. Sex- ratio was calculated from the counts of males and females that emerged in the laboratory rearing on different cucurbits. Minimum of 15 cases were considered for the sake of calculating different periods. The total immature development (larval+ protonymphal+ deutonymphal) and total life duration (immature + adult) were also recorded. For all these biological studies stereoscopic binocular microscope was used.

3.4 Feeding preference

The experiment on the feeding preference of red spider mite , *T. cinnabarinus* on different cucurbits was conducted at 27±1°C temperature maintained in B.O.D. incubator. Free choice method was used for these studies. A thin layer of Tanglefoot® barrier was applied in a circular fashion along the inner margins of a white enamel tray (30 x 30 cm size) to prevent the escape of mites. The circular leaf-discs (2.5 cm dia.) of different cucurbit species were placed in a circular manner at equidistant intervals. One hundred and fifty (150) female mites pre-starved for 30 minutes were released in the central region of enamel tray kept at 27±1°C in the B.O.D incubator. Five replications were kept for this experiment and this experiment was repeated three times. Observations regarding the mites found on both surfaces of leaf-discs of different cucurbit species after 3 hours of releasing were recorded. The number of mites trapped in the Tanglefoot® barrier or found wandering inside the enamel tray or found dead in the tray were recorded and their percentages were calculated.

3.5 Damage index

This experiment was conducted under screen house conditions on the potted plants of different cucurbit species. Ten leaves of almost equal size of each cucurbit species were selected and a ring of Tanglefoot® was applied on the petiole so that mites may not have interleaf movement. On the selected leaves, ten teneral females and ten males per leaf were released with the help of sable hair brush in the morning time when the temperature was comparatively low. In the first experiment, mites were released on test leaves on 9th May, 2002 and in the second experiment, mites were released on 29th May, 2002. Observations on the nature and extent of damage caused by mite feeding were recorded in the screen house after 13 and 18 days of releasing mites in the first experiment while observations were recorded after 10, 15, 19 and 22 days of releasing mites in the second experiment (Plate 2). Based on yellowish-white symptoms found on test leaves because of mite feeding, following five grades were taken for finding average damage index:

Grade 0	:	Leaves exhibiting no or negligible damage
Grade 1	:	Leaves exhibiting about 25 per cent yellowish-white symptoms
Grade 2	:	Leaves exhibiting about 50 per cent yellowish-white symptoms
Grade 3	:	Leaves exhibiting about 75 per cent yellowish-white symptoms
Grade 4	:	Leaves exhibiting about more than 75 per cent yellowish-white symptoms to drying up or falling off of leaves

3.6 Meteorological data

Records of maximum, minimum temperatures (°C) and relative humidity (R.H.) (%) were made daily in the morning at 8.30 a.m. and in the evening at 2.30 p.m. in the screen house during the period of experimentation (Table 5).

PLATE 2

NATURE OF DAMAGE ON DIFFERENT CUCURBIT LEAVES

Fig. 1. Musk melon (Damaged vs. healthy)

Fig. 2. Water melon (Damaged)

Fig. 3. Summer squash (Healthy vs. damaged)

Fig. 4. Bottle gourd (Healthy vs. damaged)

Fig. 5. Ash gourd (Healthy vs. damaged)

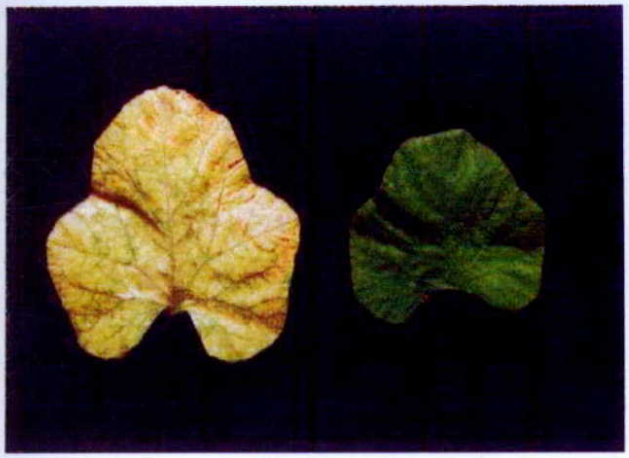


Fig. 1

Fig. 2

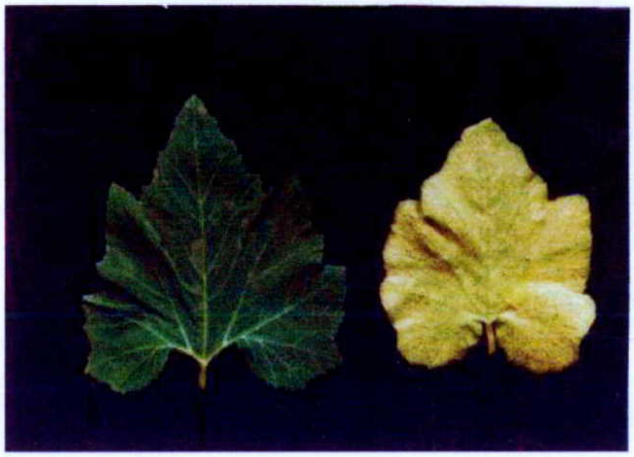


Fig. 3

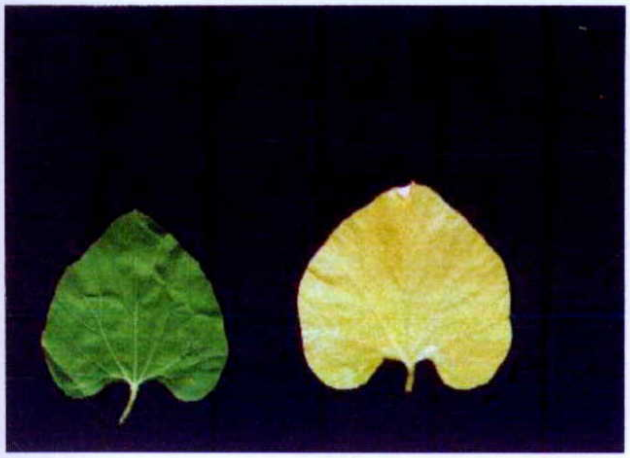


Fig. 4

Fig. 5

PLATE 2

NATURE OF DAMAGE ON DIFFERENT CUCURBIT LEAVES

Fig. 6. Ridge Gourd (Healthy vs. damaged)

Fig. 7. Squash melon (Healthy vs. damaged)

Fig. 8. Cucumber (Healthy vs. damaged)

Fig. 9. Long melon (Healthy vs. damaged)

Fig. 10. Wanga (Healthy vs. damaged)

Fig. 11. Wild melon (Healthy vs. damaged)

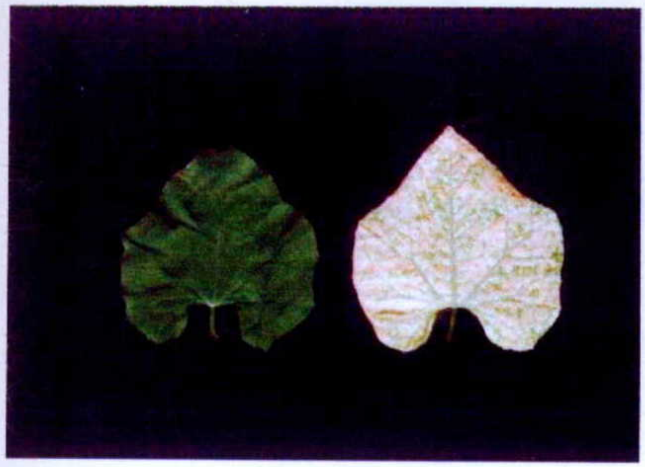


Fig. 6

Fig. 7

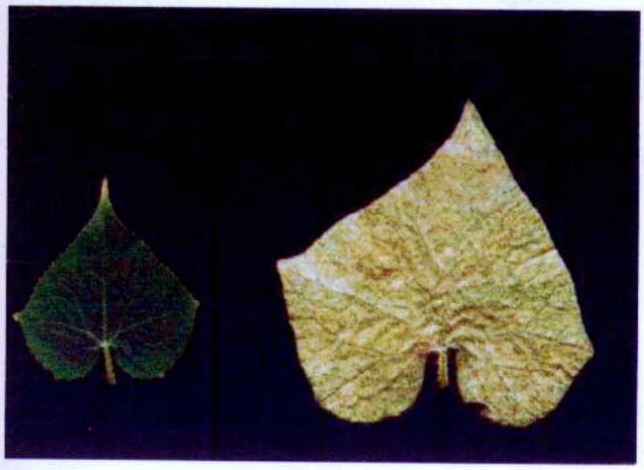


Fig. 8

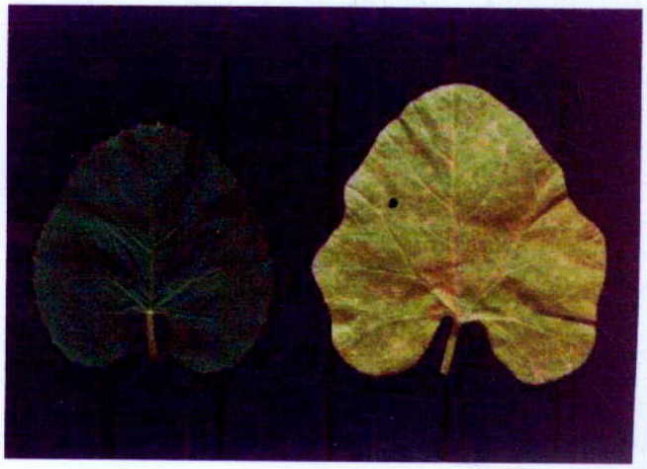


Fig. 9

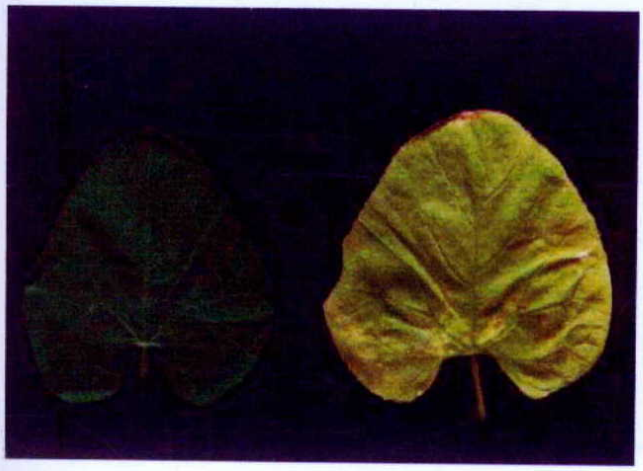


Fig. 10

Fig. 11

Table 5. Meteorological data on minimum, maximum temperature (°C) and per cent relative humidity recorded under screen house conditions during experimental period

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum (8.30 a.m.)	Maximum (2.30 p.m.)	Morning (8.30 a.m.)	Evening (2.30 p.m.)
09.05.2002	27.0	44.0	44	15
10.05.2002	26.2	45.0	45	17
11.05.2002	25.4	45.4	36	12
12.05.2002	23.0	45.5	34	26
13.05.2002	31.3	45.6	52	23
14.05.2002	32.6	43.0	64	39
15.05.2002	28.0	45.6	65	54
16.05.2002	30.1	40.0	62	28
17.05.2002	27.0	43.3	78	22
18.05.2002	24.5	44.7	42	20
19.05.2002	24.0	45.0	40	25
20.05.2002	27.4	44.0	42	27
21.05.2002	23.4	43.0	43	17
22.05.2002	22.2	43.0	40	18
23.05.2002	26.7	45.2	29	21
24.05.2002	28.4	46.0	38	24
25.05.2002	29.6	46.0	46	39
26.05.2002	22.4	42.4	64	51
29.05.2002	20.0	33.0	80	56
30.05.2002	24.0	32.4	72	45
31.05.2002	26.0	35.4	81	42
01.06.2002	26.2	38.0	70	49
02.06.2002	24.5	34.5	64	30
03.06.2002	25.0	38.4	64	37
04.06.2002	24.8	36.6	75	29
05.06.2002	27.5	40.4	60	40
06.06.2002	26.2	41.0	55	48
07.06.2002	26.5	41.7	73	45

(Contd.)

Table 5 (Contd.)

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum (8.30 a.m.)	Maximum (2.30 p.m.)	Morning (8.30 a.m.)	Evening (2.30 p.m.)
08.06.2002	29.5	42.0	78	34
09.06.2002	31.5	43.5	72	33
10.06.2002	31.0	43.0	68	30
11.06.2002	32.4	42.8	68	45
12.06.2002	24.4	40.6	70	55
13.06.2002	28.5	36.5	72	52
14.06.2002	28.0	40.0	82	54
15.06.2002	26.7	36.4	74	43
16.06.2002	29.0	41.0	51	44
17.06.2002	29.5	37.6	78	55
18.06.2002	28.0	35.7	84	47
19.06.2002	29.6	36.0	83	56
20.06.2002	26.7	35.8	84	44
21.06.2002	29.4	39.8	68	46
22.06.2002	29.0	41.5	70	43

3.7 Statistical analysis

Means of all biological parameters and other aspects such as feeding preference and leaf damage index were worked out in order to determine variability of a distribution and magnitude of the deviation of values from their mean, the standard deviation (σ) was worked out. But in case of the feeding preference and damage index, data analysis were done by comparing means and standard errors.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Studies on the biology and feeding preference of red spider mite, *Tebanychus cinnabarinus* (Boisd.) were conducted on 12 different cucurbits under laboratory conditions through leaf-disc technique at 27±1°C. Extent of leaf damage caused by this mite on different cucurbit species was studied under screen house conditions. The results obtained during the course of these investigations are presented and discussed below experiment-wise.

4.1 Biology of red spider mite on different cucurbits

Biology of the red spider mite, *T. cinnabarinus* was studied on 12 different cucurbit species through leaf-disc technique at 27±1°C maintained in B.O.D. incubator. Different life stages of the mite are shown in Plate 3. Observations on the detailed biology of mite were recorded on ventral surface of fresh leaves.

4.1.1 Incubation period

The egg duration varied from 3.5 to 4.5 days (3.74±0.27 days). All the eggs successfully hatched at this temperature. Gupta *et al* (1972) reported mean incubation period of 3.03 to 5.11 days at 25° to 30°C. The present findings are in accordance with those reported by above authors. Mukherjee *et al* (1992) and Meyer (1981) also reported incubation period of 3-5 days at 29±5°C.

4.1.2 Larval, protonymphal and deutonymphal duration

4.1.2.1 Larval duration

Larvae took comparatively more time to develop on wanga (3.18±0.87 days) followed by that on cucumber (2.93±0.50 days) and squash melon (2.45±0.50 days) while minimum larval duration was found on bottle gourd, summer squash and water melon

PLATE 3

DIFFERENT DEVELOPMENTAL STAGES OF *T. cinnabarinus*

A. Eggs

B. Larva

C. Nymph

D. Adult male

E. Adult female

A

B

C

D

E

(1.54±0.14 days). Larvae took 2.06±0.41 days to develop on musk melon (Table 6). Gupta *et al* (1972) also reported mean larval duration of 2.12 days at 25°C and 1.83 days at 30°C on musk melon.

Interestingly all the larvae released for development on bitter gourd leaf-discs died without transforming to the nymphal stage. Mortality of larvae on bitter gourd may be due to higher concentration of bitter component (cucurbitacin) or some other alkaloids in the leaves. Dhooria (1985) also found mortality of larvae on bitter gourd under laboratory conditions.

4.1.2.2 Protonymphal period

The larvae after becoming full-fed became quiescent and first stage nymphs, i.e., protonymphs emerged from them. Mean protonymphal period varied from 1.10±0.32 days on summer squash to 2.50±0.28 days on wanga. Mean protonymphal period on squash melon was 2.33±0.76 days and on musk melon it was 2.02±0.61 days (Table 7). On musk melon, Gupta *et al* (1972) reported protonymphal period of 1.54±0.28 days at 30°C and 2.87±0.53 days at 25°C. The protonymphal period found in the present studies lies in the range of that reported by above authors.

4.1.2.3 Deutonymphal period

The protonymphs after becoming full-fed again became quiescent and from this, second stage nymphs i.e., deutonymphs emerged. In the present findings, mean deutonymphal period was quite high on wanga (2.63±0.61 days), squash melon (2.60±1.10 days), cucumber (2.52±0.50 days) and wild melon (2.28±0.63 days) but was comparatively very low on water melon (1.57±0.21 days) and ash gourd (1.36±0.47 days) (Table 8). But Gupta *et al* (1972) reported mean deutonymphal period of 1.14±0.35 days on musk melon at

Table 6. Development of larvae of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Larval duration (days)	
		Mean ± S.D.	Range
1.	Musk melon	2.06±0.41	1.5-3.0
2.	Water melon	1.54±0.14	1.5-2.0
3.	Summer squash	1.53±0.12	1.5-2.0
4.	Bottle gourd	1.53±0.13	1.5-2.0
5.	Bitter gourd *	-	-
6.	Ash gourd	1.87±0.40	1.5-4.0
7.	Ridge gourd	2.18±0.40	1.5-3.0
8.	Squash melon	2.45±0.50	2.0-3.0
9.	Cucumber	2.93±0.50	2.0-3.5
10.	Long melon	1.93±0.72	1.0-3.5
11.	Wanga	3.18±0.87	2.0-5.0
12.	Wild melon	2.09±0.36	1.5-2.5

* All larvae died without transforming into protonymphs.

Table 7. Development of protonymphs of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Protonymphal duration (days)	
		Mean ± S.D.	Range
1.	Musk melon	2.02±0.61	1.5-3.0
2.	Water melon	1.53±0.13	1.5-2.0
3.	Summer squash	1.10±0.32	0.5-2.0
4.	Bottle gourd	1.50±0.50	0.5-3.0
5.	Bitter gourd *	-	-
6.	Ash gourd	1.45±0.35	1.0-2.5
7.	Ridge gourd	1.52±0.31	1.0-2.0
8.	Squash melon	2.33±0.76	1.0-4.0
9.	Cucumber	1.93±0.81	1.0-3.0
10.	Long melon	1.64±0.54	1.0-2.5
11.	Wanga	2.50±0.28	2.0-3.5
12.	Wild melon	1.50±0.51	1.0-3.0

* No observations could be recorded.

Table 8. Development of deutonymphs of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Deutonymphal duration (days)	
		Mean ± S.D.	Range
1.	Musk melon	1.83±0.50	1.0-3.0
2.	Water melon	1.57±0.21	1.5-2.0
3.	Summer squash	1.73±0.51	1.0-3.5
4.	Bottle gourd	1.80±0.65	0.5-3.5
5.	Bitter gourd *	-	-
6.	Ash gourd	1.36±0.47	0.5-3.0
7.	Ridge gourd	1.86±0.68	1.0-4.5
8.	Squash melon	2.60±1.10	1.0-5.0
9.	Cucumber	2.52±0.50	1.5-4.0
10.	Long melon	1.95±0.42	1.5-2.5
11.	Wanga	2.63±0.61	2.0-4.0
12.	Wild melon	2.28±0.63	1.5-4.0

* No observations could be recorded.

25°C to 1.44±0.50 days on same host at 30°C. More duration of deutonymphal period on musk melon (1.83±0.50 days) in the present studies may be due to different variety of musk melon used which may have more preference for development of mite.

4.1.3 Total immature development

Total mean developmental period (larval plus nymphal) varied from 4.40±0.51 days on summer squash to 8.31±1.06 days on wanga. This period was also quite high on cucumber (7.58±1.05 days) and squash melon (7.33±1.60 days). Developmental period was also shorter on water melon (4.64±0.25 days), ash gourd (4.69±0.48 days) and bottle gourd (4.84±0.60 days) (Table 9). Pande and Reddy (1985) studied biology of a closely related mite, *Tetranychus neocaledonicus* and reported mean developmental period of 5.51, 7.94 and 8.49 days respectively on pumpkin, ridge gourd and bottle gourd at 30±1°C temperature. Present findings regarding developmental period also fall somewhat in above range. Dhooria (1985) also conducted preliminary studies under laboratory conditions on development of *T. cinnabarinus* on different cucurbits and reported developmental period of 3-4 days on long melon and squash melon, 6.0 days on ash gourd, 3.0 days on musk melon and bottle gourd, and 3.75 days on sponge gourd. The higher developmental period on various cucurbits in the present studies may be due to temperature conditions i.e., 27±1°C as against laboratory conditions in case of above author. Gupta *et al* (1972) reported mean developmental period of 6.13 days at 25°C and 4.81 days at 30°C.

4.1.4 Per cent mortality during development

The per cent mortality during larval, protonymphal and deutonymphal development was worked out on different cucurbits (Table 10). During larval development there was 100 per cent mortality in case of bitter gourd. On cucumber, ash gourd, wanga and musk melon

Table 9. Total larval plus nymphal development of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Larval plus nymphal development (days)	
		Mean ± S.D.	Range
1.	Musk melon	5.83±0.81	4.5-7.5
2.	Water melon	4.64±0.25	4.5-5.0
3.	Summer squash	4.40±0.51	3.5-6.0
4.	Bottle gourd	4.84±0.60	3.5-6.0
5.	Bitter gourd *	-	-
6.	Ash gourd	4.69±0.48	3.5-6.5
7.	Ridge gourd	5.53±0.79	4.5-8.0
8.	Squash melon	7.33±1.60	5.0-11.0
9.	Cucumber	7.58±1.05	6.0-9.0
10.	Long melon	5.45±0.52	4.5-7.0
11.	Wanga	8.31±1.06	7.0-11.0
12.	Wild melon	5.84±0.63	5.0-7.0

* No observations could be recorded

Table 10. Per cent mortality of different stages of red spider mite, *T. cinnabarinus* during development at 27±1°C

Sr. No.	Cucurbit species	Per cent mortality during development			
		Larval	Protonymphal	Deutonymphal	Total
1.	Musk melon	0	8	16	24
2.	Water melon	2	6	4	12
3.	Summer squash	8	6	6	20
4.	Bottle gourd	10	10	14	34
5.	Bitter gourd	100	-	-	100
6.	Ash gourd	0	18	4	22
7.	Ridge gourd	10	6	6	22
8.	Squash melon	16	12	12	40
9.	Cucumber	0	4	0	4
10.	Long melon	20	24	0	44
11.	Wanga	0	10	26	36
12.	Wild melon	8	4	8	20

all the larvae developed successfully and entered into the protonymphal stage. Negligible larval mortality (2%) was observed in case of water melon. On rest of the cucurbits, 8-20% larvae died during development. During protonymphal development, maximum mortality (24%) was found on long melon followed by ash gourd (18%). Minimum mortality during protonymphal development was found on cucumber and wild melon. On the remaining hosts, from 6 to 12% mortality was observed. Maximum mortality during deutonymphal stage was found on wanga (26%) while no mortality was observed on cucumber and long melon. Negligible mortality during deutonymphal development was observed on water melon, ash gourd and ridge gourd. During development from larval to adult stage, 100% mortality occurred on bitter gourd. Mortality during immature development was high on long melon (44%) followed by squash melon (40%), wanga (36%) and bottle gourd (34%). Minimum mortality during development was found on cucumber (4%) and water melon (12%). Dhooria (1985) also studied development of *T. cinnabarinus*, on different cucurbits and recorded minimum mortality on musk melon (13.33%) and bottle gourd (26.67%). The above author also reported quite high mortality on long melon (46.67%). Pande and Reddy (1985) studied development of *T. neocaledonicus* on pumpkin, ridge gourd and bottle gourd, also found high mortality on bottle gourd (32.44%) and ridge gourd (21.33%), and 17.33% on pumpkin.

4.1.5 Pre-oviposition, oviposition and post-oviposition periods

Perusal of Table 11 reveals that mean pre-oviposition period of *T. cinnabarinus* varied from 1.20 to 2.20 days on different cucurbits. It was lowest on bottle gourd but was highest on squash melon. Pande and Reddy (1985) studied biology of *T. neocaledonicus* on three cucurbits namely pumpkin, ridge gourd and bottle gourd at 30±1°C and found very low

pre-oviposition (1.22 to 1.59 days) on these hosts. Shorter pre-oviposition duration in above studies may be due to higher temperature i.e., 30±1°C at which the development was studied. Gupta *et al* (1972) studied biology of *T. cucurbitae* on different temperatures and found 1.23 days as mean pre-oviposition period on musk melon at 25°C which is very much within the range reported in the present studies.

Oviposition period i.e., the total period of egg laying, in the life of a mite was highest on water melon (6.40±1.64 days) closely followed by that on musk melon (6.33±1.45 days) and ridge gourd (6.13±1.60 days). Lowest duration of oviposition activity (4.27±0.80 days) was recorded on long melon. But Gupta *et al* (1972) reported higher oviposition period of 9.45±1.64 days at 25°C and 16.72±7.88 days at 30°C on musk melon. However, Pande and Reddy (1985) reported very low duration of oviposition on pumpkin (2.66 days), ridge gourd (2.06 days) and bottle gourd (1.98 days). Too high oviposition period in case of Gupta *et al* (1972) may be due to the more suitability of musk melon variety used for mite development.

Mean post-oviposition period ranged from 0.73 days on bottle gourd to 2.13 days on squash melon. Post-oviposition was also quite high on wild melon and musk melon (2.0 days). It also had shorter duration on summer squash (1.13 days). Pande and Reddy (1985) reported 0.70 to 0.81 days as mean post-oviposition period on different cucurbits at 30±1°C. Gupta *et al* (1972) reported mean post-oviposition period of 1.85 days and 1.57 days respectively at 25° and 30°C which is very much in the range as reported in the present studies. However, quite low post-oviposition period reported by Pande and Reddy (1985) might be due to higher temperature, i.e., 30±1°C at which their studies were conducted.

Table 11. Pre-oviposition, oviposition and post-oviposition periods of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Duration (days)					
		Pre-oviposition		Oviposition		Post-oviposition	
		Mean±S.D.	Range	Mean±S.D.	Range	Mean±S.D.	Range
1.	Musk melon	1.60±0.51	1-2	6.33±1.45	4-10	2.00±0.76	1-3
2.	Water melon	1.40±0.63	1-3	6.40±1.64	4-10	1.47±0.64	1-3
3.	Summer squash	1.33±0.49	1-2	5.20±1.01	4-7	1.13±0.52	0-2
4.	Bottle gourd	1.20±0.56	0-2	4.40±0.74	3-6	0.73±0.46	0-1
5.	Bitter gourd *	-	-	-	-	-	-
6.	Ash gourd	1.73±0.70	1-3	4.87±0.92	3-6	1.87±0.74	1-3
7.	Ridge gourd	1.80±0.41	1-2	6.13±1.60	4-8	1.33±0.82	0-3
8.	Squash melon	2.20±0.56	1-3	4.67±1.35	3-7	2.13±0.64	1-3
9.	Cucumber	1.87±0.64	1-3	5.40±1.35	3-7	1.80±0.86	1-4
10.	Long melon	1.80±0.68	1-3	4.27±0.80	3-6	1.40±0.63	0-2
11.	Wanga	1.73±0.46	1-2	5.13±1.12	4-7	1.60±0.74	0-3
12.	Wild melon	1.60±0.51	1-2	4.40±1.18	3-8	2.00±0.76	1-3

* No observations could be recorded

4.1.6 Longevity

Observations on longevity of females revealed that mites had highest mean longevity on wanga (9.16 days), cucumber (9.07 days) followed by that on ridge gourd (8.67 days), water melon (8.56 days), wild melon (8.38 days) and squash melon (8.14 days). However, shortest mean longevity was recorded on long melon (6.80 days), bottle gourd (6.85 days) and summer squash (6.93 days). In case of males, longevity was highest on ridge gourd (10.00 days) and was closely followed by on squash melon (9.50 days), musk melon and ash gourd (9.00 days) (Table 12). Gupta *et al* (1972) reported mean longevity of females of *T. neocaledonicus* as 12.00 days, 12.04 days and 8.39 days respectively on okra, musk melon and brinjal at 25°C while these figures were respectively 14.44, 16.72 and 13.56 days at 30°C. Higher longevity of both males and females in case of Gupta *et al* (1972) might be due to more suitable variety of musk melon and other hosts used than those tried in the present studies.

4.1.7 Fecundity

Perusal of Table 13 reveals highest mean fecundity per female on musk melon (52.93 eggs) followed by that on water melon (37.40 eggs), ridge gourd (36.33 eggs) and squash melon (32.64 eggs). But comparatively very low mean fecundity was observed on wild melon (6.53 eggs) followed by that on ash gourd (12.20 eggs), cucumber (13.73 eggs) and on wanga (15.53 eggs). Moderate fecundity per female was recorded on bottle gourd (27.87 eggs), long melon (26.20 eggs) and on summer squash (22.53 eggs). Gupta *et al* (1982) conducted biological studies on horse gram, castor and brinjal in Punjab at 25°, 30° and 35°C. They reported mean fecundity per female from 14.00 to 46.44 eggs on above hosts and temperature combinations. Dhooria (1985) reported very high fecundity of 250 eggs per

Table 12. Longevity of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Longevity (days)			
		Male		Female	
		Mean±S.D.	Range	Mean±S.D.	Range
1.	Musk melon	9.00±0.00	9	7.69±2.04	4-12
2.	Water melon	8.00±1.15	7-12	8.56±1.46	7-9
3.	Summer squash **	-	-	6.93±0.83	5-8
4.	Bottle gourd	6.42±1.13	5-8	6.85±1.10	5-9
5.	Bitter gourd *	-	-	-	-
6.	Ash gourd	9.00±0.00	9	7.93±1.03	7-9
7.	Ridge gourd	10.00±0.00	10	8.67±1.54	7-13
8.	Squash melon	9.50±0.58	9-10	8.14±1.51	6-11
9.	Cucumber	8.67±0.52	8-9	9.07±0.73	8.10
10.	Long melon	6.44±1.81	4-10	6.80±1.03	5-8
11.	Wanga	7.33±0.58	5-12	9.16±1.93	7-8
12.	Wild melon	7.00±0.00	7	8.38±1.75	6-11

* No observations could be recorded.
** Observations on male longevity could not be recorded.

female on musk melon which was followed by sponge gourd (43 eggs) and squash melon (37 eggs). Pande and Reddy (1985) reported mean fecundity per female of *T. neocaledonicus* as 35.90, 44.74 and 54.83 eggs, respectively on bottle gourd, ridge gourd and pumpkin at 30±1°C. Gupta *et al* (1972) reported 46.64 eggs and 56.33 eggs as average fecundity per female on musk melon respectively at 25° and 30°C. Observations reported by above authors quite fall in the range as reported in present studies.

4.1.8 Sex-ratio

The sex-ratio of females to males emerged during development in case of all the cucurbits excepting long melon was in favour of the females. Highest female to male ratio was observed in case of wanga (7:1) followed by on ash gourd (5.60:1), summer squash (5:1) and musk melon (4.25:1) but female to male ratio was almost same on cucumber (1.10:1). But in case of long melon, interestingly sex-ratio was in favour of males (0.81:1) (Table 13). Sex-ratio in favour of females have also been reported by Pande and Reddy (1985) for a related species, *T. neocaledonicus*. Sex-ratio in favour of females on different cucurbits excepting on long melon have also been reported by Dhooria (1985).

Overall comparison of development on different cucurbits

Based on lesser mortality during development, shorter larval plus nymphal development, and higher fecundity and longevity of females of *T. cinnabarinus*, musk melon was the best host among cucurbits tested followed closely by water melon, ridge gourd and squash melon. However, longevity of females was higher in case of cucumber, wanga, wild melon and ash gourd but they had prolonged larval plus nymphal development, and very poor fecundity as compared to cucurbits given above as more favourable. Wild melon, ash gourd, cucumber and wanga were less preferred hosts as on them both larvae and nymphs took

Table 13. Fecundity and sex-ratio of red spider mite *T. cinnabarinus* recorded on different cucurbits at 27±1°C

Sr. No.	Cucurbit species	Fecundity (eggs)		Sex-ratio (F:M)
		Mean±S.D.	Range	
1.	Musk melon	52.93±11.52	33-70	4.25:1
2.	Water melon	37.40±11.54	19-65	3.55:1
3.	Summer squash	22.53±5.00	13-30	5:1
4.	Bottle gourd	27.87±6.71	17-41	1.89:1
5.	Bitter gourd *	-	-	-
6.	Ash gourd	12.20±3.49	8-18	5.60:1
7.	Ridge gourd	36.33±6.94	24-48	2.09:1
8.	Squash melon	32.64±5.08	25-42	2.75:1
9.	Cucumber	13.73±3.71	8-24	1.10:1
10.	Long melon	26.20±3.89	16-31	0.81:1
11.	Wanga	15.53±3.14	12-20	7:1
12.	Wild melon	6.53±2.59	3-13	2.6:1

* No observations could be recorded.

longer time for development and there was more mortality during development. Fecundity was also comparatively very low on these hosts. Studies revealed that there was no development on bitter gourd as none of the larvae released for development transformed to protonymph (Table 14). Gupta *et al* (1972) studied development of *T. neocaledonicus* on horse gram, okra, musk melon and brinjal also found musk melon to be the most preferred host based on faster development and higher fecundity as compared to other hosts. Pande and Reddy (1985) studied biology of *T. cinnabarinus* on 3 cucurbits, i.e., pumpkin, ridge gourd and bottle gourd, and found pumpkin as the most suitable and bottle gourd comparatively less suitable. Dhooria (1985) also did preliminary studies on the biology of *T. cinnabarinus* on different cucurbits and found musk melon as the most favourable cucurbit species followed in order of preference by sponge gourd and squash melon. Above author also found mortality of all the larvae released for development on bitter gourd before transforming to protonymph, and even the field collected females released for egg-laying on bitter gourd died within 1-3 days without laying eggs. DaCosta and Jones (1971) also found very high mortality of larvae (99%) on bitter variety of cucumber whereas on non-bitter variety mortality was only 5%. Above authors attributed the higher mortality due to the adverse effect of cucurbitacin on mite development. But Soans *et al* (1973) studied relationship between the bitter character and mite resistance in cucumber, and found bitter varieties, i.e., Marketmore and Tablegreen to be significantly resistant to *T. urticae* causing high mortality in the immature stages and kept mite populations under effective control.

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Table 14. Overall development of red spider mite, *T. cinnabarinus* on different cucurbits at 27±1°C

Sl No.	Cucurbit species	Development period (days) (Mean±S.D.)				Mortality during development (%)	Duration (days)			Longevity (days)		Fecundity	Sex-ratio (Female :Male)
		Larval	Proto-nymphal	Deuto-nymphal	Larval plus nymphal		Pre-ovi-position	Ovi-position	Post-ovi-position	Female	Male		
1.	Musk melon	2.06±0.41	2.02±0.61	1.83±0.50	5.83±0.81	24	1.60±0.51	6.33±1.45	2.00±0.76	7.69 ±2.04	9.00 ±0.00	52.93 ±11.52	4.25:1
2.	Water melon	1.54±0.14	1.53±0.13	1.57±0.21	4.64±0.25	12	1.40±0.63	6.40±1.64	1.47±0.64	8.56 ±1.46	8.00 ±1.15	37.40 ±11.54	3.55:1
3.	Summer squash	1.53±0.12	1.10±0.32	1.73±0.51	4.40±0.51	20	1.33±0.49	5.20±1.01	1.13±0.52	6.93 ±0.80	-	22.53 ±5.00	5:1
4.	Bottle gourd	1.53±0.13	1.50±0.50	1.80±0.65	4.84±0.60	34	1.20±0.56	4.40±0.74	0.73±0.46	6.85 ±1.10	6.42 ±1.13	27.87 ±6.71	1.89:1
5.	Bitter gourd*	-	-	-	-	100	-	-		-	-	-	-
6.	Ash gourd	1.87±0.40	1.45±0.35	1.36±0.47	4.69±0.48	22	1.73±0.70	4.87±0.92	1.87±0.74	7.93 ±1.03	9.00 ±0.00	12.20 ±3.49	5.6:1
7.	Ridge gourd	2.18±0.40	1.52±0.31	1.86±0.68	5.58±0.79	22	1.80±0.41	6.13±1.60	1.33±0.82	8.67 ±0.54	10.00 ±0.00	36.33 ±6.94	2.09:1
8.	Squah melon	2.45±0.50	2.33±0.76	2.60±1.10	7.33±1.60	40	2.20±0.56	4.67±1.35	2.13±0.64	8.14 ±1.51	9.50 ±0.52	32.64 ±5.80	2.75:1
9.	Cucum-ber	2.93±0.50	1.93±0.81	2.52±0.50	7.58±1.05	4	1.87±0.64	5.40±1.35	1.80±0.86	9.07 ±0.73	8.67 ±0.52	13.73 ±3.71	1.10:1
10.	Long melon	1.93±0.72	1.64±0.54	1.95±0.42	5.45±0.52	44	1.80±0.68	4.27±0.80	1.40±0.63	6.80 ±1.03	6.44 ±1.81	26.20 ±3.89	0.81:1
11.	Wanga	3.18±0.87	2.50±0.28	2.63±0.61	8.31±1.06	36	1.73±0.46	5.13±1.12	1.60±0.74	9.16 ±1.95	7.33 ±0.58	15.53 ±3.14	7:1
12.	Wild melon	2.09±0.36	1.50±0.51	2.28±0.63	5.84±0.63	20	1.60±0.51	4.40±1.18	2.00±0.76	8.38 ±1.75	7.00 ±0.00	6.53 ±2.59	2.6:1

* All larvae died before transforming to protonymphs, so no further observations were recorded.

4.2 Feeding preference

Three different experiments were done to find out the feeding preference of red spider mite, *T. cinnabarinus*, on different cucurbits through free choice method as explained under Materials and Methods. One hundred fifty (150) female mites prestarved for 30 minutes were released in the centre in each set up. The observations regarding number of mites found on leaves of different cucurbits were noted in each experiment. Status of mites that were trapped in Tanglefoot® – a sticky substance, or found wandering or dead in the circle were also noted in each experiment. In the first experiment (Table 15) maximum number of mites were found on bottle gourd (Mean = 11.8 mites), ash gourd (Mean = 11.6 mites), summer squash (Mean = 10.2 mites) and squash melon (Mean = 9.8 mites). Minimum per cent mites were found on wild melon (1.33%), long melon (2.40%) and wanga (2.93). Per cent mites found on rest of the hosts varied form 3.33 (on musk melon) to 7.87 (on bottle gourd). Data revealed that 55.59 per cent of mites were able to locate the different hosts successfully while 37.70 per cent were unable to locate their hosts and were wandering in the arena at the time of observations. But 5.87 per cent were found dead, and 1.07 per cent were found trapped in the Tanglefoot®. In the second experiment maximum number of mites were found on ash gourd (Mean = 18.4 mites), squash melon (Mean = 15.0 mites) and water melon (Mean =13.2 mites). However, minimum number of mites opted for wild melon (Mean = 0.2 mites), long melon (Mean = 1.0 mites) and cucumber (Mean = 2.2 mites). Interestingly 3.33% of mites were also found on bitter gourd (Table 15). Perusal of Table 15 revealed that in the third experiment also water melon, musk melon, summer squash, ash gourd and ridge gourd were more preferred for settling while wild melon, cucumber and wanga were least preferred by the mites.

Table 15. Feeding preference of red spider mite, *T. cinnabarinus* on different cucurbits in different experiments at 27±1°C

Sr. No.	Cucurbit species	Number of mites found feeding on different cucurbits					
		Experiment I		Experiment II		Experiment III	
		Mean±S.E.	Per cent	Mean±S.E.	Per cent	Mean±S.E.	Per cent
1.	Musk melon	5.0±1.00	3.33	3.4±2.15	2.27	8.6±0.35	5.33
2.	Water melon	5.4±2.39	3.60	13.2±1.11	8.80	13.0±0.88	9.60
3.	Summer squash	10.2±2.28	6.80	10.6±0.98	7.07	15.2±1.05	10.13
4.	Bottle gourd	11.8±0.88	7.87	8.0±0.83	5.33	8.0±0.56	5.33
5.	Bitter gourd	6.6±1.52	4.40	5.0±0.77	3.33	6.0±0.64	4.00
6.	Ash gourd	11.6±2.33	7.73	18.4±0.59	12.27	15.2±0.61	10.13
7.	Ridge gourd	6.0±1.96	4.00	7.8±1.97	5.20	14.6±0.54	9.73
8.	Squash melon	9.8±4.94	6.53	15.0±2.57	10.00	12.0±0.46	8.00
9.	Cucumber	7.0±3.50	4.67	2.2±1.87	1.47	2.0±0.50	1.33
10.	Long melon	3.6±2.26	2.40	1.0±0.46	0.67	9.2±0.72	6.13
11.	Wanga	4.4±2.40	2.93	5.6±3.90	3.73	2.6±0.55	1.73
12.	Wild melon	2.0±2.45	1.33	0.2±1.01	0.13	1.4±0.96	0.93

Per cent mites	I	II	III
a) Trapped in Tanglefoot	1.07	1.33	0.40
b) Found dead in circle	5.87	6.67	2.53
c) Wandering in circle	37.70	30.93	24.67
d) Successful in finding different hosts	55.59	60.53	72.40

Overall comparison of data in the three experiments revealed that water melon, summer squash, ash gourd and squash melon exhibited maximum feeding preference by *T. cinnabarinus*, while wild melon, wanga, cucumber and long melon showed least feeding preference.

Rahman and Sapra (1940) also reported very high infestation of mites, *T. cucurbitae* and *T. telarius* on squash melon, bottle gourd and pumpkins under field conditions than on other vegetable crops. Gupta *et al* (1972) studied development and fecundity of *T. neocaledonicus* on horse gram, okra, musk melon and brinjal, and found musk melon to be highly preferred for feeding and breeding of mite. Dhooria (1985) studied development and fecundity of *T. cinnabarinus* on long melon, ash gourd, squash melon, bottle gourd, musk melon, bitter gourd and sponge gourd under laboratory conditions. Above author on the basis of faster development during larval and nymphal stages, and higher fecundity of mite on different cucurbits concluded musk melon to be the most suitable cucurbit species followed in order of preference by sponge gourd, squash melon, long melon and bottle gourd. Pande and Reddy (1985) also studied biology of *T. neocaledonicus* on bottle gourd, pumpkin and ridge gourd, and concluded pumpkin to be the most preferred while bottle gourd was least preferred. In the present studies also bottle gourd and ridge gourd were less preferred by the mites. Pumpkin was, however, not tested in the present studies.

4.3 Leaf damage index

For recording extent of damage by red spider mite, *T. cinnabarinus* on different cucurbits, ten teneral females and ten males were released per test leaf of each cucurbit species tested. Petioles of selected leaves of each cucurbit species were ringed with Tanglefoot® to avoid any interleaf movement of mites. Ten replications were kept for each

species. The experiment was conducted for two times. Observations on extent of damage were recorded as per 5 grades as given under Materials and Methods.

In the first experiment, females and males were released on 9th May 2002 and observations on extent of damage were recorded after 13 and 18 days of releasing mites. In data given in Table 16, observations after 13 days revealed very high damage on water melon followed by that on ash gourd and ridge gourd. No damage at this stage was observed on wanga, cucumber and bitter gourd, while minimum damage was observed on long melon, summer squash and squash melon. But in the second observation recorded after 18 days of releasing, water melon, ridge gourd, ash gourd and bottle gourd suffered more damage [Damage index (DI): 3 and above]. Least damage was noticed on cucumber, wanga and squash melon (DI: 1 and below). Bitter gourd leaves did not exhibit any mite damage symptoms and looked quite healthy (Table 16). In the second experiment, mites were released on 29th May 2002 and the first observation recorded after 10 days of releasing mites revealed damage index varying from 0.80 in wanga to 3.40 on water melon (Table 17). Maximum damage was found on water melon followed by that on ash gourd, ridge gourd and musk melon, but minimum damage was noticed on wanga, wild melon, cucumber and bottle gourd. Rest of cucurbit species exhibited moderate damage. In the second observation recorded after 15 days of releasing mites, damage index varied from 0.00 (bitter gourd) to 3.50 (water melon) in different cucurbits. Bitter gourd leaves looked quite healthy and green at this stage also. Maximum damage was found on water melon (DI: 3.50), ash gourd (DI.: 3.10) and bottle gourd (DI: 3.00). Wild melon exhibited minimum damage (DI.: 1.10). In the third observation recorded after 19 days of releasing, damage index varied from 0.00 on

Table 16. Degree of damage done by red spider mite, *T. cinnabarinus* on different cucurbits in first experiment

Sr.No.	Cucurbit species	Damage index rating days after releasing (DAR) mites (based on grading*)			
		13 DAR		18 DAR	
		Mean ± S.E.	Range	Mean ± S.E.	Range
1.	Musk melon	1.20±0.20	0-2	1.60±0.27	1-3
2.	Water melon	3.40±0.16	3-4	4.00±0.00	4
3.	Summer squash	0.60±0.16	0-1	1.70±0.15	1-2
4.	Bottle gourd	1.70±0.15	1-2	3.00±0.26	2-4
5.	Bitter gourd	0.00	0	0.00	0
6.	Ash gourd	2.40±0.22	1-3	3.00±0.21	2-4
7.	Ridge gourd	2.00±0.37	1-4	3.30±0.30	2-4
8.	Squash melon	0.90±0.23	0-2	1.00±0.21	0-2
9.	Cucumber	0.00	0	0.20±0.13	0-1
10.	Long melon	0.50±0.17	01	1.80±0.33	1-4
11.	Wanga	0.00	0	0.80±0.18	0-2
12.	Wild melon	1.60±0.22	0-2	2.60±0.16	2-3

* Damage index grades 0, 1, 2, 3 and 4 respectively correspond to no damage, 25%, 50%, 75% and more than 75% yellowish-white symptoms.

Table 17. Degree of damage done by red spider mite *T. cinnabarinus* on different cucurbits in second experiment

Sr. No.	Cucurbit species	Damage index rating days after releasing (DAR) mites (based on grading)							
		10 DAR		15 DAR		19 DAR		22 DAR	
		Mean ± S.E.	Range	Mean ± S.E.	Range	Mean ± S.E.	Range	Mean ± S.E.	Range
1.	Musk melon	1.80±0.25	1-3	2.60±0.34	1-4	3.70±0.15	3-4	4.00±0.00	4
2.	Water melon	3.40±0.16	3-4	3.50±0.17	3-4	4.00±0.00	4	4.00±0.00	4
3.	Summer squash	1.20±0.20	0-2	2.90±0.35	1-4	3.50±0.22	2-4	4.00±0.00	4
4.	Bottle gourd	1.00±0.21	0-2	3.00±0.33	1-4	3.80±0.13	3-4	4.00±0.00	4
5.	Bitter gourd	0.00	0	0.00	0	0.00	0	0.00	0
6.	Ash gourd	2.90±0.10	2-3	3.10±0.10	3-4	4.00±0.00	4	4.00±0.00	4
7.	Ridge gourd	2.00±0.21	1-3	2.80±0.20	2-4	4.00±0.00	4	4.00±0.00	4
8.	Squash melon	1.60±0.22	0-2	2.40±0.37	0-4	3.60±0.16	3-4	4.00±0.00	4
9.	Cucumber	1.10±0.18	0-2	2.70±0.15	2-3	4.00±0.00	4	4.00±0.00	4
10.	Long melon	1.30±0.15	1-2	1.90±0.18	1-3	2.80±0.29	2-4	2.80±0.29	2-4
11.	Wanga	0.80±0.13	0-1	2.20±0.13	2-3	2.70±0.21	1-3	2.70±0.21	1-3
12.	Wild melon	1.10±0.10	1-2	1.10±0.10	1-2	3.80±0.13	3-4	3.80±0.13	3-4

bitter gourd to 4.00 on water melon, ash gourd, ridge gourd and cucumber. Minimum damage was observed on wanga and long melon. Bitter gourd continued to show no damage by mites at this observation also. In the last observation recorded after 22 days of releasing mites, more than 75% yellowish-white symptoms or leaf burning/drying were observed in all the cucurbits excepting long melon, wanga and wild melon. Bitter gourd still exhibited healthy growth. In the literature no information could be found regarding the comparative leaf damage on different cucurbits by *T. cinnabarinus.*

Overall comparison of extent of damage caused by the mite, *T. cinnabarinus* on different cucurbits after different intervals of releasing revealed more damage on water melon, ash gourd and ridge gourd (Table 16 and 17) even 10 days after releasing (DAR) mites (DI: 2.00-3.40) and reached maximum 19 DAR. But on musk melon, extent of damage increased from 10 DAR and reached maximum (DI: 4.00) at 22 DAR. Bottle gourd, summer squash, cucumber and squash melon were less affected initially but exhibited maximum damage 22 DAR. However, minimum damage by the mites was observed on long melon, wanga and wild melon throughout the experimental period.

CHAPTER V

SUMMARY

Development and [illegible] preference of mite were studied under laboratory conditions in BOD incubator at 27±1°C temperature on [illegible] different [illegible]. [illegible] damage caused by the mite was also studied on [illegible] cucurbit species [illegible] [illegible].

Incubation period varied from [illegible] days [illegible] days [illegible] all the eggs successfully hatched. Studies [illegible] larval period [illegible] [illegible] days) followed by that on cucumber [illegible]±0.50 days and squash melon [illegible]±0.50 days), while minimum duration was found on [illegible] and water melon [illegible] days. [illegible] [illegible] [illegible]

SUMMARY

difficult because [illegible] and [illegible] stage [illegible] [illegible]. Mean protonymphal period varied from [illegible]±0.52 days on summer squash to [illegible]±0.58 days on [illegible] and on muskmelon it was 2.02±0.61 days. [illegible] [illegible] significant [illegible] and [illegible] (>0.05) [illegible] observed. Mean deutonymphal period was [illegible] [illegible]±1.40 [illegible] [illegible] [illegible], cucumber 2.52±0.55 [illegible] [illegible] [illegible] comparatively [illegible] on water melon [illegible] days) and ash gourd [illegible] days).

Total mean developmental period (larva [illegible]) varied from [illegible]±0.57 days on summer squash to 8.71±0.60 days on [illegible]. This period [illegible] [illegible] [illegible] [illegible]±1.05 days) and squash melon [illegible]±1.05 days). Developmental period was also

CHAPTER V

SUMMARY

Development and feeding preference of mite were studied under laboratory conditions in BOD incubator at 27±1°C temperature on 12 different cucumbit species. Leaf damage caused by the mite was also studied on 12 cucurbit species grown under screen house conditions in potted plants.

Incubation period varied from 3.5-4.5 days (3.74±0.27 days). All the eggs successfully hatched. Studies revealed that larval period was comparatively more on wanga (3.18±0.87 days) followed by that on cucumber (2.93+0.50 days) and squash melon (2.45±0.50 days), while minimum duration was found on bottle gourd, summer squash and water melon (1.54±0.14 days). Interestingly all the larvae released for development on bitter gourd leaf-discs died without transforming to the nymphal stage. The larvae after becoming full-fed became quiescent and first stage nymphs, i.e., protonymphs, emerged from them. Mean protonymphal period varied from 1.10±0.32 days on summer squash to 2.50±0.28 days on wanga and on musk melon it was 2.02±0.61 days. The protonymphs after becoming full-fed again became quiescent and second stage nymphs, i.e., deutonymphs emerged. Mean deutonymphal period was quite high on wanga (2.63±0.61 days), squash melon (2.60±1.10 days), cucumber (2.52±0.50 days) and wild melon (2.28±0.63 days), but was comparatively very low on water melon (1.57±0.21 days) and ash gourd (1.36±0.47 days).

Total mean developmental period (larval + nymphal) varied from 4.40±0.51 days on summer squash to 8.31±0.60 days on wanga. This period was also quite high on cucumber (7.58±1.05 days) and squash melon (7.33±1.06 days). Developmental period was also

shorter on water melon (4.64±0.25 days), ash gourd (4.69±0.48 days) and bottle gourd (4.84±0.60 days). Per cent mortality during larval, protonymphal and deutonymphal development was also worked out on different cucurbits. In case of bitter gourd, there was 100% mortality during larval development. On cucumber, ash gourd, wanga and musk melon all the larvae developed successfully and entered into protonymphal stage. Negligible larval mortality (2%) was observed in case of water melon. During protonymphal development, maximum mortality was found on long melon (24%) followed by on ash gourd (18%). Maximum mortality during deutonymphal stage was found on wanga (26%). Very low mortality during deutonymphal development was observed on water melon, ash gourd and ridge gourd. During development from larval to adult stage, 100% mortality occurred on bitter gourd. Total mortality during larval and nymphal development was high on long melon (44%) closely followed by on squash melon (40%), wanga (36%) and bottle gourd (34%). Minimum mortality was found on cucumber and water melon.

Mean pre-oviposition period varied from 1.20 to 2.20 days on different cucurbits, it was lowest on bottle gourd but was highest on squash melon. Oviposition period was longest on water melon (6.40±1.64 days), closely followed by that on musk melon (6.33 ±1.45 days) and ridge gourd (6.13±1.60 days). Lowest oviposition period (4.27±0.80 days) was recorded on long melon. Mean post-oviposition period ranged from 0.73 days on bottle gourd to 2.13 days on squash melon. This period was also quite high on wild melon and musk melon (2.0 days). Female had maximum longevity on wanga (9.16 days), cucumber (9.07 days), water melon (8.56 days) and squash melon (8.14 days). Minimum longevity was recorded on long melon (6.80 days), bottle gourd (6.85 days) and summer squash (6.93 days). Male longevity was highest on ridge gourd (10.00 days) closely followed by that on squash melon, musk

melon and ash gourd. Highest mean fecundity per female was recorded on musk melon (52.93 eggs) followed by that on water melon (37.40 eggs), ridge gourd (36.33 eggs) and squash melon (32.64 eggs). Mean fecundity was comparatively very low on wild melon (6.53 eggs) followed by that on ash gourd (12.20 eggs), cucumber (13.73 eggs) and on wanga (15.53 eggs). The sex-ratio (female: male) was in favour of the females. Highest sex-ratio was observed in case of wanga (7:1) followed by that on ash gourd (5.60:1) and musk melon (4.25:1), but lowest sex-ratio was observed in case of cucumber. Based on higher fecundity and shorter larval plus nymphal development of mite - musk melon was the best host among cucurbits followed closely by water melon, ridge gourd and squash melon. Studies also revealed that there was no development on bitter gourd as all the larvae released died without transforming to the next stage, i.e., protonymph.

For studying feeding preference of red spider mite on different cucurbits three different experiments were conducted through free choice method. Overall comparison of data in the three experiments revealed that water melon, summer squash, musk melon, ash gourd and squash melon exhibited maximum feeding preference by mites while wild melon, wanga, cucumber and bitter gourd showed less preference for feeding.

Two experiments were conducted under screen house conditions in potted plants for recording extent of damage caused by *T. cinnabarinus* on different cucurbits as per methodology given under Materials and Methods. In both the experiments, in general maximum damage was found on water melon and musk melon, followed by that on ash gourd and ridge gourd but minimum damage was recorded on long melon, wanga, wild melon and cucumber. Rest of cucurbit species exhibited moderate damage.

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