“INVESTIGATIONS ON DAMAGE BY CHILLI YELLOW MITE, *Polyphagotarsonemus latus* (BANKS) (ACARI: TARSONEMIDAE) AND RESISTANCE IN CHILLI, *Capsicum annuum* L.”

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Affectionately Dedicated to My Beloved Family Members and Chairperson

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BANGALORE 560 065

CERTIFICATE

This is to certify that the thesis entitled "**Investigations on damage by chilli yellow mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) and resistance in chilli, *Capsicum annuum* L.**" submitted by **Mr. GIRISH, R., ID No. PAK 7005,** in partial fulfilment of the requirements for the award of **DOCTOR OF PHILOSOPHY in AGRICULTURAL ENTOMOLOGY** to the University of Agricultural Sciences, Bangalore, is a record of *bonafide* research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award for the degree, diploma, associateship, fellowship or other similar titles.

Bangalore
APRIL, 2012

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"Investigations on damage by chilli yellow mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) and resistance in chilli, *Capsicum annuum* L."

R. Girish

Abstract

Investigations were carried out on the damage by yellow mite, *Polyphagotarsonemus latus* (Banks) and resistance in chilli germplasms during 2008-2011. Mean loss in dry fruit yield due to yellow mite damage was 29.39 per cent.

Under glasshouse conditions, yellow mite infestation for 4 weeks period (on 4 and 6 weeks old plants) resulted in a cumulative mite population of 714.40 and 401.60 mites/6 leaves, respectively, with a lower biomass production (625 to 750 g/25 plants) against 2325g under mite free conditions. Mite colonization for 4 weeks period on chilli crop in the field also recorded more number of mites (361.90 to 200.10 mites/6 leaves) associated with a more significant damage score of 2.36, particularly on 4 weeks old plants. Such mite infestation treatments recorded the lower yields of red ripe chilli fruits (533 - 933 kg/acre) compared to the highest yield of 3313 kg in a relatively mite free conditions (control).

Continuous mite infestation from 15 or 30 or 45 days after planting till maturity under glasshouse conditions resulted in complete yield loss (100%) and in the field, due to continuous infestation (from 15 or 30 or 45 or 60 or 75 days after planting till maturity), the corressponding yield losses were 83%, 75%, 58%, 46% and 31%.

Out of 107 chilli entries evaluated, 32 entries were advanced and based on the mean mite population data were categorised as, Highly resistant (Aparna & S 49 with <5 mites), Resistant (BVC 47 with 5 to 10 mites), Moderately resistant (BVC 53 & *Capsicum frutescence* with 11 to 20 mites), Susceptible (CA 2, KDC 2 & CA 9 with 21 to 30 mites) and Highly susceptible (22 entries including *Byadgi kaddi* with >30 mites).

Susceptible chilli entries had higher total sugars and protein contents to encourage the mite infestation, while chlorophyll and capsaicin contents in leaves did not show any relationship with mite infestation levels. Consequent to mite infestation, the levels of phenols, proline, peroxidase and PAL were found enhanced (16.80 to 22.80 mg/g; 4.42 to 6.54 µ moles/g tissue; 825 to 1362 units/g of tissue; 3.20 to 4.67×10^3 µmoles/min/ml), might be due to induced resistance or hypersensitive reaction, particularly in resistant entries namely, Aparna, S 49, BVC 47, BVC 53 and *Capsicum frutescence*.

April, 2012

Department of Agril. Entomology | **Dr. N. Srinivasa**
UAS, GKVK, BANGALORE-65 | (Major adviser)

"ಮೆಣಸಿನಕಾಯಿ ಹಳದಿ ನುಸಿ, ಪಾಲಿಫ್ಯಾಗೊಟಾರ್ಸೋನಿಮಸ್ ಲೇಟಸ್ (ಬ್ಯಾಂಕ್ಸ್) (ಅಕ್ಯಾರಿ: ಟಾರ್ಸೋನೆಮಿಡೆ) ಯಿಂದಾಗುವ ಹಾನಿ ಮತ್ತು ಮೆಣಸಿನಕಾಯಿ (ಕ್ಯಾಪ್ಸಿಕಮ್ ಆ್ಯನಮ್ ಎಲ್.) ಬೆಳೆಯಲ್ಲಿ ನುಸಿ ನಿರೋಧಕತೆ"

ಆರ್. ಗಿರೀಶ್

ಸಾರಾಂಶ

2008 ರಿಂದ 2011 ರ ಅವಧಿಯಲ್ಲಿ ಹಳದಿ ನುಸಿಯ ಹಾನಿ ಮತ್ತು ಮೆಣಸಿನಕಾಯಿ ತಳಿಗಳಲ್ಲಿ ನುಸಿ ನಿರೋಧಕ ಶಕ್ತಿಯ ಮೇಲೆ ಅಧ್ಯಯನ ನಡೆಸಲಾಯಿತು. ಮೆಣಸಿನಕಾಯಿ ಬೆಳೆಯಲ್ಲಿ ಹಂತ ಹಂತವಾಗಿ ಬರುವ ವಿವಿಧ ಕೀಟ ಮತ್ತು ನುಸಿಯ ಸಂಕೀರ್ಣದಲ್ಲಿ ಒಟ್ಟು 26 ಪ್ರಭೇಧದ ಕೀಟಗಳು ಮತ್ತು ಒಂದು ಪ್ರಭೇಧ ನುಸಿಯನ್ನು ದಾಖಲಿಸಲಾಯಿತು. ಈ ಪೀಡೆಗಳಲ್ಲಿ ಹಳದಿ ನುಸಿಯ ಬಾಧೆಯಿಂದಾಗಿ ಒಣಮೆಣಸಿನಕಾಯಿಯ ಸರಾಸರಿ ಇಳುವರಿಯು ಶೇ. 29.39 ರಷ್ಟು ಕಡಿಮೆಯಾಗುವುದೆಂದು ಕಂಡುಕೊಳ್ಳಲಾಯಿತು.

ಪಾಲಿಕಾರ್ಬೋನೇಟ್ ಮನೆಯಡಿಯಲ್ಲಿ ಹಾಗೂ ಕೃಷಿ ತಾಕುಗಳಲ್ಲಿ ಮೆಣಸಿನಕಾಯಿ ಬೆಳೆಯ ಮೇಲೆ ಹಳದಿ ನುಸಿಯ ಬಾಧೆ ಮತ್ತು ಹಾನಿಯ ಬಗ್ಗೆ ವಿಮರ್ಶಾತ್ಮಕ ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ಪಾಲಿಕಾರ್ಬೋನೇಟ್ ಮನೆಯಡಿಯಲ್ಲಿ 4 ಮತ್ತು 6 ವಾರಗಳ ವಯಸ್ಸಿನ ಮೆಣಸಿನಕಾಯಿ ಸಸಿಗಳ ಮೇಲೆ 4 ವಾರಗಳವರೆಗೆ ಹಳದಿ ನುಸಿಯ ನಿರಂತರ ಹಾವಳಿಯಿಂದ ಒಟ್ಟಾರೆ ನುಸಿಯ ಸಂಖ್ಯೆಯು ಪ್ರತಿ 6 ಎಲೆಗಳಿಗೆ ಅನುಕ್ರಮವಾಗಿ 714.40 ಮತ್ತು 401.60 ರಷ್ಟು ವೃದ್ಧಿಯಾಗಿರುತ್ತದೆ. ಇದರಿಂದಾಗಿ ಪ್ರತಿ 25 ಗಿಡಗಳ ಬಯೋಮಾಸ್ ಪ್ರಮಾಣ 625 ರಿಂದ 750ಗ್ರಾಂ ಇರುತ್ತದೆ ಮತ್ತು ಅದೇ ವಯಸ್ಸಿನ ಸಸಿಗಳಲ್ಲಿ ಬಯೋಮಾಸ್ ನುಸಿರಹಿತ ಪ್ರಮೇಯದಲ್ಲಿ ಹೆಚ್ಚಾಗಿರುತ್ತದೆ (2325ಗ್ರಾಂ). ಹಾಗೆಯೇ ಕೃಷಿ ತಾಕುಗಳಲ್ಲಿ ನಾಟಿ ಮಾಡಿದ 4 ಮತ್ತು 6 ವಾರದ ವಯಸ್ಸಿನ ಸಸಿಗಳಲ್ಲಿ ಕೂಡ ಇದೇರೀತಿಯ ನುಸಿಯ ಬಾಧೆಯಿಂದ ಕ್ರಮವಾಗಿ ಪ್ರತಿ 6 ಎಲೆಗಳಲ್ಲಿ 361.90 ಮತ್ತು 200.10 ನುಸಿಗಳಿದ್ದು (ಸಂಚಿತವಾಗಿ), ಉಂಟಾಗುವ ಹಾವಳಿಯಿಂದ ಬಾಧೆಯ ಲಕ್ಷಣವು (2.36 ಸ್ಕೋರ್) ಗಮನಾರ್ಹವಾಗಿರುತ್ತದೆ. ಅಲ್ಲದೇ ಆ ಗಿಡಗಳಿಂದ ಕೆಂಪು ಬಣ್ಣದ ಮೆಣಸಿನ ಹಣ್ಣಿನ ಇಳುವರಿ ಗಣನೀಯವಾಗಿ ಕುಂಠಿತಗೊಳ್ಳುತ್ತದೆ.

ಗಾಜಿನ ಮನೆ ವಾತಾವರಣದಲ್ಲಿ ನಾಟಿ ಮಾಡಿದ ಮೆಣಸಿನ ಸಸಿಗಳ ಮೇಲೆ 15–45 ದಿನಗಳಿಂದ ಕೊಯ್ಲಿನತನಕ ನಿರಂತರ ನುಸಿ ಬಾಧೆಗೆ ಒಳಗಾದ ಗಿಡಗಳ ಇಳುವರಿಯು ಶೂನ್ಯವಾಗುವುದರಿಂದ ನಷ್ಟದ ಪ್ರಮಾಣ ಶೇ. 100ರಷ್ಟಿರುತ್ತದೆ. ಇದೇ ರೀತಿ ಕೃಷಿ ತಾಕುಗಳಲ್ಲಿ ಬೆಳೆದ ಮೆಣಸಿನಕಾಯಿ ಗಿಡಗಳನ್ನು ನಾಟಿ ಮಾಡಿದ 15/30/45/60/75 ದಿನಗಳಿಂದ ಕೊಯ್ಲಿನತನಕದ ನುಸಿ ಬಾಧೆಯಿಂದ ಕೆಂಪು ಮೆಣಸಿನಕಾಯಿಯ ಇಳುವರಿಯಲ್ಲಿ ಅನುಕ್ರಮವಾಗಿ ಶೇ. 83, 75, 58, 46 ಮತ್ತು 31 ರಷ್ಟು ನಷ್ಟವಾಗುತ್ತದೆ.

ಮೆಣಸಿನಕಾಯಿ ಬೆಳೆಯ ನುಸಿ ನಿರೋಧಕ ಶಕ್ತಿಯ ಅಧ್ಯಯನದಲ್ಲಿ ಒಟ್ಟು 107 ತಳಿಗಳನ್ನು ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು, ಅದರಲ್ಲಿ 32 ತಳಿಗಳನ್ನು ಹಳದಿ ನುಸಿ ಆವರಿಸುವ ಸಂಖ್ಯೆಯ (ಪ್ರತಿ 6 ಎಲೆಗಳಲ್ಲಿ) ಮೇಲೆ 5 ಗುಂಪುಗಳಾಗಿ, ಅಂದರೆ ಅತಿ ನಿರೋಧಕ (ಅಪರ್ಣ ಹಾಗೂ ಎಸ್49 – <5 ನುಸಿಗಳು), ನಿರೋಧಕ (ಬಿವಿಸಿ 47–5 ರಿಂದ 10 ನುಸಿಗಳು), ಮಿತ ನಿರೋಧಕ (ಬಿವಿಸಿ 53 ಹಾಗೂ ಕ್ಯಾಪ್ಸಿಕಮ್ ಫ್ರೂಟಸೆನ್ಸ್ – 11 ರಿಂದ 20 ನುಸಿಗಳು), ಪರಿಣಾಮಕಾರಕ (ಕೆಡಿಸಿ 2 ಮತ್ತು ಸಿಎ 9 – 21 ರಿಂದ 30 ನುಸಿಗಳು) ಹಾಗೂ ಅತೀ ಮೃದು (22 ತಳಿಗಳು – >30 ನುಸಿಗಳು) ಎಂದು ವಿಂಗಡಿಸಲಾಯಿತು. ಮೆಣಸಿನಕಾಯಿ ತಳಿಗಳ ಎಲೆಗಳಲ್ಲಿನ ಪತ್ರಹರಿತ್ತು ಮತ್ತು ಕ್ಯಾಪ್ಸಸಿನ್ ಪ್ರಮಾಣವು ಹಳದಿ ನುಸಿಯ ಬಾಧೆಯೊಂದಿಗೆ ಯಾವುದೇ ಸಂಬಂಧದ ತೋರ್ಪಡೆಯಾಗಿಲ್ಲ, ಆದರೆ ಸಸಿಗಳಲ್ಲಿ ಒಟ್ಟು ಸಕ್ಕರೆ ಮತ್ತು ಪ್ರೋಟೀನ್ ಪ್ರಮಾಣವು ಹೆಚ್ಚಿದ್ದಲ್ಲಿ ಹಳದಿ ನುಸಿಯನ್ನು ಉತ್ತೇಜಿಸುವ ಸಾಧ್ಯತೆ ಹೆಚ್ಚಿರುತ್ತದೆ. ನುಸಿ ಬಾಧೆಯ ನಂತರದಲ್ಲಿ ಎಲೆಗಳಲ್ಲಿ ಜೈವಿಕ ರಾಸಾಯನಿಕಗಳಾದ ಫಿನಾಲ್, ಪ್ರೋಲಿನ್, ಪರಾಕ್ಸಿಡೇಸ್ ಮತ್ತು ಫಿನೈಲ್ ಅಲನೈನ್ ಅಮೋನಿಯ ಲೈಯೇಸ್ ಅಂಶವು ಕ್ರಮವಾಗಿ 16.8 ರಿಂದ 22.80 ಮಿ. ಗ್ರಾಂ. ಪ್ರತಿ ಗ್ರಾಂ. ಗೆ, 4.42 ರಿಂದ 6.54 ಮೈಕ್ರೋ ಮೋಲ್ಸ್ ಪ್ರತಿ ಗ್ರಾಂ.ಗೆ, 825 ರಿಂದ 1362 ಯುನಿಟ್ ಪ್ರತಿ ಗ್ರಾಂ.ಗೆ, 3.2 ರಿಂದ $4.67 \text{ x } 10^{3}$ ಮೈಕ್ರೋ ಮೋಲ್ಸ್ ಪ್ರತಿ ಗ್ರಾಂ.ಗೆ ಹೆಚ್ಚಾಗಿರುವುದು, ವಿಶೇಷವಾಗಿ ನುಸಿ ನಿರೋಧಕ ತಳಿಗಳಾದ ಅಪರ್ಣ, ಎಸ್ 49, ಬಿವಿಸಿ 47, ಬಿವಿಸಿ 53 ಮತ್ತು ಕ್ಯಾಪ್ಸಿಕಮ್ ಫ್ರೂಟಸೆನ್ಸ್‌ಗಳಲ್ಲಿ ಪ್ರೇರಿತ ಪ್ರತಿರೋಧ ಅಥವಾ ಶೀಘ್ರ ಪ್ರತಿಕ್ರಿಯೆಯ ಕಾರಣವಿರಬಹುದೆಂದು ತಿಳಿದು ಬಂದಿರುತ್ತದೆ.

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ಕೃ.ವಿ.ವಿ., ಜಿ.ಕೆ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು – 65

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Introduction

I. INTRODUCTION

Chilli which belongs to family Solanaceae is one of the most important vegetable cum spice crops. The origin of chilli is said to be Mexico, with secondary centers in Guatemala and Bulgaria (Salvador, 2002), which thrived in Mexico as early as 7000 BC. Chilli was the original Aztec name. Chirstopher Colombus, the discoverer of America, came across chillies during his voyages and noticed a similarity in spicyness to the black and white pepper cultivated in Europe and named his discovery as 'Red pepper'. In 17th century, Portuguese introduced chilli into India and incorporated it into Indian cuisines instantly (Bosland and Votava, 2000).

Pungent peppers commonly known as chilli in India, belong to the species *Capsicum annuum* L. (2n=24) which is the most widely cultivated species in the world. It is one of the important condiment crops grown both as a garden crop and as a field crop on a large scale in India especially in the South. Dry chilli is widely used for various foods and non-food purposes *viz*., in preparing different dishes, pharmaceutical and beverage industries. Chilli besides imparting pungency and red colour, is an important source of vitamin A, C and E, which helps in digestion. Capsaicin, an alkaloid responsible for pungency in chillies has medicinal properties and it prevents heart attack by dilating the blood vessels (Gill, 1988).

Chilli is grown throughout the tropics and warm temperate regions of the world. The important chilli growing countries are India, Spain, Japan, Mexico and East-Africa. Being a crop of tropical and sub-tropical region, it requires a warm humid climate. It is grown on many types of soils, well drained loamy soils rich in organic matter content are best suited for its cultivation. India contributes for one fourth of the world's production of chilli with 7 million tonnes from an area of 9.15 lakh hectares (*http:/www.spices.com*, 2009). Although, chilli is cultivated in almost all parts of the country, Andhra Pradesh, Karnataka, Maharashtra, Tamil

Nadu and Orissa contribute to about 85 per cent of the total production. In Karnataka, chilli is grown in more than two lakh hectares with a production of more than one lakh tonnes every year. In Karnataka, major chilli cultivating tracts are Haveri, Dharwad, Gadag, Koppal, Belgaum, Bagalkot and Raichur.

Despite concerted efforts at various levels, chilli productivity has not gained expected momentum in the country. The crop enjoys vast potentialities to increase its production in order to promote export, besides meeting the domestic requirements. A number of limiting factors may be attributed to low chilli productivity, of which damage due to pests is more important.

The pest spectrum on chilli crop is vast with more than 293 insects and a mite species infesting the crop in the field as well as in the storage (Anonymous, 1987). Butani (1976) reported about 21 species of pests inflicting damage to chilli in India. Further, Reddy and Puttaswamy (1983) encountered 51 and 39 species of pests attacking nursery and transplanted crops, respectively in Karnataka, of these pests, thrips, mites, aphids and whiteflies have been identified as major and key pests.

Out of many insect and non-insect pests of chilli, yellow mite *Polyphagotarsonemus latus* (Banks) is most destructive (Butani, 1976) causing nearly 25 per cent loss in yield (Ahmed *et al*., 1987). The yield loss due to this pest may be more than 90 per cent (Borah, 1987) and at times complete devastation of the crop might occur. *P. latus,* a member of the family Tarsonemidae commonly known as yellow mite, broad mite *etc*. is an important mite pest of chilli with wide host range including many cultivated crops like potato, sweet pepper, tomato, egg plant, beans, melons, celery, pakchoi (Chinese white cabbage), cotton, pears, guava, passion fruit and flower crops like chrysanthemum, dahlia *etc* (Gibson and Valencia, 1978).

Characteristic leaf curl symptoms called ‘murda syndrome’ is a typical malady with which chilli crop suffers in India to a great extent. The syndrome is also known as ‘mutlagariroga’ or ‘chandiroga’ in Karnataka (Kulkarni, 1922; Ningappa, 1972; Karmakar, 1997). The murda syndrome is attributed to the damage of the tarsonemid mite, *P. latus* and of the thrips, *Scirtothrips dorsalis* Hood or both (Channabasavanna and Puttarudraiah, 1959). The nymphs and adults of mites prefer to feed on top succulent leaves, often seen in large numbers on the terminal young leaves and shoots of the plants. Leaves of mites infested chilli plants curl downwards in an inverted boat shaped manner, petioles of reasonably matured leaves become elongate, brittle and curl downward completely, the lower surface turns to silvery shiny tinge which gradually turns brownish. With infestation in the early stage of the crop, leaves turn thickened and cracked. The apical shoot gets crumpled, rosette and plants become stunted.

Though the occurrence of yellow mite as well as its damage on chilli crop is often reported to be throughout the cropping season, the proper understanding of the crucial coincidence of mite abundance with the critical crop stage is necessary for planning and execution of a management strategy. Host plant resistance as an important component of integrated pest management suits well in the management of the yellow mite *P. latus* as well. To reduce the unwarranted pesticide load in the environment and also in the process of developing an economically feasible management strategy, a sound knowledge on the seasonal fluctuation of the pests species and the crop phenology is a pre-requisite. Realizing the importance of these aspects, investigations were carried out with the following major objectives:

1. Critical assessment of damage and yield loss due to yellow mite, *Polyphagotarsonemus latus* (Banks) on chilli crop
2. Screening of chilli lines/cultivars for resistance to yellow mite and identification of probable resistance mechanisms.

Review of literature

II. REVIEW OF LITERATURE

Yellow mite, *Polyphagotarsonemus latus* (Banks) commonly known as chilli mite has a wide host range worldwide and it is a cosmopolitan pest of many cultivated crops like chilli, potato, tomato, beans, maize, egg plant, sweet pepper, celery, melons, pear, guava, passion fruit, cotton, jute, tea, coffee and numerous wild plants. Though sizeable quantum of data have been documented on the host plants and other aspects of this mite species, concerted efforts on the reaction of chilli lines to *P. latus* are limited. The available literature on various aspects of this mite and its main host plant, chilli are reviewed hereunder.

2.1. Pests of chilli, *Capsicum annuum* L.

Chilli crop is known to be damaged by 21 insect and non-insect pests, of which the tarsonemid mite, *P. latus* is most destructive causing 25 per cent loss in yield (Butani, 1976). Reddy and Puttaswamy (1983) encountered 51 and 39 species of pests infesting both transplanted and nursery chilli, respectively. In Karnataka, this mite has been identified as one of the major pests, others being thrips, aphids and whiteflies and the pest spectrum of chilli crop, which is more complex debilitate the crop in field as well as in storage (Anonymous, 1987). Karupuchamy *et al*. (1993) reported 21 insect and 12 non-insect pest species on chilli in Tamil Nadu.

2.2. Broad mite or yellow mite, *Polyphagotarsonemus latus* (Banks)

Polyphagotarsonemus latus (Banks) is known by various names in different parts of the world. Colour of this mite, its principal host plant in the region and its body shape bear relation with its common name. In India, it is commonly called by names such as broad mite, yellow mite, yellow tea mite or chilli mite *etc*. (Puttarudraiah and Channabasavanna, 1955).

a) Systematic position and Nomenclature

Order: Acariformes

Class: Arachinida

Subclass: Acari

Super family: Tarsonemoidea

Family: Tarsonemidae

The mite was first discovered by Green (1890) from Sri Lanka who named it initially as *Acarus translucens* and then redescribed it in 1900 as *Tarsonemus translucens*. In 1904, Banks collected a mite from mango galls on main shoot in United States of America and described it as *Tarsonemus latus* (Denmark, 1980). Ewing (1939) considered the *Tarsonemus* (=*Acarus*) *translucens* of Green and *Tarsonemus latus* of Banks as synonyms and erected a new genus *Hemitarsonemus* and named it as *Hemitarsonemus latus.* Later, Beer and Nucifera (1965), while revising the various genera under the family Tarsonemidae proposed a new generic name *Polyphagotarsonemus* for *Hemitarsonemus*. Since then the yellow mite is known as *Polyphagotarsonemus latus* (Banks).

b) Damage: Leaf curl in chilli is mainly caused by both thrips and mites and is referred by various names such as 'murda' or 'chandiroga' (in Karnataka) or 'mudatha' (in Andhra Pradesh) or 'murnai' (in Tamil Nadu) or 'churda murda' (in Maharastra) (Kar, 1926; Ayyar, 1952; Moghe, 1977). This leaf curl is characterized by the upward or downward curling associated with distortion areas resulting in partial suppression of laminal region, especially near the petiolar end and which results in narrowing of leaves. In advanced damage the apical meristem is aborted and consequently auxiliary bud development is interfered. The arrested auxiliary buds produce clusters of minute, thickened and brittle leaves. Severely affected plants do not flower as a consequence of abortion of their reproductive meristems.

Chief symptoms of *P. latus* infestation on chilli plants would be that, the affected leaves curl downwards often with distortion and are wrinkled with reduced size. Continued damage during flowering makes the flowers to wither-off, while infested fruits get malformed and undersized (Kulkarni, 1922). Park and Fernando (1938) reported that leaf curl due to *P. latus* consisted of abaxial curling of leaf blades, distortion of interveinal areas in leaves and narrowing of laminal region near the petiole.

c) Other Host plants: Yellow mite also infests many fruits and vegetable crops. Many common weeds besides serve as reservoir hosts between crop plants. *P. latus* is virtually cosmopolitan and known to occur worldwide.

Host plants of *P. latus* reported from Karnataka (Channabasavanna & Puttarudraiah, 1959; Puttaswamy and Reddy, 1981;Borah, 1987) are as in Table 1.

d) Natural enemies of yellow mite, *Polyphagotarsonemus latus* (Banks)

The biology and feeding efficiency of the predatory mite, *Amblyseius longispinosus* (Evans) on yellow mite was studied in laboratory conditions at 23-27^{0}C and 65-70% RH. The egg, larval, protonymph and deutonymphal stages lasted for 46.45, 14.27, 23.18 and 24.41 hours in females and 45.67, 14.10, 22.78 and 22.71 hours in males. The females consumed 11.72 larvae, 9.33 nymphs or 5.07 adults/day, the larvae consumed 3.76, 1.38 and 0 prey larvae, nymphs and adults, respectively. Protonymphs consumed 9.18 larvae, 7.87 nymphs and 3.18 adults (Hariyappa and Kulkarni, 1988).

Karuppuchamy *et al*. (1994) reported a phytoseiid mite, *Amblyseius ovalis* (Evans) as a most efficient predator, devouring the mite with an average of 5.76, 4.64, 3.20, 3.12 and 2.12 eggs, first and second instar nymphs, pupae and adults, respectively. The predating efficiency gradually reduced in protonymph and deutonymphal stages of the predator and the larval stage was least predatory.

Table 1. List of host plants of *Polyphagotarsonemus latus* (Banks) reported from Karnataka

Family	Host
Amaranthaceae	*Amaranthus spinosus* L. *Amaranthus* sp.
Asteraceae	Dahlia *Chrysanthemum* sp. *Tagetes erecta* L. *Tagetes* sp. *Lactuca* sp.
Boraginaceae	*Trichodesma indica* L.
Cucurbitaceae	*Cucumis* sp. *Momardica charantia* L. *Momardica cochinchinensis* L.
Euphorbiaceae	*Euphorbia hirta* L.
Fabaceae	*Phaseolus vulgaris* L. *Dolichos uniflorus* Lam *Glycine max* L. *Lablab purpureus* (L.) *Psophocarpus tetragonolobus* (Stickm.) *Vigna mungo* L. *Vigna radiata* (L.) *Vigna ungiculata* L. *Vicia indica* L.
Laminaceae	*Leucas aspera* (Willd)
Malvaceae	*Gossypium* sp. *Datura stramonium* L.
Moraceae	*Morus alba* L.
Myrtaceae	*Psidium guajava* L.
Pedaliaceae	*Sesamum indicum* L.
Solanaceae	*Solanum nigrum* Linn. *Capsicum annuum* L. *Solanum tuberosum* L. *Lycopersican esculentum* Mill. *Physalis minima* L. *Solanum melangena* L.
Tiliaceae	*Corchorus aestuans* L.

Field release of *Amblyseius ovalis* @ 5, 10, 15 and 20 mites per plant in chilli crop compared with recommended pesticides indicated that 20 mites per plant proved superior with the lowest number of yellow mites (0.61/3 leaves) as well as thrips (0.81/3 leaves) (Manjunatha *et al*., 2001).

e) Biology of yellow mite, *Polyphagotarsonemus latus* (Banks)

The number of eggs laid by a female and population growth were affected by temperature and relative humidity. Life cycle of yellow mite from egg to adult was completed in 4 to 6 days (Brown and Jones, 1983).

According to Borah (1987) the development of *P. latus* on chilli during different months of a year under laboratory conditions varied from 96.51 to 146.59 hours with an average of 128 hrs. The mite developed faster during summer months than during winter months.

Studies of Ahmed *et al*. (2000) revealed that total developmental period of the mite from egg to adult was 84.15 ± 7.23 hours in males and 86.36 ± 6.68 hours in females, it completed many generations on the chilli crop under favourable conditions.

Rani (2001) reported the mean developmental period of 84.98 ± 2.83 hours and 88.07 ± 3.58 hours for males and females, respectively. Female mites lived longer (7-11 days) than males (6-8 days) and adult longevity was observed to be more during summer than during winter.

Srinivasulu *et al.* (2002) studied the biology and reported the mean durations of egg, larval and quiescent stages of males as 36.3, 19.8 and 17 hours and those of females as 38.8, 21.5 and 19.3 hours, respectively. The longevity of males and females was 6.41 and 7.92 days, respectively.

Hosamani *et al.* (2007) reported average egg period of 36.20± 3.60 h and the larval period of 28.70 ± 3.60 h. Females lived for 8.66± 1.57 days with a preoviposition period of 20.56 ± 4.83 hours. Oviposition lasted for 7.9 ± 0.9 days with a mean fecundity of 19 – 40 eggs per female.

Egg

Yellow mite eggs are oval in shape and slightly flattened, also described as round, oval elongate, oblong and globbose (Gadd, 1946; Hugon, 1983). The eggs are white in colour, with smooth flattened undersurface and sculptured with tubercles arranged in rows on the upper surface (Lavoipierre, 1940). The eggs which measure about 0.7mm long (Hill, 1983), are usually laid singly on the undersurface of the leaves. On fruits eggs are laid on protected surfaces or in depressions (Waterhouse and Norris, 1987; Brown and Jones, 1983). Ahmed *et al.* (2000) reported that the eggs were confined mostly near to mid and lateral veins on the underside of the leaf. Six longitudinal rows of tubercles were observed on the dorsal surface of the egg. The egg period was 36.04±3.12 hours. The fecundity varied from 17 – 41 eggs, the preoviposition period was 20.56 ± 4.88 hours and egg laying lasted for 7.9 ± 0.94 days.

Larva

Larva is minute with pear shaped body with three pairs of legs and moves slowly compared to adults, with a whitish stripe along the mid dorsal line of the body (Lavoipierre, 1940; Gadd, 1946). The young larva measures on an average 116µm in length and 65 µm in breadth, correspondingly it would be 182 µm and 95µm when fully developed.

Nymph

The nymph of *P. latus* is a non-feeding quiescent stage and appears elongate, broadest in the middle region and transparent except for a milky white stripe on the dorsum, it remains attached to the underside of leaves until the time of moulting (Hill, 1983).

Ahmed *et al*. (2000) reported that quiescent nymph is spindle shaped and remained in depressions around the mid rib and lateral veins of leaves. The duration of quiescent nymphal stage was 21.67 ± 1.79 hours for females and 19.5 ± 1.33 hours for males.

Adult

Adult broad mites are elliptical in shape, but slightly wider at the front than the rear (Brown and Jones, 1983). Females are about 1.5 mm long and males are slightly shorter and broader (Lavoipierre, 1940). Live adults are light, translucent yellowish green. A pale white stripe runs longitudinally down the back of the female. Dead adults look yellowish brown.

Female: The colour of the newly emerged female is whitish or hyaline, body is smooth and glistering, oval in shape and clear amber in colour (Mann *et al*., 1920). The legs are comparatively slender. A fully developed female is amber coloured. The first three pairs of legs are used in locomotion, while the fourth pair is reduced to a whip like appendage (Brown and Jones, 1983).

Male: The male body is broadest near the third pair of legs and gradually tapers towards the posterior end. The male measures 120μm in length and 70μm in breadth (Hugon, 1983). Fully developed male is white to light yellow in colour (Rao, 1970). The fourth pair of legs are peculiar and stronger than that of the females. The male emerges about 3-6 h earlier than the female and is extremely active and moves in search of quiescent females, which are carried by it with the help of their fourth pair of legs and the papilla of the abdomen which are attached to the female so that it is held at right angle (Borah, 1987).

2.3. Behaviour & spatial distribution of yellow mite, *Polyphagotarsonemus latus* (Banks)

Larvae and adults prefer to feed on the undersides of leaves usually in the near vicinity of eggs, and then migrate to new leaf growth carrying the developing females (Hill, 1983). The males often carry the pupae to newly opened leaves. Copulation occurs immediately after the emergence of female from the pupal stage. Females are more sedentary (Waterhouse and Norris, 1987), however the species is generally considered fast moving compared to other tarsonemids (Brown and Jones, 1983).

Srinivasa *et al*. (2007) studied the distribution pattern of the yellow mite *P. latus* on potato. The results showed that terminal leaflet in a compound leaf in the top canopy harboured maximum number of eggs (21.8) as well as the active stages (19.8) compared to corresponding leaflets in the compound leaf of the bottom canopy (with 11.4 eggs and 11 active stages, respectively).

2.4. Seasonal occurrence of *Polyphagotarsonemus latus* (Banks) on chilli

Polyphagotarsonemus latus is reported to occur throughout the year with varying densities (Ningappa, 1972). Seasonal fluctuation of chilli mites showed more population from Febraury to May and from October to November than in the other months (Mote, 1976). Such variations in the mite population reported by several workers are attributed to environmental factors. Combination of high temperature, low humidity and rainy days with less intense rainfall favoured the mite population (Borah, 1987).

Lingeri *et al*. (1998) observed the activity of mites throughout the cropping period. Peak activity was noticed in the months of November and February during the periods of high temperature, low humidity and less intense rainfall. The population tends to increase during dry periods of lower minimum temperature and less intense rainfall.

Rani (2001) reported that the overall mite population (inclusive of eggs and active stages) was maximum (11.4/five leaves) at 75 days after planting of chilli during last week of June with maximum and minimum temperatures of 28.2^0 C and 19.2^0C, respectively and with a relative humidity of 73%.

Prasad (2006) observed that chilli crop was attacked by the mite almost throughout the year, but was more severe during summer months (April – July) followed by post monsoon (September – October) periods. During winter season population was almost negligible.

Eswarareddy *et al.* (2007) studied the incidence of yellow mite on chilli under protected and open field conditions. The mite population was maximum during the month of March (55.05 – 104.65 mites/leaf). The mean temperature and humidity of 33^0C and 63%, respectively under protected conditions, which influenced the mite to be a regular pest in the polyhouse.

2.5. Relationship with weather parameters

Mohammed *et al.* (1999) studied the influence of abiotic parameters on the population of yellow mite on chilli. Prevalence of prolonged cool weather (maximum temperature of 29 ± 0.5^0C and minimum temperature of 16 ± 1^0C) coupled with cloudiness, high humidity (74±1%) and absence of rainfall coincided with the peak activity of yellow mite.

Hosamani *et al.* (2007) observed a negative significant correlations between mite population and rainfall, maximum and minimum temperatures. The decline in mite population during April to July months was due to high temperature (38^0 to

44^0C) and high relative humidity which was positively correlated with the mite population**.**

Karmakar and Mazumdar (2007) analysed population fluctuation of yellow mite on different cultivars of jute (*Corchorus* spp.) in relation to some abiotic parameters. Higher minimum temperature enhanced larval, quiescent, male and female populations and higher maximum temperature enhanced the larval population more. Wind velocity reduced mite abundance except for females. Quiescent population declined by rainfall, but it enhanced the female number, while humidity reduced the female abundance.

2.6. Yield loss due to yellow mite in chilli

Butani (1976) considered the yellow mite as most destructive pest on chilli causing 25 per cent loss in yield. Borah (1987) concluded that the plant growth and yield in chilli were significantly affected due to the mite attack. Complete loss in dry fruit yield was noticed because of 100 per cent damage, and due to the failure in fruit setting. Economic injury level estimated was one mite day/cm^2 leaf area on chilli (var. *Byadgi*) in Dharwad.

Kulkarni (1922) reported complete failure of chilli crop due to severe attack of *P. latus.* 25.50 per cent loss in yield due to thrips, *S. dorsalis* and mites, *P. latus* was observed by Ayyar *et al.* (1935). Ahmed *et al.* (1987) reported 34 per cent yield loss due to combined infestation of *P. latus* and *S. dorsalis.*

According to Kareem *et al.* (1977) the chilli crop failed to yield any fruits due to the infestation by *P. latus* at flowering and fruiting stages of the crop. The mite infestation reduced the yield by 40 per cent inflicting a monetary loss of Rs. 4950 per hectare (Anonymous, 1999).

Sudharma and Madhavan (1999) assessed the loss caused by *P. latus* on chilli, by releasing different number of mites on chilli plants from six weeks after transplanting @ 24, 50 and 100 mites per plant, which caused significant reduction in yield compared to uninfested plants. Maximum damage grade index based on 0 to 6 scoring was 2.31, 3.79 and 3.88, respectively. Ukey *et al.* (1999) reported the economic threshold level of mites on chilli crop as one mite per leaf, assessed based on the cost benefit ratio of 1:3.82.

Mean mite population of yellow mite in protected plot was 6.79 mites/cm^2 as against 22.93 mites/cm^2 in unprotected plot with a dry fruit yield of 10.2 kg and 3.61kg/3m^2 plot, respectively, observed in Kalyani region of West Bengal with an extent of loss of 40 per cent. Whereas, the yield loss due to yellow mite was as high as 65 per cent in Coimbatore region of Tamil Nadu (Anonymous, 2009)

2.7. Host plant resistance against yellow mite

Painter (1951) defined host plant resistance as "the relative amount off heritable qualities that influence the ultimate degree of damage done by the insect".

Since the reports establishing relationship between yellow mite infestation and chilli plant characterstics are limited, plant resistance mechanisms against other mite pests like spider mites *etc.* on other cultivated crops are reviewed hereunder.

2.7.1. Screening of lines/varieties

Ningappa (1972) screened 19 accessions of chilli against thrips as well as mites at Dharwad of Karnataka. Chilli variety S- 7 was least affected and variety *Bydagi* was found to be most susceptible to both the pests. Fifteen varieties were screened by Ram *et al.* during 1997 in Guntur (Andhra Pradesh) against yellow mite. Among them varieties K2, Lam X235, Musalwadi, NP 46A, Sel 118-2 and

Semiliguda local were moderately resistant. The least mite population was recorded on varieties *Sindhur* and *Suryamukhi* with 1.24 and 3.52 mites/twig, respectively. Eleven genotypes evaluated at Dharwad (Karnataka) revealed that line GPC 80 was least susceptible to both yellow mites and thrips attack, followed by GPC 77 (Lingeri *et al*., 1997). Singh *et al*. (1998) observed that *Pusa sadabahar*, *Pant C-2* and *Jawahar mirch-2* were tolerant to mite attack, *Pusa sadabhar* being outstanding compared to other varieties.

Reddy *et al*. (2000) studied the response of 33 chilli genotypes in Ghataprabha command area of northern Karnataka. The genotype Selection 4-1 recorded the least mite incidence 90 and 120 days after planting (13.88 and 17.22%, respectively), followed by the genotypes 7-11, 11-9 and 1-12 (18.05, 19.30 and 21.52%, respectively). Leaf curl incidence increased with the advance in crop growth. The extent of leaf curl was maximum in *Bydagi* selection followed by Selection 7-9-1-4 (58.33 & 40.27%, respectively).

Preliminary field screening of 308 accessions of chilli germplasm, of which 17accessions were found promising on the basis of visual rating of leaf curl. Five entries namely EC 378630, EC378633, EC 391082, IC214991 and NIC23897 were found resistant to the mite, *P. latus* and three entries EC391082, PBC 613 and IC 23906 were found resistant to thrips, *S. dorsalis*. Most of the germplasm accessions reacted independently to leaf curl caused by thrips and mites. An exotic variety EC391082, a paparika type was found resistant to leaf curl caused by both thrips and mites (Sarathbabu *et al*., 2002).

Ahmed *et al*. (2001) screened 77 chilli cultivars/lines for resistance to yellow mite. On the basis of mite incidence, injury grade and damage index, nine entries namely, LIC 19, LCA 312, YAM, LIC 13, LCA 235, Clustar mutant, LCA 330, EC 128946 and LIC 45 were identified as resistant cultivars. 31 entries were categorized as susceptible, while 37 were found highly susceptible to mite infestation or damage.

Rani (2001) screened true potato seed lines for resistance against yellow mite. The lowest number of mites (22.33/compound leaf) was recorded on TPS 1/67 at peak infestation period, while TPS2/67 and *Kufri Jyothi* recorded the maximum number of mites (158.83 – 168.50 mites/compound leaf).

Desai *et al*. (2006) noticed among 21 chilli varieties/ germplasm screened, *Pusa jwala*, RHRC erect and ACG-77 were promising and G-4 and PBS 86-1 were extremely susceptible to yellow mite.

2.7.2. Morphological resistance

Peter and Berry (1980) studied the effect of morphological characters like ventral hairs and glands in hop leaf on two spotted spider mite oviposition, development and survival. The leaves varied significantly in moisture content and leaf hair density. Oviposition increased on leaves with higher hair density. More female progeny was produced on leaves with dense pubescence, but development of immature mites slowed down on leaves with higher hair density and lower moisture content.

Gibson and Valencia (1978) studied the resistance in potato species, *Solanum polyadenium, S. tarjense* and *S. berthaultii,* which had foliar hairs with a sticky tip and type B glandular hairs to confer resistance to damage by *P. latus*. These hairs restricted the mite population by trapping them when were blown on to the plants. The hair exudates were toxic or repellent as in the case of tomato plants of *Lycopersicon* spp.

You *et al.* (2001) studied the relationship between leaf structure in egg plant and its resistance to broad mite. The thickness of obverse and reverse epidermis, palisade layer and spongy layer differed among the cultivars. Thicker the reverse epidermis and palisade layer of the leaf, higher the resistance to *P. latus*. Cultivars with thick obverse epidermis had higher mite population growth rates and as a result the resistance to mite was low.

Trichomes play an important role in both antixenosis and antibiosis based resistant mechanisms. The glands with secondary plant metabolites *i.e.* sticky exudates entrap and immobilize small insects and mites and also the constituents make tissues unpalatable or toxic. Exudates of type IV & VI glandular trichomes of *Lycopersicon* were found associated with resistance to spider mites (Williams *et al.*, 1980).

2.7.3. Biochemical resistance

Many insects use dietary fats or fatty acids for energy and as a source of metabolic water. The host plant on which they feed influences the body fat of insects both quantitively and qualitatively. Plants with sufficient amount of fats in the insect diet have detrimental effect on the insect biology, development *etc*. Sugar content of plants may also be a limiting factor for proper growth and survival of pest species.

Dabrowski and Rodriguez (1971) observed that the essential oil vapours from strawberry *viz.,* furfural, nonamyl alcohol, α – terpinol, methyl salicylate and methyl naphthalene at high concentration repelled the mite, *Tetranychus turkestani* Ehara.

Palanisamy (1973) reported that varieties of okra resistant to *Tetranychus urticae* Koch contained high total carbohydrates, calcium, potassium, free amino acids, resin and less total nitrogen than that of the susceptible varieties. Mite feeding reduced the carbohydrate content in all the varieties, but it increased the nitrogen content, which was maximum in susceptible varieties.

Ramadas (1979) observed that chilli cultivars susceptible to *P. latus* had high leaf moisture content, high amount of total carbohydrates, high nitrogen, increased amounts of phosphorous and high potassium, calcium, total and ortho-dihydroxy phenols besides total amino acids.

Hildebrand *et al.* (1986) observed peroxidative responses of two soybean genotypes injured by two spotted spider mites. The mite resistant soybean cultivar showed greater loss of carotenoids, chlorophyll and lipid peroxidation (with intial *T. urticae* infestation) than the susceptible cultivars. Increased resistance could be induced in remote tissues of resistant cultivars, the activity of prooxidant enzyme lipoxygenase and peroxidase increased with *T. urticae* feeding and lipid peroxidation.

Composition of trichome secretion, glandular trichome densities and spider mite resistance were measured for 10 accessions of *Lycopersicon hirsutum* a wild, South American relative of tomato exhibiting high arthropod resistance. The sesquiterpene hydrocarbon zingiberene and γ elements were identified as major volatile components of type VI trichome secretion from *L. hirsutum* f. *typicum*. These compounds predominated trichome secretion from five other accessions, whereas methyl ketones 2-undecanone and 2-tridecanone predominated trichome secretion from five accessions of *L. hirsutum* f. *glabratum*. Type VI trichome densities were more on *glabaratum* than *hirsutum* accessions, whereas type VI trichome densities were more on *hirsutum* than on *glabaratum*. *hirsutum* accessions were more resistant to mites than *glabratum* accessions (Weston *et al*., 1989).

Richard *et al.* (1997) observed inheritance of biochemical and morphological characters associated with resistance to two spotted spider mite, *T. urticae* in geranium. Geraniums were able to resist the attack by spider mite when exudates produced by tall glandular trichomes contained high percentage of unsaturated anacardic acids. The susceptible plants produced low concentrations of anacardic acids compared to resistant inbred (*Pelargonium x hortorum*) plants. The low densities of tall glandular trichomes producing anacardic acid enforced resistance against *T. urticae*.

Nawalagatti *et al.* (1999) studied the biochemical resistance to murda complex in chilli varieties *Byadgi*, Sankeshwar, G3 & Jwala, Lines and hybrids. The resistant variety like Jwala had high total chlorophyll content, higher phenols and lower sugars. It was observed that the total phenols decreased after mite infestation in all the unprotected varieties. Per cent reduction in total phenol increased with the age of the crop, indicating that the plants are more resistant at early stages than at the later stages.

Ni *et al.* (2001) studied the oxidative responses of resistant and susceptible cereal leaves to symptomatic and nonsymptomatic cereal aphid feeding. The Russian wheat aphid, *Diuraphis noxia* feeding probably resulted in oxidative stress in plants. Moderate increase in peroxidase activity in resistant Halt variety of wheat compared with the susceptible Arapahoe wheat might contributed to its resistance, whereas nine folds increased peroxidase activity possibly contributed to susceptibility in barleys. The aphid feeding caused significant increase in total protein content and peroxidase activity in resistant plant.

Rani (2001) reported that the potato variety TPS1/67 which recorded the lowest number of mites (22.33/compound leaf) at peak infestation period at Bangalore was attributed to higher leaf content of phenolic compounds (catechin 14mg/g), whereas the variety TPS 2/67 with more number of mites (168.50/compound leaf) was associated with lower content of phenolic compounds (6 mg/g).

Zhen *et al.* (2006) observed changes in the levels of capsaicin, flavonoid, free phenolics and enzyme activity during the development of chilli fruit. The capsaicin content increased and reached maximum at 50 days after flowering, but decreased later. Maximum level of phenols and flavonoids was observed during early stage of the crop, further decreased with fruit ripening. The enzyme activity increased rapidly during 29-36 days after flowering.

Saeidi and Mallik (2006) studied the nature of resistance in *Lycopersicon* species to two spotted spider mite. Tomato cultivars/accessions were grouped into five categories based on the overall performance in leaf dip/thumb tack bioassay, as highly resistant, resistant, susceptible, highly susceptible and tolerant. Based on biochemical results the maximum content of phenolic compounds was observed in *L. pimpinellifolium* (19.24ppm) followed by *L. esculentum* (NDTVR 73) (14.89ppm) and the lowest concentration in *L. pennellii* accession (3.33ppm).

2.8. Genetic studies

Genetic analysis of resistance to yellow mite, *P. latus* in tossa jute revealed highly significant differences in the incidence of yellow mite among the parents and the crosses, indicating genetic variability for mite resistance. Genetic analysis estimates of SCA and GCA effects and mean percentage of yellow mite resistance of parents and hybrids suggested that both additive and non-additive genes were involved in inheritance of resistance (Choudary and Das, 1999).

Jagadeesha and Mruthyunjaya (2006) made genetic analysis for thrips and mite resistance in chilli *Capsicum annuum* L. Eighteen divergent lines and 45 F1 hybrids were studied for general and specific combining ability effects for leaf curl index (LCI) due to thrips and mites. The degree of dominance indicated that the leaf curl index for thrips was predominantly under the control of additive gene effect, whereas the LCI for mites exhibited non-additive gene effect.

Ghosh *et al*. (2010) investigated on the SSR markers linked to mite *P. latus* resistance in jute (*Corchorus olitorius* L.). Total of 88 SSR primers were screened, among them only 21 primer pairs showed polymorphism. A genetic linkage map was constructed between parents using this polymorphism and 150 F2 populations were derived. SSR markers J-170, HK-89 and HK-64 showed 100% selection efficiency in combinations.

Material and Methods

III. MATERIAL AND METHODS

Field investigations and glasshouse/polycarbonate house experiments on the assessment of damage due to yellow mite, *Polyphagotarsonemus latus* (Banks) on chilli crop and host plant resistance related studies were carried out in the Department of Agricultural Entomology, University Agricultural Sciences, Bangalore during the period 2008-11. Material used and the methods adopted for various investigations are detailed hereunder.

3.1. Pest complex in chilli

Chilli variety '*Byadgi kaddi*' was used for the study. The seedlings were initially raised in the nursery and four weeks old seedlings were then transplanted in the main field. The chilli crop was raised in an area of 10mx10m in three replications with a spacing of 60cmX45cm (Plate 1). All the agronomic practices were followed during the entire crop period as per the recommended package of practices for chilli crop except the plant protection measures.

Observations on the occurrence and abundance of various pests including mites on the chilli crop were recorded at weekly intervals starting from 15days after planting till maturity.

3.2. Assessment of loss due to yellow mite *Polyphagotarsonemus latus* in chilli

The potentiality of yellow mite, *P. latus* to inflict significant loss in the yield of chilli crop was examined by conducting paired treatment experiment (Anonymous, 1971) during the *Kharif* seasons of 2008 & 2009 in the farmer's fields of Karjagi and Mannur villages in Haveri district. The experiment consisted of mainly two treatments namely protected and unprotected, each with six replications, with the plot size of 10mx10m. All the recommended agronomic practices were followed for both protected and unprotected plots except the plant

Plate 1. Chilli experimental plot for study on succession of insect and mite pests

protection measures against the yellow mite. A guard row of 1 meter length was maintained between the plots so as to avoid cross infestation of mites and also to avoid spray drifts. The chilli crop in protected plots was completely protected from yellow mite damage by the application of acaricides at regular interval of two weeks from planting till maturity. Acaricide sprays in protected plots included alternative application of dicofol (0.05%) or propargite (570 g a.i/ha) or fenazaquin (125 g a.i/ha). The yield from protected crop was compared with that of the unprotected crop which was exposed to natural yellow mite infestation.

Before acaricide application, the population of mites both in protected and unprotected plots was recorded from 15 plants selected at random from each plot. From each plant one shoot tip with atleast six fully opened leaves were sampled to record the number of different stages of the mite *i.e.* eggs and the active stages (nymphs and adults) under a stereobinocular microscope. The mite population was expressed as the mean number per six leaves.

Analysis of data:

The statistical significance between protected and unprotected plots was ascertained by “t” test by comparing calculated “t” with the table “ t” at (n-2) df as follows

Standard Deviation (SD) = $\sqrt{\frac{Sum\ of\ d^2}{n-1}}$ *where*, n=No. of paired plots

Standard Error of the mean of difference (SE) = $\frac{SD}{\sqrt{n}}$

Calculated or Observed ‘t’ = $\frac{\overline{X1} - \overline{X2}}{SE}$

Per cent reduction in crop yield was calculated using the formula

Reduction in yield (%) = $\frac{\overline{X1} - \overline{X2}}{\overline{X1}}$ X 100

Where $\overline{X1}$= Mean yield from protected plots

$\overline{X2}$= Mean yield from unprotected plots

3.3. Assessment of damage caused by yellow mite, *Polyphagotarsonemus latus*

The experiments were conducted both in glasshouse/polycarbonate house (Plate 2) and in the open field at ZARS farm, GKVK, Bangalore with main objective of knowing the critical age of chilli plant more prone for yellow mite damage which could result in significant reduction in the fruit yield.

Potted chilli plants with healthy green foliage were used for maintaining the culture of yellow mites in polycarbonate house. Initially, yellow mite infested leaves in the field were collected and placed on healthy chilli plants to allow the mites to establish and colonize.

Experiment I

The damage caused by yellow mite was assessed by confining the mites at different growth stages of chilli crop in glasshouse and field.

A. Experiment in glasshouse

Four weeks old chilli seedlings of variety *Byadgi kaddi* were planted individually in 30cm diameter earthern pots filled with red soil and FYM. Required quantity of NPK and antagonistic fungal culture of *Trichoderma* were applied to potted plants at planting and these pots were watered regularly.

To ascertain the growth stage of chilli plants more prone for damage by *P. latus*, experiments were conducted in glasshouse with the following treatments in three replications.

Treatments

T1: Mites infestation from 15 days after planting till maturity

T2: Mites infestation from 30 days after planting till maturity

T3: Mites infestation from 45 days after planting till maturity

T4: Mites infestation from 60 days after planting till maturity

T5: Mites infestation from 75 days after planting till maturity

T6: Mites infestation from 90 days after planting till maturity

T7: Free from mite infestation throughout (control)

Ten potted chilli plants were used for each treatment with three replications. These pots were arranged in a group or intermingled with potted chilli plants infested by mites as mentioned above. The plants sprayed with either dicofol (0.05%) or fenazaquin (125g a.i/ha) or propargite (570g a.i/ha) at weekly intervals to avoid yellow mite infestation served as control (T7).

For recording the mite population on leaves, destructive sampling/ removing of leaves from the potted plants had to be done. Hence the mite infestation was recorded indirectly by scoring for mite damage (downward curling of leaves) on 0 – 4 scale (Score 0– no curling symptom, Score 1 – 1 to 25%, Score 2 – 26 to 50%, Score 3 – 51 to 75% and Score 4- >75% of leaves in a plant showing downward curling). Also data on plant height, number of fruits/plant, fruit yield/10 plants, biomass yield/10 plants (wet and dry weight basis) were recorded and compared among the different treatments for critical assessment of damage due to mite infestation/feeding.

B. Experiment in the field

An experiment with similar treatments as mentioned above was conducted in the field in randomized complete block design with 3mx3m sized plots in 3 replications. Recommended row to row spacing of 60 cm and plant to plant spacing of 45cm was maintained. In each plot there were 36 plants in 6 rows. The

Plate 2. Polycarbonate house of AINP (Agril. Acarology) at GKVK, Bangalore

mite infestation in the field was ensured by keeping atleast six mite infested potted chilli plants between the rows in a zigzag manner in all the treatments except in control.

For recording observations on mite population 5 shoot tips with atleast 6 leaves from 5 different plants from each plot were sampled at fortnightly interval and were observed under a stereobinocular microscope to record the number of eggs and the active stages. The mite population was expressed as the mean number per 6 leaves. Simultaneously, mite feeding which caused downward leaf curling was scored on 0-4 scale as mentioned above in polyhouse experiment. Fruit yield from different treatments was recorded separately and compared. The mite population data were analysed statistically after $\sqrt{x + 0.5}$ transformation following Anova for RCBD and results were interpreted at 5% level of significance.

Experiment II

A. Experiment in polycarbonate house

To ascertain the relationship between duration of mite infestation at different growth stages (ages) of chilli crop and the resulting damage by yellow mites experiments were conducted in polycarbonate house and in the field with 2 to 4 weeks duration of mite infestation on 4 to 12 weeks old chilli plants. The following were the treatments imposed with 3 replications.

Treatments

T1: Mite infestation between 4 - 6 weeks –
(Mite infestation for 2 weeks period on 4 weeks old chilli crop)

T2: Mite infestation between 4 - 8 weeks –
(Mite infestation for 4 weeks period on 4 weeks old chilli crop)

T3: Mite infestation between 6 - 8 weeks –
(Mite infestation for 2 weeks period on 6 weeks old chilli crop)

T4: Mite infestation between 6 - 10 weeks –
(Mite infestation for 4 weeks period on 6 weeks old chilli crop)

T5: Mite infestation between 8 - 10 weeks –
(Mite infestation for 2 weeks period on 8 weeks old chilli crop)

T6: Mite infestation between 8 - 12 weeks –
(Mite infestation for 4 weeks period on 8 weeks old chilli crop)

T7: Mite infestation between 10 - 12 weeks –
(Mite infestation for 2 weeks period on 10 weeks old chilli crop)

T8: Mite infestation between 10 - 14 weeks –
(Mite infestation for 4 weeks period on 10 weeks old crop)

T9: Free from mite infestation or Control

The experiment in the polycarbonate house consisted of 25 potted chilli plants for each treatment, with 3 replications. These 25 potted plants were arranged in groups and surrounded by mite infested plants depending on the age of the plants as detailed in the treatments above. Set of potted chilli plants thoroughly sprayed with dicofol (0.05%) or fenazaquin (125 g a.i/ha) or propargite (570 g a.i/ha) alternatively at weekly/fortnightly interval to eliminate mite infestation served as control.

B. Experiment in the field

In the field experiment the plot size was 3mx3m with recommended row to row and plant to plant spacing of 60cm and 45cm, respectively. Mite infestation in the field was either ensured or imposed by keeping (atleast six) mites infested potted chilli plants for a specified period of 2 or 4 weeks in different treatments between the rows in zig zag manner.

Observations were recorded from 5 shoot tips randomly sampled from 5 plants in each treatment at fortnightly interval. The leaf samples were observed under a stereobinocular microscope to record the number of eggs and active stages, and the mite population was expressed as the mean number per 6 leaves. The scoring for mite damage was also recorded simultaneously using 0 – 4 scale as mentioned in the previous section.

Since the plants in the polycarbonate house experiment did not bear flowers normally, the total plant biomass (dry and wet basis) was recorded treatmentwise at maturity. However, in the field experiment data on mite population and fruit yield were recorded treatmentwise separately. The data were subjected to statistical analysis after suitable transformations. The buildup of mite population in each of these treatments was recorded at fortnightly intervals and compared across the different treatments both for mite damage (score) and the yield (biomass/fruit).

3.4. Screening of chilli genotypes for their reaction to infestation by yellow mite, Polyphagotarsonemus *latus*

Reaction of 107 chilli genotypes/lines/accessions/entries to *P. latus,* infestation was studied in the experimental field of Acarology section and Genetics and Plant Breeding Division at GKVK during 2008 – 10. The genotypes used for screening study are listed in Table 2. The genotypes studied were obtained from the Department of Genetics and Plant breeding, UAS, GKVK, Bangalore (68 entries); UAS, Dharwad (20 entries); Punjab Agricultural University, Ludhiana (3 entries); Bidhan Chandra Krishi Vishwa Vidyalaya, Kalyani (8 entries); Anand Agricultural university, Gujarat (5 entries); Tamil Nadu Agriculture University, Coimbatore (2 entries) and Indian Institute of Horticultural Research, Hessaraghatta, Bangalore (1 entry).

Initially the seedlings of these entries were raised in a nursery and later 4 weeks old seedlings were planted in the main field in Complete Randomized Block Design with three replications. Each entry was planted in a plot of 3m x 3m size in 5 rows with a spacing of 60cm x 45cm. Depending on the availability of

Table 2. Chilli entries screened for their reaction to yellow mite, *Polyphagotarsonemus latus*

UAS, Bangalore			
1	CMS 2B	35	LCA 334
2	CMS 7A	36	PMR 21
3	CMS 8A	37	KDC 1
4	CMS 6B	38	PBC 81
5	CMS 6A	39	CA 9
6	CA 14	40	G- 4
7	CMS 7B	41	Vamsi
8	Susceptible *baccatum*	42	PBC 80
9	CMS 2A	43	PBC 631
10	*Capsicum frutescens*	44	*Phule Jyothi*
11	CMS 8B	45	Koira
12	Darpung	46	BVC 53
13	LCA 273	47	*Pusa sadabahar*
14	CMS 5B	48	CA 2
15	Lampong local short	49	KNG 2
16	CMS 1A	50	CA 3
17	PBC 1752	51	BVC 47
18	CMS 3A	52	Chiagmai local
19	CMS 1B	53	CA 10
20	Utkal rashmi	54	Vietnam
21	Lampong local long	55	CA 12
22	CMS 5A	56	ICPN 14
23	CMS 3B	57	CA 6
24	Pant C-1	58	PL 3
25	*Byadgi kaddi*	59	Vangara
26	*Byadgi dabbi*	60	North Assam
27	*Oothgod local*	61	KNG 1
28	Aparna	62	PL 5
29	HMT 1	63	Tiwari
30	PBC 142	64	Gowribidnur
31	LCA 336	65	Chikkaballapur local
32	LCA 424	66	Minchalli betta
33	LCA 353	67	LCA 335
34	Scoul I	68	CCA336B

Table 2 ***contd…..***

UAS, Dharwad		**BCKV, Kalyani**	
69	KDC -2	90	CNS 1
70	KDSC -1	91	CNS 8
71	S 112-4	92	BCSL 4
72	20-1	93	SB 3
73	132-2	94	CNS 2
74	149-2	95	SB 1
75	133-5	96	Falatkal local
76	101-3	97	Cluster suryamukhi
77	107-1	**NAU, Navsari**	
78	101-4	98	AVNPC 131
79	94-1	99	GVC 111
80	101-1	100	GVC 121
81	65-1	101	GVC 101
82	S 65-3	102	S 49
83	S 20-1	**TNAU, Coimbatore**	
84	4 – 4	103	CO – 2
85	S 120-1	104	CO – 1
86	S 112-1	**PAU, Ludhiana**	
87	132-2-2	105	*Punjab gucchedhar*
88	HMT 2	106	CH 1
IIHR, Hessaraghatta		107	KA 2
89	*Arka lohit*		

seeds in some seasons, entries were planted in 5m rows with 2 replications. On either side of each plot single row of susceptible chilli variety *Byadgi kaddi* was planted as an infector row to ensure natural mite infestation. All the agronomic practices recommended for a chilli crop were followed except the application of acaricides. The screening study with varying number of entries was conducted during seven different cropping periods namely January – November 2008 (early summer), February- June 2008 (summer), March–August 2008 (late summer), July – November 2008 (*Kharif*), August – December 2008 (late *Kharif*), February-June 2009 (summer) and March – August 2010 (late summer).

Parameters considered for field evaluation of chilli entries against yellow mite, *P. latus* were:

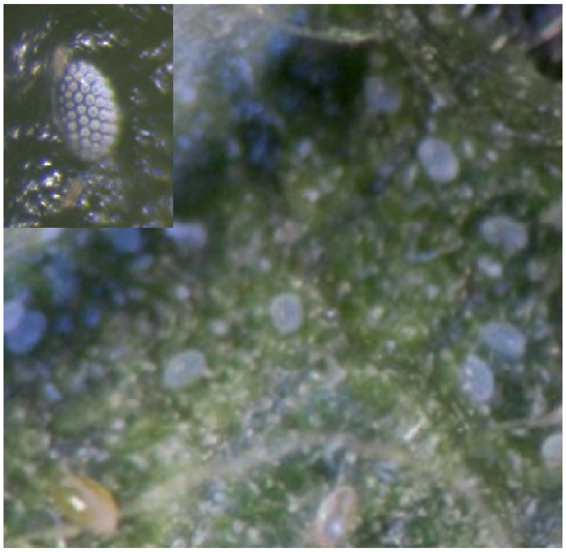
a) Population density of yellow mite

The mite population density was recorded from five plants selected randomly from each plot/row and from each plant, one shoot tip with at least six fully opened young leaves were sampled and counts were made for the number of eggs and active stages (Plate 3) of the mite under a stereobinocular microscope. Such observations for mite populations were recorded at fortnightly interval starting from 15 days after planting. The mite population was expressed as the number per six leaves. Data on mite population from 5 to 6 observations were pooled to compute the mean mite population.

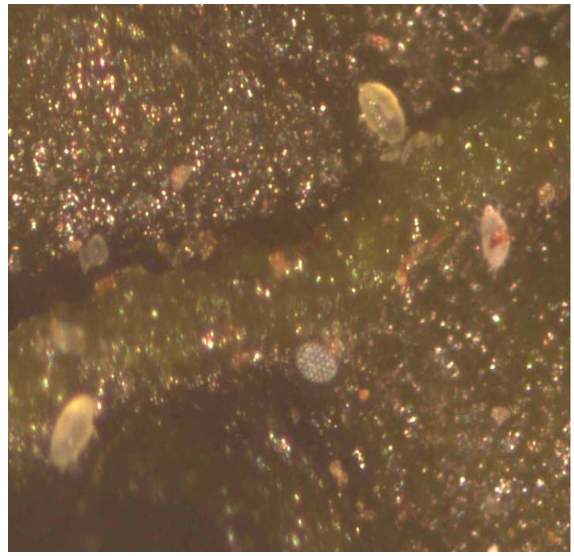
At each interval the total number of plants and the number of mite infested plants in each entry were recorded at each interval and per cent incidence (percentage of plants infested by yellow mite) in each entry was computed.

b) Scoring for the mite damage

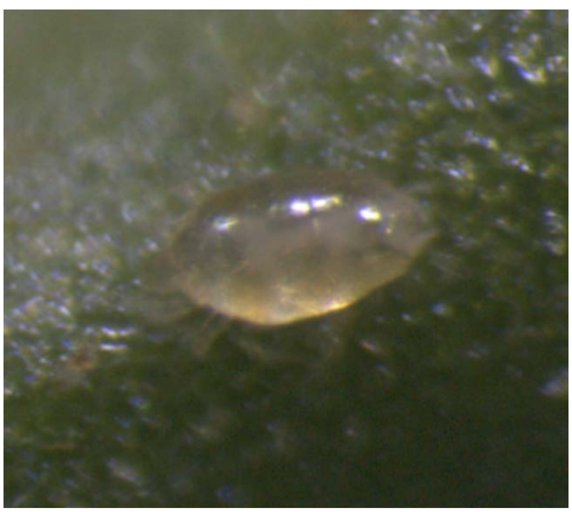
Chilli plants showing the symptom of yellow mite damage *i.e.* downward curling of leaf margin (Plate 4) were scored individually on 0 - 4 scale (Niles,



Eggs



Nymphs



Adult female

Adult male

Plate 3. Eggs & Active stages of chilli yellow mite, *Polyphagotarsonemus latus* (Banks)

Plate 4. Yellow mite infested chilli plant (downward curling symptom)

1980) at fortnightly intervals, and pooled to compute the overall mean scoring for each entry.

Damage score	Leaf damage due to yellow mite
0	No Symptom of leaf curling due to mites
1	1-25 per cent of leaves in a plant with downward leaf curling damage due to mites
2	26-50 per cent of leaves in a plant with downward leaf curling damage due to mites
3	51-75 per cent of leaves in a plant with downward leaf curling damage due to mites (malformation of growing tips, stunted growth *etc*.)
4	>75 per cent of leaves in a plant with downward leaf curling damage due to mites (complete malformation of shoot tips, severe stunting *etc*.)

Results from different screening trials (6) at different periods/seasons were pooled for 107 entries and arranged in the ascending order considering the mean total mite (eggs and active stages) population. Finally 32 entries were short listed (Table 21) representing different population levels of mite, namely < 5 mites/six leaves (6 entries), 5 to 10 mites/six leaves 6 entries), 11 to 50 mites/six leaves (18 entries), > 50 mites/six leaves (2 entries) and all these 32 short listed entries were planted during March – August 2010 (late summer) for a final screening.

Observations for mite population and damage score were recorded as done during earlier screening trials and all these entries were studied for different biochemical constituents to understand the basis of biochemical resistance, if any, against the yellow mite.

3.5. Biochemical mechanism of resistance

From each of the 32 short listed entries both mite free and mite infested (with visible symptoms of damage) plants were analyzed separately for different biochemical constituents. The leaves for biochemical analysis were collected from the plants in the early morning hours *i.e.* before 09.00 hrs and subjected to different biochemical analysis following the methods of Sadasivam and Manickham (1991) with minor modifications.

Preparation of oven dried sample

The freshly collected plant samples were dried at 60^0C to a constant weight in a hot-air oven. The samples were then powdered using a waring blender and the leaf powder was stored in sealed polyethylene covers at room temperature.

Preparation of acetone powder

The plant samples were homogenized with pre-chilled acetone using a pestle and mortar. The resulting slurry was filtered immediately under suction using Whatman No.1 filter paper and washed with chilled acetone to remove chlorophyll and other pigments (Mahadevan and Sridhar, 1982).

Biochemical Analysis

3.5.1. Estimation of chlorophyll

To quantify the chlorophyll loss due to mite feeding, the leaf chlorophyll content before and after mite infestation was estimated separately and compared. For chlorophyll estimation leaf samples were collected separately from each variety, before and after mite infestation (before flowering). One gram of leaf sample was taken and incubated over night in 20ml mixture of DMSO (Dimethyl sulphoxide) and acetone (80%) at 1:1 ratio. The supernatant extract (0.5ml) was diluted with 9.5ml DMSO and acetone mixture. Absorbance was recorded using Spectrophotometer (TranUV) at 645 and 663nm wave lengths and using these absorbance values total chlorophyll content was estimated (Arnon, 1949) as below.

Total Chlorophyll: [20.8 (A_{645}) +8.02(A_{663}) X V/W] X100

[V-volume of dilution by solvent in ml, and W-weight of leaves in grams, A_{663} and A_{645} -Absorbance values at 663 and 645nm, respectively].

3.5.2. Estimation of total sugar content

Reagents

1. **Phenol reagent:** 5g of redistilled phenol was dissolved in water and volume made 100ml.
2. **Standard glucose solution:** Glucose stock solution was prepared containing 15 mg glucose/10 ml in water. The solution was diluted 1:10 to obtain 150 µg glucose/ml working standard solution.

Sample extraction: 100mg of oven-dried leaf powder was used for extraction in 10 ml of 80% warm ethanol for one hour on a magnetic stirrer at room temperature. The extract was then centrifuged at 6000 rpm for 15 minutes. The supernatant was evaporated to dryness on a water bath and the residue was dissolved in 5 ml of distilled water. This alcohol free extract was used for the estimation of total soluble sugars (Dubois *et al.*, 1956).

Estimation: 0.1 ml of sample aliquot was diluted to 1ml with water. 1ml of 5% phenol reagent and 5ml of 98% H_2SO_4 were added and incubated for 10 minutes and then placed in a water bath at 30^0C for 20 minutes. The absorbance was read at 490nm against the reagent blank in a Colorimeter (TransUV).

A standard curve was constructed using standard glucose in the range of 15-150 µg. The total sugar estimated was expressed as mg per gram of oven-dried sample.

3.5.3. Estimation of total protein content

Reagents

1. **Solution A:** 20g of anhydrous sodium carbonate (Na_2 CO_3 $2H_2O$) and 4g of sodium hydroxide dissolved in 1000 ml of distilled water.
2. **Solution B:** 1ml of 1.35% sodium potassium tartarate and 0.1 ml of 5.5% $CuSO_4.5H_2O$ solutions mixed together.
3. **Solution C:** 50ml of solution A mixed with 1 ml of solution B just before use.
4. **Folin-Ciocalteau reagent (FCR):** The commercial FCR diluted in the ratio of 1:1 before use.
5. **Standard bovine serum albumin (BSA) solution:** A stock BSA solution was prepared containing 2mg BSA/ml in water. This solution was diluted 1:10 to obtain 200µg BSA/ml of working standard solution.

Sample extraction: 100mg of oven-dried sample powder was used for extraction in 10ml of 0.1M sodium phosphate buffer, pH 7.0 for 1 hour on a magnetic stirrer at room temperature. The extract was centrifuged at 10,000 rpm for 20 minutes and the supernatant was used for the estimation of total soluble protein content (Lowry *et al*., 1951).

Estimation: A known volume of sample aliquot was made to 1ml with distilled water. To this, 5ml of solution C was added, and mixed well. After 10 minutes, 0.5ml of FCR was added and mixed immediately. The blue colour complex developed was read at 660 nm after 30 minutes against a reagent blank in a Colorimeter (TransUV).

A standard curve was constructed using BSA solution as a standard in the range of 20-200µg. The total protein content estimated was expressed as mg per gram of oven-dried sample.

3.5.4. Capsaicin estimation

Capsaicin is a protoalkaloid which is responsible for the pungency of chillies. The quality of chilli fruit extracts or oleoresins was determined by the capsaicin content using spectrophotometric method. Capsaicin was extracted from leaves with ethyl acetate and made to react with ethyl acetate solution of vanadium oxychloride, and absorbance was read at 720nm. This method is sensitive and is used to measure small quantities of capsaicin less than 0.05%**.**

Reagents

Vanidium oxychloride (0.5%) in ethyl acetate

Pure capsaicin (0.01%) in ethyl acetate (10mg in 100ml)

The sample was ground well to pass through No. 40 sieve filter paper. 2 g sample was placed in 100ml volumetric flask and allowed to stand for 24 hrs for extraction and the volume was made to 100ml. 1 ml of the extract was diluted to 5ml with ethyl acetate. To which 0.5 ml vanadium oxychloride solution (just before reading) was added and mixed. The absorbance was read at 720nm in a Spectrophotometer (TransUV). The standard curve using 0.5, 1.0, 1.5, 2.0 and 2.5 ml of standard capsaicin solution containing 50, 100, 150, 200 and 250µg capsaicin, respectively was prepared and used to estimate the quantity of capsaicin in the sample as follows:

$$\% \text{ Capsaicin} = \frac{\mu\text{g Capsaicin x100x100}}{\text{1000x1000x1x2}} = \frac{\mu\text{g Capsaicin}}{200}$$

3.5.5. Estimation of proline

Reagents

1. **Acid ninhydrin:** Warmed 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6M phosphoric acid, with agitation until dissolved. Stored at 4^0C and used within 24h.
2. **3% Aqueous sulphosalicylic acid**
3. **Glacial acetic acid**
4. **Toluene**
5. **Standard proline solution:** 5mg of proline was dissolved in 10 ml of water in a volumetric flask. 1 ml of this stock was diluted to 10ml for working standard solution. A series of volumes from 0.1 to 1ml of this working standard gave a concentration range of 5 µg to 50 µg. A standard curve was constructed using absorbance *versus* concentration.

Assay: 0.5g of plant material was homogenized in 10 ml of 3% aqueous sulphosalicylic acid and the homogenate was filtered through Whatman No. 2 filter paper. 2 ml of filtrate was taken in a test tube and 2 ml of glacial acetic acid and 2 ml acid ninhydrin were added and the content was heated over boiling water bath for 1h. The reaction was terminated by placing the tube in an ice bath. 4 ml toluene was added to the reaction mixture and stirred well for 20-30 sec. The toluene layer was separated and warmed to room temperature. The intensity of red colour was measured at 520 nm. Standard curve was drawn for pure proline in a similar way. The amount of proline in the test sample was determined from the standard curve and expressed on fresh-weight basis as µ moles per gram tissue.

3.5.6. Estimation of total phenol content

Reagents

1. Folin-ciocalteau reagent (FCR): Commercial grade reagent diluted to 1:1 with water.
2. 20% Sodium carbonate solution: 20g of Na_2 CO_3 dissolved in water and volume made to 100ml.
3. Acidified methanol**:** 10 ml of HCl mixed with 90 ml of methanol.
4. Standard catechol solution**:** A stock catechol solution was prepared containing 0.025 mg catechol/ml in water. This solution diluted with distilled water to obtain 2.5μg catechol/ml for working standard solution.

Extraction: 100mg of oven-dried leaf powder was used for extraction in 10ml of 80% warm ethanol for 1 hour at room temperature. The extract was then centrifuged at 6000 rpm for 15 minutes. The supernatant was evaporated to dryness in a water bath and the residue was dissolved in 5ml of water. The alcohol free extract was used for the estimation of total phenols (Malick and Singh, 1980).

Estimation: 0.1 ml sample aliquot was diluted to 3ml with distilled water and 0.5 ml of FCR was added and mixed. Exactly after 3 minutes, 2ml of 20% sodium carbonate solution was added and kept in a boiling water bath for one minute. After cooling under running tap water, the absorbance was read at 650nm, against the reagent blank in a Colorimeter (TransUV).

A standard graph was constructed with catechol as standard in the range of 0.25-2.5 μg. The total phenol content determined was expressed as the mg per gram of oven-dried sample.

Enzyme assays

3.5.7. Total peroxidase activity

Reagents

1. **Hydrogen peroxide solution:** 0.14ml of 30% hydrogen peroxide was diluted to 100ml with 0.1M sodium phosphate buffer of pH 7.0 to get 12.3mM solution.
2. **Guaiacol solution (20mM):** 1ml of 1M guaiacol solution was diluted to 100ml to get 20mM. It was stored frozen until use.

Preparation of enzyme extract: 100mg acetone powder of plant sample was used for extraction with 10ml of ice-cold 0.1 M sodium phosphate buffer of pH 7.0 containing 0.1 per cent polyvinylpyrrolidone in a pestle and mortar for 2-5 minutes. The slurry was centrifuged at 10,000 rpm for 20 minutes at 4^0C. The supernatant was used as enzyme source for the estimation of total peroxidase.

Assay: 3ml of 0.1 M sodium phosphate buffer of pH 7.0, 0.1ml of 20mM guaiacol solution and 0.1ml of 12.3mM hydrogen peroxide were taken in a cuvette. The reaction was initiated by adding 0.1ml of enzyme extract pre-incubated at 25^0C and the increase in absorbance was measured at 470nm at a time interval of 30 seconds upto 5 minutes in a Spectrophotometer (TransUV). The activity of the enzyme was calculated from the linear part of the progress curve.

One unit of peroxidase is defined as increase in absorbance of 0.01/minute under standard assay conditions and the activity was expressed as units/g acetone powder.

3.5.8. Phenylalanine ammonia lyase (PAL) activity

Reagents

1. **Substrate solution:** 165mg of L-phenylalanine was dissolved in 5ml of water. pH was adjusted to 9.0 with 0.1N KOH and the volume was made up to 10ml to obtain 100mM L-phenylalanine solution.
2. ***trans*-cinnamic acid solution:** 29.64mg of *trans*-cinnamic acid was dissolved in 10ml of water. 100µl of this solution was diluted to 10ml to obtain 2µ moles *trans*-cinnamic acid/ml working standard solution.

Preparation of enzyme extract: 100 mg of acetone powder of plant sample was used for extraction with 10 ml of ice cold 25mM borax-HCl buffer of pH 9.0 containing 5 mM mercpatoethanol in a pestle and mortar for 2-5 minutes. The extract was centrifuged at 10,000 rpm for 20 minutes at 4^0C. The supernatant was used as the enzyme source for assay.

Assay: 0.5ml of 25mM borax-HCl buffer, pH 9.0, 0.6 ml of enzyme extract, 0.9 ml of water was pre-incubated at 37^0C for 5 minutes. The reaction was initiated by adding 1 ml of 0.1M L-phenylalanine substrate solution. The reaction was terminated after 40 minutes by adding 0.5ml of 1M TCA solution. A control was run in which the substrate solution was added after the TCA. The change in absorbance was read at 290 nm in a Spectrophotometer (Incline nanophotometer). The *trans*-cinnamic acid liberated in the reaction mixture was calculated from the standard graph constructed using *trans*-cinnamic acid with the range of 0.02 to 0.2 µ moles and expressed as µ moles of product (*trans*-cinnamic acid) formed /min/ml of enzyme extract.

3.6. Molecular basis of Resistance

Considering that morphological character based assay criteria alone is inadequate for genotypic identification due to overlapping of morphological characters between the genotypes. DNA based assay using Internal Transcribed Spacer (ITS) region of ribosomal DNA based markers were used to distinguish the genotypes.

DNA extraction protocol (CTAB method)

Genomic DNA was extracted from 15 days old transplanted chilli plants as suggested in the CTAB method with minor modifications. The following was the protocol used for extracting DNA from leaf samples.

- Extraction buffer (1M Tris HCl, 0.5M EDTA, 5M NaCl, 2% CTAB) proportionate to quantify 200 mg of the lyophilized ground tissue in a sterile centrifuge tube was added and contents were transferred to 2ml centrifuge tubes.
- The extract was incubated at 60^0C in a water bath for 45 minutes with intermittent shaking
- Equal volume of 24:1 chloroform-isoamyl alcohol was added to the extract after cooling to room temperature and mixed vigorously for 5 to 10 minutes until a homogenous suspension was obtained.
- The suspension was centrifuged at 12000rpm for 5 to 7 minutes.
- The supernatant was transferred to fresh 2ml centrifuge tube and then equal volume of 24:1 chloroform-isoamyl alcohol was added and mixed thoroughly.
- The suspension was centrifuged at 12000rpm for 5 minutes.
- The supernatant was transferred into fresh 2ml centrifuge tube and equal volume of cold isopropanol was added and then incubated for 1 hour or overnight at -20^0C.
- The suspension was centrifuged at 5000 rpm for 5 minutes and supernatant was discarded by retaining the pellet.

- The pellet was washed with 70% alcohol and centrifuged at 5000 rpm for 5 minutes.
- The supernatant was discarded; 50-100µl of TE buffer was added to dissolve the pellet.
- The quality and quantity of DNA was assessed using 0.8% agarose gel.

PCR amplification: PCR was carried out with 20 SSR primers (Table 3) in a total reaction volume of 15µl mixture containing 20ng of template DNA, 1unit of Taq polymerase, 1.5µl of reaction buffer, 0.2µl $MgCl_2$ (50mM), 2.5µl dNTP (1mM), 1µl of species specific primer1 (10pmol) and 1µl of primer2 (10pmol).

Amplification conditions were:

Initial denaturation: 94^0C for 3 minutes

94^0C for 30 seconds

55^0C for 30 seconds

72^0C for 1 minute

} 35 cycles, Annealing temperature 55^0C

Final extension: 72^0C for 10 minutes

Visualization of PCR products: Visualized on 2% agarose gel

Agarose gel electrophoresis: 2g agarose was added to 100ml of 1X TAE buffer and mixture was heated in a microwave oven until the agarose completely dissolved with care to avoid over boiling. The agarose solution was cooled to 40^0C and 5µl of ethidium bromide stock (10mg/ml) was added and mixed thoroughly. The solution was then poured on gel casting tray with combs. Five µl of gel loading dye was mixed with 5 µl of PCR product and loaded onto the gel. 100bp ladder was loaded along side. Electrophoresis was run at 100V, 50mA for 45 to 90 minutes. The gel was visualized under UV transilluminator and captured in a gel documentation system (BioRad).

Table 3. SSR markers used for polymorphism in chilli entries screened for their reaction to yellow mite, *Polyphagotarsonemus latus* (Banks)

Sl. No.	Primer	Sl. No.	Primer
1	Hpms E 072	11	Hpms E 125
2	Hpms E 074	12	Hpms E 135
3	Hpms E 078	13	Hpms E 136
4	Hpms E 081	14	Hpms E 137
5	Hpms E 083	15	Hpms E 140
6	Hpms E 084	16	Hpms E 142
7	Hpms E 090	17	Hpms E 143
8	Hpms E 100	18	Hpms E 144
9	Hpms E 101	19	Hpms E 148
10	Hpms E 122	20	Hpms E 058

3.7. Coexistence of yellow mite, *Polyphagotarsonemus latus* and thrips, *Scirtothrips dorsalis* on chilli

The seedlings of chilli variety *Byadgi kaddi* were raised in nursery and 28 days old seedlings were then planted individually in 22cm diameter earthen pots with recommended pot mixture and with recommended chemical fertilizers applied at 2, 5 and 11 weeks after planting. The plants were watered regularly and maintained in a glass house. Culture of yellow mite, *P. latus* and thrips, *S. dorsalis* were maintained on potted chilli plants separately in a polycarbonate house.

The associative occurrence of mites, *P. latus* and thrips, *S. dorsalis* was studied in glass house on chilli plants of variety *Byadgi kaddi* raised in earthen pots. 4 weeks old ten potted chilli plants free from thrips as well as mites were arranged in a single row. These healthy plants were surrounded by potted chilli plants having separate infestation of thrips and mites kept alternatively at distance of 1 metre in a circular fashion.

Leaves from terminal shoots of each of these centrally placed potted plants were sampled at weekly interval to record the population of mites under a stereobinacular microscope, while the plants were individually tapped on a black card board to record the thrips population. Observations were also recorded for the symptoms of upward curling of leaves caused due to feeding by thrips and downward curling of leaves caused due to feeding by mites at different intervals. Population of thrips and mites as well as the corresponding leaf curling damages at different intervals were compared for joint invasion or occurrence of thrips and mites on chilli plants.

Experimental Results

IV. RESULTS

Investigations on the damage by yellow mite, *Polyphagotarsonemus latus* (Banks) on chilli crop and the reaction of selected chilli lines to this mite infestation were carried out in the Department of Agricultural Entomology, University of Agril. Sciences, Gandhi Krishi Vignana Kendra, Bangalore including the field studies in Karjagi and Mannur villages of Haveri district. The results of these studies are presented in this chapter.

4.1. Pest complex on chilli crop

A total of 26 species of insects and one species of mite were associated with chilli crop in the ZARS farm at GKVK, Bangalore. These insects belonged to 14 different families in six different Orders (Table 4 & Plate 5). The only mite species is from family Tarsonemidae, *Polyphagotarsonemus latus* (Banks).

One week after planting cut worm, *Spodoptera litura* Fabricius damaged chilli seedling by nibbling at the ground level in few patches only.

After 2 weeks the incidence of rasping and sucking pests *viz.*, thrips, *Scirtothrips dorsalis* Hood and mite, *P. latus* was observed with characteristic damage symptom of upward and downward curling of leaves, respectively. The number of thrips (nymphs and adults) ranged from 1 to 3 thrips/plant and that of mites (eggs and active stages) ranged from 1.6 to 11.4 mites/6 leaves. Both thrips and mites were observed to inhabit the chilli crop upto 10-12 weeks, but with varying levels of infestation and damage.

Four weeks after planting, aphid, *Myzus persicae* Sulzer infested chilli seedlings in patches which encouraged the development of sooty mold occasionally. At flowering, gall midge, *Asphondylia capsici* Barnes caused galls on the floral parts resulting in premature dropping of flowers. Fruit borer,

Table 4. Succession of insects and mites on chilli, *Capsicum annuum* L. at GKVK, Bangalore during 2008

Sl. No.	Crop stage	Scientific name	Order & Family
1	Seedling stage	*Spodoptera litura* Fabricius	Lepidoptera: Noctuidae
2	Seedling to vegetative stage	*Myzus persicae* Sulzer	Hemiptera: Aphididae
3	Seedling to fruiting stage	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
		Polyphagotarsonemus latus (Banks)	Acarina: Tarsonemidae
4	Vegetative stage	*Leptocentrus taurus* (Fabricius)	Hemiptera: Membracidae
		Farona sp.	Hemiptera: Flatidae
		Oxycarenus hyalipennis Kirby *Oncopeltus nigriceps* (Dallas)	Hemiptera: Lygaeidae
		Nezara viridula (Linnaeus) *Canthecona furcellata* (Wolff)	Hemiptera: Pentatomidae
		Cletus sp.	Hemiptera: Coreidae
		Myllocerus discolor Boheman *Ptochus ovulum* Fabricius	Coleoptera: Curculionidae
		Alcidodes sp.	
		Apion sp.	Coleoptera: Apionidae
		Monolepta signata Olivier	Coleoptera: Chrysomelidae
		Pagria signata (Motschulsky)	
		Chaetocnema sp.	
		Phyllotreta sp.	
		Gastrimargus africanus Sauaaure	Orthoptera: Acrididae
		Catantops sp.	
		Pyrgomorpha sp.	
		Atractomorpha crenulata Fabricius	
5	Flowering stage	*Creontiades* sp. *Nesidiocoris* sp.	Hemiptera: Miridae
		Asphondylia capsici Barnes	Diptera: Cecidomyiidae
6	Fruiting stage	*Helicoverpa armigera* (Hübner)	Lepidoptera: Noctuidae
Natural enemies			
1	Vegetative stage to fruiting stage	*Harmonia* sp. *Scymnus* sp.	Coleoptera: Coccinellidae
		Cunaxa sp.	Acari: Cunaxidae
		Not identified	Acari: Stigmaeidae

***Helicoverpa armigera* (Hübner)**

***Spodoptera litura* Fabricius**

***Scirtothrips dorsalis* (Hood)**

***Monolepta signata* Oliver**

***Myzus persicae* Sulzer**

***Asphondylia capsici* Barnes**

Plate 5. Succession of potential insect pests on chilli crop

Helicoverpa armigera (Hubner) appeared at the fruiting stage *i.e.,* beyond 90 days after planting with a characterstic symptom of fairly large entry hole on the green fruits.

Natural enemies, namely coccinellids (*Harmonia* sp. and *Scymnus* sp.) and few mite predators from families Cunaxidae and Stigmaeidae were observed on chilli plants at different crop growth stages.

4.2. Estimation of loss due to yellow mite, *Polyphagotarsonemus latus* (Banks) on chilli crop

The crop loss due to yellow mite, *P. latus* in chilli was estimated in farmer's fields in Karjagi and Mannur villages of Haveri district during two different seasons, *kharif* 2008 and *kharif* 2009.

4.2.1. Kharif 2008

Data from crop loss study at Karjagi village during 2008-09 are presented in Table 5. Mean mite population (eggs and active stages) in the protected plots was 29.15 mites/6 leaves against 48.43 mites/6leaves in unprotected plots. The fruit yield from protected plot and unprotected plots were 567 kg/acre and 400 kg/acre, respectively.

Mean yield of dry fruits in treated plot – 567 kg

Mean yield of dry fruits in untreated plot – 400 kg

Standard deviation (S.D) = $\sqrt{\frac{Sum\ of\ d^2}{n-1}}$ = 0.84

Standard Error of the mean of difference (SE) = $\frac{SD}{\sqrt{n}}$ = 0.37

The paired't' value 3.95* was significant.

The extent of loss due to mite infestation was 29.45%.

Table 5. Crop loss study in chilli (cv. *Byadgi kaddi*) during *kharif* 2008 (Karjagi, Haveri)

Paired Plot	Protected plot				Unprotected plot			
	Mean mite population/6 leaves			Yield (Kg/acre)	Mean mite population/6 leaves			Yield (Kg/acre)
	Eggs	Active stages	Total		Eggs	Active stages	Total	
1	23.49	9.22	32.71	620	41.05	20.89	61.94	400
2	17.88	11.44	29.32	640	31.72	12.89	44.61	440
3	19.77	16.55	36.32	480	28.22	15.78	44.00	370
4	16.10	9.44	25.54	560	20.66	13.22	33.88	350
5	10.21	11.66	21.87	520	37.39	13.66	51.05	390
6	17.99	11.16	29.15	580	32.05	23.05	55.10	450
Mean	**17.57**	**11.57**	**29.15**	**567**	**31.85**	**16.58**	**48.43**	**400**

4.2.2. *Kharif* 2009

The yield loss due to *P. latus* in chilli crop from the second season study in Mannur village during 2009-10, revealed the mean mite population (eggs and active stages) in the protected plots as 4.60 mites/6 leaves and in unprotected plots it was 6.73 mites/6 leaves (Table 6). The fruit yields from protected and unprotected plots were 634 kg/acre and 448 kg/acre, respectively.

Table 6. Crop loss study in chilli (cv. *Byadgi kaddi)* during *Kharif* 2009 (Mannur, Haveri)

Paired Plot	Protected plot				Unprotected plot			
	Mean mite population/6 leaves			Yield (Kg/acre)	Mean mite population/6 leaves			Yield (Kg/acre)
	Eggs	Active stages	Total		Eggs	Active stages	Total	
1	2.78	1.08	3.85	700	4.90	2.83	7.73	460
2	1.03	0.43	1.45	630	5.85	4.75	10.60	520
3	1.23	0.58	1.80	600	3.65	1.98	5.63	360
4	4.68	3.13	7.80	720	4.03	2.03	6.05	330
5	4.73	2.48	7.20	640	4.23	1.63	5.85	480
6	5.58	3.33	8.90	520	4.38	2.13	6.50	500
7	0.73	0.48	1.20	630	3.15	1.63	4.78	490
Mean	**2.96**	**1.64**	**4.60**	**634**	**4.31**	**2.42**	**6.73**	**448**

Mean yield of dry fruit in treated plot – 634 kg/acre

Mean yield of dry fruit in untreated plot – 448 kg/acre

Standard Deviation (S.D) = $\sqrt{\frac{Sum\ of\ d^2}{n-1}}$ = 3.22

Standard Error of the mean of difference (SE) = $\frac{SD}{\sqrt{n}}$ = 1.21

The paired‘t’ value of 4.19** was highly significant.

The per cent yield loss due to mite infestation was 29.33%.

4.3. Critical assessment of damage due to yellow mite on chilli

4.3.1. Damage due to yellow mite, *P. latus* at different growth stages

4.3.1.1. Glasshouse study

The study was conducted using chilli variety *Byadgi kaddi* during April to September 2009. The potted chilli plants of different growth stages, 15 days to 90 days old (10 potted plants for each age/stage) were allowed to be infested by the yellow mite. Infestation by the mites was effected by keeping the mite infested potted chilli plants in a circular fashion around the healthy plants of different age. Since the mite population could not be recorded *in situ*, the plants were scored for the mite damage 15 days after effecting the mite infestation. Thus there were 2 to 7 scoring intervals for different treatments. The data on damage score, plant height, plant biomass (fresh weight & dry weight), number of fruits per plant and fruit yield were recorded and presented in Table 7.

The mean leaf damage score was highest (3.83), when mite infestation initiated/effected at early stage of crop and the resultant damage (score) declined as the mite infestation was effected on the aged plants. Thus the mean damage score in further treatments were 3.57, 3.36, 3.25 & 3.0 and plants in control (*i.e.* mite infestation free plants) also recorded a mean damage score of 0.47 as the mites migrated from neighbouring infested plants.

Maximum plant height of 123.17 ± 55.62 cm was observed in control/ mite free plants as compared to 56.23 ± 7.86 cm, when the mites infested the plants from 15 days after planting and continued to damage till crop maturity. The mean plant height was affected significantly as mites infested the chilli plants at early stage of its development. It was also evident that plant height was found adversely affected when the mites infested chilli plants from 45 days onwards (Table 7).

Table 7. Assessment of damage due to yellow mite, *P. latus* on chilli cv. *Byadgi kaddi* due to mite infestation at different plant ages (Glasshouse study)

Mites infestation	Mite damage score at							Mean plant height (cm)	Biomass at maturity (g/10 plants)		Mean no. of fruits harvested per plant	Matured fruit yield (g/10 plants)
	Age 30 days (12/5/09)	Age 45 days (27/5/09)	Age 60 days (12/6/09)	Age 75 days (28/06/09)	Age 90 days (13/7/09)	Age 105 days (27/7/09)	Mean		Fresh Weight	Dry Weight		
From 15 Days after planting till maturity	1.9	3	4	4	4	4	3.48	56.23± 7.86	625	425	0.00 ±0.00	0
From 30 Days after planting till maturity	0	3.13	4	4	4	4	3.83	66.04± 13.41	1130	925	1.00 ±0.00	0
From 45 Days after planting till maturity	-	0	2.6	3.7	4	4	3.57	89.90± 26.05	1050	875	1.00 ±0.00	0
From 60 Days after planting till maturity	-	-	0	2.1	4	4	3.36	120.84± 51.38	1250	1000	4.47 ±0.95	200
From 75 Days after planting till maturity	-	-	-	0	2.6	3.9	3.25	116.79± 54.41	1850	1500	5.37 ±0.97	225
From 90 Days after planting till maturity	-	-	-	-	0	3	3.00	113.19± 54.34	1175	980	7.90 ±3.95	210
Mite free / No mites	0	0	0	0	0	2.8	0.47	123.17± 55.62	2100	1775	16.37 ±2.20	500

The mean plant biomass at maturity was recorded both on ‘fresh weight’ and ‘dry weight’ basis. The lower plant biomass (fresh & dry weight, 625 & 425 g/10 plants, respectively) was noticed with mite’s infestation treatment from 15 DAP to maturity. Higher biomass of 2100 g (fresh weight) and 1775 g (dry weight)/10 plants was recorded with mite free plants (Table 7).

No flowers or fruits were set when yellow mites infested the plants when they were 15, 30 & 45 days old and the infestation continued up to maturity (Plate 6 & 7).

Mean fruit yield of 500g/10 plants was recorded in mite free/control plants (Plate 8) as compared to no yield/zero yield in treatments when mites infested 15, 30 and 45 days old plants and continued to damage the plants till maturity (Table 7).

4.3.1.2. Field Experiment

A study similar to that mentioned in 4.3.2.1 was conducted under field conditions during August 2009 to February 2010 at ZARS farm, GKVK, Bangalore using chilli cultivar *Byadgi kaddi.* Mite infestation was encouraged at different age/growth stages of the crop from 15 to 75 days after planting by keeping at least 5 heavily infested potted chilli plants in each plot, with at least one pot in a row of 3m length. Observations on mite population as well as damage score were recorded at 15 days interval as mentioned above. Five plants from each plot were selected at random and from each plant one growing shoot with atleast six leaves were sampled to record the number of mites (including eggs and active stages). For scoring the mite damage (0-4 scale) all the plants in a plot showing symptom of downward curling due to mite feeding were scored individually.

Severely damaged chilli plants infested by yellow mite from 15 days/45 days after planting till maturity (100% yield loss)

Chilli plants severely damaged by yellow mites

Plate 6. Glasshouse experiment for critical damage assessment due to yellow mite on chilli

Plate 7. Damage on chilli plants when infested by yellow mites 60 days after planting (40 per cent loss)

Plate 8. Healthy chilli plants free from yellow mite infestation

The data recorded at 15 days intervals with respect to progressive buildup of mite population and the associated damage on the leaves upto 90 days from planting are presented in Table 8.

When 15 days old seedlings were infested by mites, further buildup of mite population was more evident up to 45 days and a fair population of mites was observed upto 90 days (Table 8). After 15 days (30 days age) mite population increased to 99.5/6 leaves, which further increased to a maximum 155.1mites/6 leaves by 45th day, followed by 81.50, 44.40 and 24.20 mites/6 leaves observed on 60th, 75th and 90th day, respectively. So the cumulative mite population when the plants were infested at 15 days after planting was 404.70 mites/6 leaves (mean of 80.9mites/6 leaves over 5 intervals). More gradual increase in the leaf damage was evidenced by the increase in the record of damage score of 0.23 on the 30th day to 1.95 on the 90th day, which corresponded to 50 per cent of leaves in a plant with downward curling caused due to yellow mite feeding on the under surface of leaves. The mean damage score over 5 intervals was 1.22 when the chilli seedlings were continuously menaced by mites from 15 to 90 days from planting (Table 9).

In plots where mite infestation started from 30 days after planting the mite population increased to 141.33, 80.06, 80.27 and 79.94 mites/6 leaves at 15 days interval up to 90 days (Table 8). Thus the cumulative mite population was 383.4 mites/6 leaves with a mean of 76.68 mites/6 leaves for 4 intervals. In this treatment of mite infestation also (from 30 days to maturity) increase in the record of damage score was from 0.39 (age 45 days) to 1.85 (by 90th day) with a overall mean score of 1.15 next to the highest of 1.22, *i.e.* when the seedlings were allowed for mite infestation from 15 days onwards (Table 9).

When 45 days old plants in the field were exposed for mite infestation the initial population of 1.13 mite/6 leaves increased to 116.2, 109.9 and 103.9 at 15 days interval upto 90 days. Thus the cumulative mite load was 332.4 mites/6 leaves between 45 and 90 days with a mean of 66.5 mites/6 leaves over 3 intervals (Table 8). When the chilli seedlings were allowed for mite infestation from 45 days after planting continuously, the lower damage score of (0.17) was evidenced at the age of 60 days and by 90th day damage score was found increased to 1.48, which corresponded to nearly 30 per cent of leaves in a plant with the symptom of downward curling (Table 9).

When 60 days old plants allowed for continuous mite infestation (up to 90 days) recorded a mite population of 72 to 76 mites/6 leaves during 75 to 90 days age, which accounted for a cumulative population of 150 mites/6 leaves in 30 days duration (from 3.11.09 to 4.12.2009). The overall mean (5 intervals) mite population was 30 mites/6 leaves. Simultaneously the mite damage score observed was 0.56 on 75th day and 0.73 on the 90th day.

When mite infestation was prevailed from 75 days after planting to maturity, the population buildup in the next fortnight (on the 90th day) was observed to be 51.8 mites/6 leaves, which could lead to a cumulative mite load of 54.2 mites/6 leaves by 90 days and a lower mean mite population of 10.84 mites/6 leaves in a fortnight. Also a marginal increase in the damage score was noticed (0.11 to 0.28) from 75 to 90 days.

Control or mite free designated plots harboured fewer number of mites (1.13 to 1.27 mites/6 leaves up to 45 days) (Table 8), which however could record as many as 5.67 mites/6 leaves on the 90th day with a mite damage scoring of 0.33. Cumulative mite load up to 90 days was a low of 8.07 mites/6 leaves, so also a lower mean mite population of 1.61 mites/6 leaves per fortnight.

Comparative analysis of mite population data from chilli plants which were exposed to mite infestation at different ages/stages revealed that cumulative mite population was highest, 404.7 mites/6 leaves for 75 days period followed by

Table 8. Yellow mite infestation at different stages/ages of chilli cv. *Byadgi kaddi* and buildup of mite population (Field experiment)

Mite infestation treatments	Mite population/6 leaves					Cumulative mite population	Mean mite population
	Age 30 days (2.10.09)	Age 45 days (18.10.09)	Age 60 days (3.11.09)	Age 75 days (19.11.09)	Age 90 days (4.12.2009)		
From 15 Days after planting to maturity	99.47 (9.45)	155.13 (12.47)	81.53 (9.04)	44.40 (6.69)	24.18 (4.96)	404.71	80.94 (9.02)
From 30 Days after planting to maturity	1.27 (1.16)	141.33 (11.89)	80.60 (9.00)	80.27 (8.85)	79.94 (8.97)	383.41	76.68 (8.78)
From 45 Days after planting to maturity	1.27 (1.16)	1.13 (1.12)	116.20 (10.80)	109.87 (10.45)	103.88 (10.21)	332.35	66.47 (8.18)
From 60 Days after planting to maturity	1.27 (1.16)	1.13 (1.12)	0.00 (0.70)	75.93 (8.68)	71.79 (8.50)	150.12	30.02 (5.52)
From 75 Days after planting to maturity	1.27 (1.16)	1.13 (1.12)	0.00 (0.70)	0.00 (0.70)	51.80 (7.23)	54.20	10.84 (3.36)
No mites/Mite free	1.27 (1.16)	1.13 (1.12)	0.00 (0.70)	0.00 (0.70)	5.67 (2.48)	8.07	1.61 (1.45)
F test	*	*	*	*	*	-	*
SEM±	(0.17)	(0.87)	(1.04)	(0.55)	(1.17)	-	(0.58)
CD at P=0.05	(0.55)	(2.74)	(3.27)	(1.73)	(3.69)	-	(1.82)

Figures in parentheses are $\sqrt{x+0.5}$ transformation; * significant at 5% probability

Table 9. Yellow mite infestation at different stages/ages of chilli cv. *Byadgi kaddi* and damage score and matured fruit yield (Field experiment)

Mite infestation treatments	Damage score at						Matured fruit yield (kg/acre)
	Age 30 days (2.10.09)	Age 45 days (18.10.09)	Age 60 days (3.11.09)	Age 75 days (19.11.09)	Age 90 days (03.12.09)	Mean	
From 15 Days after planting till maturity	0.23	0.89	1.20	1.82	1.95	1.22	533
From 30 Days after planting till maturity	0.00	0.39	1.66	1.86	1.85	1.15	800
From 45 Days after planting till maturity	0.00	0.00	0.17	0.87	1.48	0.50	1333
From 60 Days after planting till maturity	0.00	0.00	0.00	0.56	0.73	0.25	1733
From 75 Days after planting till maturity	0.00	0.00	0.00	0.11	0.28	0.08	2222
Mite free/No mites	0.00	0.00	0.00	0.00	0.33	0.06	3199
F-test	*	*	*	*	*	*	*
SEM±	0.03	0.10	0.14	0.37	0.40	0.07	166.12
CD at P=0.05	0.12	0.31	0.43	1.14	1.23	0.24	511.94

383.41, 332.35, 150.12 and 54.2 mites/6 leaves for 60, 45, 30 and 15 days durations, respectively, against a meagre number of 8.07 mites for the entire period of 90 days in check or control plot. This concurrently showed descending order of mean mite population as 80.94, 76.68, 66.47, 30.02, 10.84 and 1.61 for different mite infestation treatments from 15 days/30 days/45 days/60 days/75 days to maturity (Table 8). Inverse relationship between mite population load and the resultant red ripe chilli yield per plot was apparent (Table 9). The fruit yield data showed significant difference among the mite infestation treatments at different stages of chilli plant. As a result chilli crop which suffered due to mite infestation for a longer period of time (75 days) recorded the lowest yield of 533.33 kg/acre compared to the highest yield of 3200kg/acre when they were virtually mite free or with meager number of mites (Table 9).

4.4. Damage by yellow mite infestation at different intervals (2 – 4 weeks) during the cropping period on chilli crop

4.4.1. Study in polycarbonate house

The damage by yellow mite on chilli crop following its infestation for a period of 2 to 4 weeks during the cropping period was assessed by a polycarbonate house study. Potted chilli plants were allowed for mite infestation (by interspacing 15 mite infested potted plants for a group of 25 healthy potted chilli plants in each treatment) for a period of 2 to 4 weeks starting from 4, 6, 8 and 10 weeks after planting. Further the buildup of mite population as well as the damage (scoring) was recorded at 2 weeks interval. Because of severe flower drop and poor fruit set observed under polyhouse conditions, the data on economic fruit yield could not be recorded and hence plant biomass (fresh and dry weight) were recorded to compare different mite infestation treatments.

Inspite of removing the interspaced mite infested pots after 2 or 4 weeks and applying acaricides like dicofol/fenazaquin/propargite, still considerable mite population was observed at successive fortnightly observations in all the treatments (Table 10).

Restricting mite infestation for a period of 2weeks on 4weeks old plants recorded a mite population of 167.40 mites to 418.60 mites/6 leaves by 6th week. The number of mites in the further four successive fortnights was 38.8, 47.6, 45.4 and 25.2 mites/6 leaves when infestation allowed for a period of 2 weeks on 4 weeks old seedlings. But the number of mites in successive fortnights varied after confining the mite infestation for a period of 4 weeks on the same 4 weeks old seedlings (Table 10). As a result mite population by 6th week was 418.6 mites/6 leaves and was 208 mites/6 leaves by the 8th week. Further, the mite population was fairly low, which ranged from 25.4 to 35 mites/6 leaves in the next three fortnight period.

Cumulative mite population was as high as 714.4 mites/6 leaves with 4 to 8 weeks infestation compared to 324.4 mites/6 leaves with mite infestation treatment from 4 to 6 weeks. Mean mite population per fortnight was 142.88 mites/6 leaves when mites were allowed to colonize for a period of 4 weeks compared to a mean of 64.88 mites/6 leaves, when colonized for 2 weeks. Also damage due to mites was relatively more with 4weeks of infestation (mean score of 2.56) compared to infestation of two weeks (damage score 2.44) (Table 11).

Allowing mite infestation for a period of 2 weeks on 6 weeks old seedlings recorded a mite population of 93.6, 61.8, 31.6 and 36 mites/6 leaves in the successive 4 fortnights leading to a cumulative mite load of 223 mites/6 leaves up to 14th week. But allowing mite infestation for a period of 4 weeks on the same 6 weeks old seedlings resulted in a higher cumulative mite load of 401.60 mites/6 leaves by 14th week, with 57.6, 249.8, 52.4 and 41.8 mites/6 leaves in the corresponding 8th, 10th, 12th and 14th weeks, respectively. Similarly, mite population per fortnight was more (100.4 mites/6 leaves) with the infestation period of 4 weeks against a lower population of 55.75 mites/6 leaves with the infestation of 2 weeks period (Table 10).

154.4 mites/6 leaves were found colonized in the following fortnight (Table 10) when 8 weeks old chilli seedlings were allowed for mite infestation. Further mite population buildup on such seedlings was 77 and 1.2 mites/6 leaves in the next 2 successive fortnights. This could record a cumulative mite population of 232.6 mites/6 leaves between 8th and 4th week an overall fortnightly mean of 77.53 mites/6 leaves. In the next treatment where the mites were allowed for colonization for 4 weeks period between 8th and 12th week age could record a mite population of 94.4 mites/6 leaves in the following fortnight of 10th week, which however rapidly raised to 251 mites/6 leaves in the following fortnight and this did not encourage the mites to buildup further as it recorded only 1.4 mites/6 leaves in the following fortnight of 14th week. Colonization of mites in this treatment for a period of 4 weeks (8 to 12 weeks) resulted in a higher cumulative population of 346.8 mites/6 leaves with a fortnightly mean of 115.6 mites/6 leaves.

Allowing mite infestation for a period of 2 to 4 weeks on 10 weeks old chilli crop resulted in the mite population of 57.2 to 75.20 mites/6 leaves in the following fortnight followed by 44.40 to 95.80 mites/6 leaves in the further fortnights. This resulted in a cumulative mite population of 119.6 to 153 mite/ 6 leaves with a fortnightly mean of 59.8 to 76.5 mites/6 leaves. Treatment with no mite infestation was maintained to harbour hardly any mites (Table 10).

Build up of mites in the following fortnight with the release of mites on 4, 6, 8 and 10 weeks old seedlings though recorded damage score of >2 (more than 50 per cent of leaves with downward curling) (Table 11) and also the mean damage score at 14th week ranged from 2.32 to 3.5. This clearly indicated that mite colonization resulted in increase in the damage score in the following weeks, which was evidently high between 10 and 14 weeks.

Table 10. Mite infestation at different growth stages and build up of mite population on chilli cv. *Byadgi kaddi* (Glasshouse study)

Mite infestation treatments	Mite population (eggs + active stages/6 leaves) at						Cumulative mite population	Mean mite population
	4th week (30.6.09)	6th week (14.7.09)	8th week (27.7.09)	10th week (10.8.09)	12th week (25.8.09)	14th week (9.9.09)		
From 4 to 6 weeks	0.00	167.40	38.80	47.60	45.40	25.20	324.40	64.88
From 4 to 8 weeks	0.00	418.60	208.00	35.00	27.40	25.40	714.40	142.88
From 6 to 8 weeks	-	0.00	93.60	61.80	31.60	36.00	223.00	55.75
From 6 to 10 weeks	-	0.00	57.60	249.80	52.40	41.80	401.60	100.40
From 8 to 10 weeks	-	-	0.00	154.40	77.00	1.20	232.60	77.53
From 8 to 12 weeks	-	-	0.00	94.40	251.00	1.40	346.80	115.60
From 10 to 12 weeks	-	-	-	0.00	75.20	44.40	119.60	59.80
From 10 to 14 weeks	-	-	-	0.00	57.20	95.80	153.00	76.50
Mite free/ No mites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 11. Damage due to yellow mite infestation at different growth stages and biomass yield in chilli cv. *Byadgi kaddi* (Glasshouse study)

Mite infestation treatments	Damage score at						Mean	Biomass (g/25 plants)	
	4th week (30.6.09)	6th week (14.7.09)	8th week (27.7.09)	10th week (10.8.09)	12th week (25.8.09)	14th week (9.9.09)		Fresh weight	Dry weight
From 4 to 6 weeks	0.00	3.0	2.4	2.4	2.4	2.0	2.44	1050	850
From 4 to 8 weeks	0.00	2.2	3.6	2.6	2.8	1.6	2.56	875	625
From 6 to 8 weeks	-	0.0	2.2	3.0	1.6	2.5	2.32	1130	920
From 6 to 10 weeks	-	0.0	2.4	3.4	1.8	2.2	2.45	950	750
From 8 to 10 weeks	-	0.0	0.0	2.6	2.8	3.2	2.86	1100	875
From 8 to 12 weeks	-	0.0	0.0	2.8	2.8	3	2.86	1850	1520
From 10 to 12 weeks	-	0.0	0.0	0.0	3.3	3.2	3.25	2000	1850
From 10 to 14weeks	-	0.0	0.0	0.0	3.2	3.8	3.50	1175	925
Mite free/No mites	0.00	0.0	0.0	0.0	0.0	0.0	0.00	2525	2325

When mite colonization and dry weight of plant biomass from different treatments were compared, the highest was 2325 g/25 plants (on dry weight basis) in mite free treatment. Encouraging mite infestation on seedlings aged between 4 and 8 weeks resulted in the lowest biomass of 625 to 875 g/25 plants followed by the treatment with mite colonization from 6 to 10 weeks (750 to 950 g/25 plants). In other treatments also mite feeding on different aged seedlings for a period of 2 to 4 weeks showed considerable adverse effect on production of plant biomass.

4.4.2. Field experiment

In this field experiment mite infested potted chilli plants were kept for a period of 2 to 4 weeks within the plots of different aged chilli crop, namely 4 weeks, 6 weeks, 8 weeks and 10 weeks. In a plot of 3m x 3m with 6 rows, five infested potted plants were kept between these 6 rows, which ensured mite spread/colonization within the plot. Mite population buildup in all these plots was monitored at fortnightly interval by recording the number of mites including eggs and active stages upto 14 weeks. Before the imposition of intended treatments the plots were kept mite free by applying acaricides like dicofol/ fenazaquin/ propargite, alternatively. A control plot (designated as mite free), though expected to have no mites throughout a considerable mite population was observed, probably by the dispersing individuals from the adjoining mite infested plots or due to lower effectiveness of acaricides used.

Mite colonization for a period of 2 to 4 weeks on 4 weeks old chilli seedlings recorded a mite population of 77.8 to 79.60 mites/6 leaves after 2 weeks *i.e.* during the 6^{th} week. Further mite population increased to 208 mites/6 leaves by 8^{th} week when mite infested plants was kept for an additional period of 2 more weeks (Table 12).

But the mite population in the plot with mite infestation from 4 to 6 weeks had lower number of mites *i.e.* 39.70 mites/6 leaves less than the previous fortnightly record of 77.8 mites/6 leaves. Further, more gradual reduction in the mite population was observed in the successive fortnights with 32.4 mites/6 leaves by 10th week, 11.5 mites/6 leaves by 12th week and 6.8 mites/6 leaves by the 14th week. This could result in a cumulative mite population of 168.82 mites/6 leaves from 6th to 14th week and the fornightly mean mite population was 33.64 mites/6 leaves. Similarly, treatment with 4 to 8 weeks of mite infestation recorded 53.4, 13.4 and 7.5 mites/6 leaves by 10th, 12th and 14th week, respectively. In this treatment cumulative mite population was the highest *i.e.* 361.90 mites/6 leaves with again a highest fortnightly mean of 72.38 mites/6 leaves.

Mite infestation from 6 to 10 weeks could result in a mite population of 45.8 to 63.8 mites/6 leaves by 8th week, 44.22 to 78.60 mites/6 leaves by 10th week, 14 to 20.7 mites/6 leaves by 12th week and 9.50 to 9.70 mites/6 leaves by the 14th week. The resulting cumulative mite load was 131.7 to 154.60 mites/6 leaves with a mean mite population of 32.93 to 38.65 mites/6 leaves per fortnight.

Cumulative mean population was 200.10 mites/6 leaves over four fortnights against 131.6 mites/6 leaves when mite infestation was encouraged from 8 to 12 weeks. In these treatments initially increase in mite population was observed by 10th or 12th week, which declined further in the following fortnights (Table 12). However, fortnightly mean mite population between 8 and 12 weeks ranged from 19.4 to 87.8 mites/6 leaves and this treatment had the highest cumulative as well as fortnightly mean mite population (200.10; 50.03 mites/6 leaves) only next to the treatment which had the mite colonization for 4 weeks *i.e.* from 4 to 8 weeks (with 361.90; 72.38 mites/6 leaves).

No much difference was observed when mites were allowed for 2 or 4 weeks on 10 weeks old seedlings either in the fortnightly buildup of mites or in the cumulative mite load or the fortnightly mean mite load (Table 12).

Table 12. Mite infestation at different growth stages and further build up of mite population on chilli cv. *Byadgi kaddi* (Field experiment)

Mites infestation treatments	Mite population(eggs + active stages)/6 leaves at						Cumulative mite population	Mean mite population
	4th week	6th week	8th week	10th week	12th week	14th week		
From 4 to 6 weeks	0.00 (0.70)	**77.80 (8.84)**	39.70 (6.34)	32.40 (5.73)	11.50 (3.46)	6.80 (2.70)	168.20	33.64 (5.84)
From 4 to 8 weeks	0.00 (0.70)	**79.60 (8.95)**	**208.00 (14.44)**	53.40 (7.34)	13.40 (3.72)	7.50 (2.82)	361.90	72.38 (8.53)
From 6 to 8 weeks	0.00 (0.70)	0.00 (0.70)	**63.80 (8.01)**	44.20 (6.68)	14.00 (3.80)	9.70 (3.19)	131.70	32.93 (5.78)
From 6 to 10 weeks	0.00 (0.70)	0.00 (0.70)	**45.80 (6.80)**	**78.60 (8.89)**	20.70 (4.60)	9.50 (3.16)	154.60	38.65 (6.25)
From 8 to 10 weeks	0.00 (0.70)	0.00 (0.70)	19.40 (4.46)	**74.40 (8.65)**	24.60 (5.01)	14.10 (3.82)	131.60	32.90 (5.77)
From 8 to 12 weeks	0.00 (0.70)	0.00 (0.70)	19.40 (4.46)	**75.70 (8.72)**	**87.80 (9.39)**	17.00 (4.18)	200.10	50.03 (7.10)
From 10 to 12 weeks	0.00 (0.70)	0.00 (0.70)	19.40 (4.46)	21.20 (4.65)	**19.90 (4.51)**	37.70 (6.18)	95.60	23.90 (4.93)
From 10 to 14 weeks	0.00 (0.70)	0.00 (0.70)	19.40 (4.46)	21.20 (4.65)	**27.80 (5.32)**	**42.40 (6.55)**	111.80	27.95 (5.33)
Mite free/No mites	0.00 (0.70)	0.00 (0.70)	19.40 (4.46)	21.20 (4.65)	23.20 (4.68)	23.70 (4.91)	87.50	21.88 (4.73)
F test	NS	*	*	*	*	*	-	*
S.EM±	-	(4.6)	(8.8)	(4.13)	(3.41)	(1.93)	-	(2.04)
CD at P=0.05	-	(14.18)	(27.11)	(12.72)	(10.5)	(5.93)	-	(6.28)

Figures in parentheses are $\sqrt{x+0.5}$ transformations; * significant at 5% probability

Table 13. Damage due to yellow mite at different growth stages and matured fruit yield in chilli cv. *Byadgi kaddi* (Field experiment)

Mite infestation	Mean mite damage score						Mean matured fruit yield (kg/acre)
	6th week	8th week	10th week	12th week	14th week	Mean	
From 4 to 6 weeks	2.2	2.4	1.4	2.4	2	2.08	1111
From 4 to 8 weeks	2	2.6	2.8	2.8	1.6	2.36	555
From 6 to 8 weeks	0	1.2	3	1.6	2.5	2.07	1444
From 6 to 10 weeks	0	1.4	3.4	1.8	2.2	2.20	933
From 8 to 10 weeks	0	0	1	2.8	3.2	1.75	2511
From 8 to 12 weeks	0	0	0	2.8	3	1.45	1733
From 10 to 12 weeks	0	1	1	3.3	3.2	2.12	3111
From 10 to 14weeks	0	0	0	3.2	3.8	1.75	2755
Mite free	0	1	1.2	1.8	1.8	1.45	3311
F test	*	*	*	*	*	*	*
SEM±	0.28	0.41	0.48	0.11	0.13	0.08	140.05
CD at P=0.05	0.88	1.28	1.49	0.36	0.42	0.23	447.61

**** Significant at 5% probability***

In the check plot complete control of mite could not be ensured inspite of acaricidal applications, which recorded a mite population ranging from 19.4 to 23.70 mites/6 leaves from 8th to 14th week with a cumulative mite population of 87.50 mites/6 leaves and a fortnightly mean of 21.88 mites/6 leaves.

From the data of this experiment, it is evident that mite colonization for a period of 4 weeks on 4 weeks or 6 weeks or 8 weeks old seedlings resulted in rapid buildup of mites in the following weeks, as a result seedlings suffered due to this higher mite load (Table 12).

With respect to damage (score), mite colonization for a period of 2 or 4 weeks either on 4 weeks or 6 weeks old seedlings not only encouraged the buildup of mites, but simultaneous damage (downward curling) due to mite feeding was apparent as evidenced by the damage score of > 2 (Table 13). Mite infestation from 4 to 8 weeks and 6 to 10 weeks resulted in more evident expression of damage symptom due to mite feeding compared to other mite infestation treatments.

Red ripe fruit yield was lowest (555 kg/acre) when 4 weeks old seedlings were exposed to mite colonization and damage for further 4 weeks. This was followed by the yield of 933 kg/acre recorded from plots with the mite infestation of 4 weeks period from 6th week onwards. Mite colonization beyond 10 weeks did not influence the fruit yield adversely (Table 13). Comparatively check plots (designated as mite free) recorded the highest red ripe fruit yield of 3311 kg/acre.

4.5. Screening of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* (Banks)

Chilli entries from different sources were evaluated for their reaction to yellow mite infestation by planting them in 5m rows in two replications during six different periods from January 2008 to August 2010 and the corresponding data are presented in Table 14 to Table 21.

4.5.1. Field Screening of chilli entries during January to May 2008 (Early summer 2008)

Twenty seven entries were evaluated during early summer 2008 (January-May 2008) in shade net conditions at GKVK, Bangalore (Table 14).

Percentage of mite infested plants in different entries ranged from zero (seven entries) to 46.67 per cent (PBC1752), and the mite damage score recorded was from zero (seven entries) to 2.33 (PBC1752). Mite population data which included the number of eggs as well as the active stages revealed the least number of zero mites per six leaves (CMS 2B and CMS 7A) to 111.78 mites/6 leaves in the chilli entry Oothgod local.

4.5.2. Field evaluation during summer 2008 (February to June, 2008)

Fourteen entries were screened during summer 2008 in open field conditions at GKVK, Bangalore (Table 15).

Eleven entries showed least mite damage with no mite infestation and maximum mite infestation was 14.29 per cent (LCA 424). The mite damage score ranged from zero (11 entries) to one (LCA 424). Total mite population recorded was zero (Aparna, LCA 336, HMT 1 and HMT 2) and the maximum was 25 mites/6 leaves, which was in the entry Minchalli betta (Table 15).

4.5.3. Assessment of chilli entries during late summer (March to August, 2008)

Screenings of 31 entries during late summer in open field conditions at ZARS, GKVK, Bangalore (Table 16) revealed upto 55 per cent mite infested plants (KDC 1) and the damage score recorded was from zero (18 entries) to 1.8

Table 14. Field evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during early summer 2008 *(January to May 2008)*

Sl. No.	Entries	Mean number/6 leaves			Mite damage	
		Eggs	Active stages	Total	Mean damage score	Percentage of plants infested by mites
1	CMS 2B	0.00	0.00	0.00	0.00	0.00
2	CMS 7A	0.00	0.00	0.00	1.33	26.67
3	CMS 6B	1.05	0.11	1.16	0.00	0.00
4	CMS 8A	1.00	0.18	1.18	0.00	0.00
5	CMS 6A	0.56	1.83	2.39	0.33	6.67
6	CMS 7B	2.00	0.40	2.40	0.00	0.00
7	CA 14	3.47	0.73	4.20	0.00	0.00
8	*Susceptible baccatum*	3.71	1.57	5.28	0.67	6.67
9	CMS 2A	6.82	0.81	7.63	0.33	5.56
10	*Capsicum frutescens*	6.05	2.63	8.68	0.33	4.76
11	CMS 8B	5.55	5.74	11.29	0.67	13.33
12	Darpung	12.50	3.78	16.28	0.67	8.33
13	LCA 273	14.72	3.33	18.05	0.33	5.56
14	CMS 5B	12.91	5.22	18.13	0.33	6.67
15	Lampong local short	14.39	4.72	19.11	0.00	0.00
16	CMS 1A	16.11	3.39	19.50	1.33	16.67
17	PBC 1752	13.68	7.94	21.62	2.33	46.67
18	CMS 3A	16.54	6.47	23.01	0.00	0.00
19	CMS 1B	30.83	3.11	33.94	1.67	16.67
20	Utkal rashmi	31.90	7.07	38.97	1.67	33.33
21	Lampong local long	31.71	7.38	39.09	1.00	12.50
22	CMS 5A	39.07	8.30	47.37	0.67	13.33
23	CMS 3B	40.61	7.55	48.16	0.67	13.33
24	Pant C-1	51.50	15.91	67.41	0.67	8.33
25	*Byadgi kaddi*	80.20	6.65	86.85	2.33	23.33
26	*Byadgi dabbi*	87.32	20.90	108.22	2.67	26.67
27	*Oothgod local*	87.73	24.04	111.78	1.00	14.29

Table 15. Field evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during summer 2008 *(February to June 2008)*

Sl. No.	Entries	Mean number/6 leaves			Mite damage	
		Eggs	Active stages	Total	Mean damage score	Percentage of plants infested by mites
1	Aparna	0.00	0.00	0.00	0.00	0.00
2	LCA336	0.00	0.00	0.00	0.00	0.00
3	HMT 1	0.00	0.00	0.00	0.00	0.00
4	HMT 2	0.00	0.00	0.00	0.00	0.00
5	PBC142	0.00	0.20	0.20	0.00	0.00
6	CCA336B	0.00	1.40	0.70	0.00	0.00
7	Scoul I	2.40	2.00	4.40	0.00	0.00
8	LCA 334	3.50	1.90	5.40	0.00	0.00
9	LCA 273	4.80	1.40	6.20	0.00	0.00
10	LCA 335	1.00	6.00	7.00	0.00	0.00
11	CO – 1	8.40	3.80	12.20	0.00	0.00
12	LCA 353	11.80	5.00	16.80	0.50	8.33
13	LCA 424	13.60	5.80	19.40	1.00	14.29
14	Minchalli betta	15.60	9.40	25.00	0.50	8.33

Table 16. Field evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during late summer 2008 *(March to August 2008)*

Sl. No.	Entries	Mean number/6 leaves			Mite damage	
		Eggs	Active stages	Total	Mean damage score	Percentage of plants infested by mites
1	PMR 21	0.00	0.25	0.25	1.40	50.00
2	KDC 1	1.70	0.35	2.05	1.20	55.00
3	PBC 81	1.75	1.25	3.00	0.00	0.00
4	CA 9	2.15	1.55	3.70	0.50	9.40
5	G- 4	1.90	1.85	3.75	0.30	12.50
6	Vamsi	4.15	2.25	6.40	0.00	0.00
7	PBC 80	3.95	3.65	7.60	0.00	0.00
8	PBC 631	6.20	2.00	8.20	0.00	0.00
9	Phule Jyothi	5.65	2.75	8.40	0.50	10.00
10	BVC 53	6.80	2.30	9.10	0.00	0.00
11	Koira	6.45	3.65	10.10	0.00	0.00
12	*Pusa sadabahar*	8.35	4.50	12.85	0.80	7.50
13	KNG 2	9.50	4.85	14.35	0.00	0.00
14	CA 3	10.35	4.25	14.60	0.00	0.00
15	BVC 47	9.20	5.50	14.70	0.00	0.00
16	CA 2	10.50	4.30	14.80	0.00	0.00
17	Chiagmai local	11.55	3.95	15.50	0.00	0.00
18	CA 10	12.50	5.05	17.55	0.00	0.00
19	Vietnam	13.30	5.85	19.15	0.50	10.00
20	CA 12	14.85	4.55	19.40	1.30	50.00
21	ICPN 14	12.55	8.00	20.55	0.00	0.00
22	CA 6	12.80	8.15	20.95	0.00	0.00
23	*Punjab gucchedhar*	18.70	6.25	24.95	0.00	0.00
24	PL 3	22.05	8.50	30.55	1.80	12.50
25	Vangara	21.25	9.80	31.05	1.50	13.90
26	KNG 1	23.35	11.05	34.40	0.00	0.00
27	North Assam	26.80	8.75	35.55	0.00	0.00
28	PL 5	28.50	11.75	40.25	1.10	35.00
29	Tiwari	34.40	13.80	48.20	1.30	15.00
30	Gowribidanur	43.50	16.45	59.95	1.00	50.00
31	Chikkaballapur local	50.15	17.35	67.50	0.90	30.00

(PL 3). The total mite population data observed was 0.25 mites/6 leaves (PMR 21) to 67.50 mites/6 leaves in the chilli entry Chikkaballapur local (Table 16).

4.5.4. Evaluation during *Kharif* 2008 (July to November, 2008)

Evaluation of 21 chilli entries was undertaken during *Kharif* 2008 in polyhouse conditions at GKVK, Bangalore (Table 17).

The mean mite damage score recorded on different chilli entries ranged from zero (entries 107-1 and S112-4) to 3.75 (4-4 & S 20-1), and the percentage of mite infested plants ranged from zero (107-1 and S112-4) to 82.50 per cent (KDSC 1 and HMT 1). The mite population data revealed a range of 15.60 mites/6 leaves (KDC 2) to 218.75 mites/6 leaves in chilli entry 132-2-2 (Table 17).

4.5.5. Field evaluation during late *Kharif*, 2008 (August to December, 2008)

Screening of 17 entries during late *Kharif* (August to December, 2008) was in open field conditions at ZARS, GKVK, Bangalore (Table 18).

Percentage of infested plants in different entries ranged from 0.0 (13 entries) to 40 per cent (GVC 121), while the mean damage score ranged from 0 (12 entries) to the highest of 0.55 (CNS 2). The mite population data including the number of eggs and active stage revealed the lowest number of zero mites (eight entries) to 20.80 mites/6 leaves (GVC 121).

4.5.6. Field screening of chilli entries during summer 2009 (February to June, 2009)

Thirty chilli entries were evaluated during summer 2009 (February to June, 2009) under open field conditions at ZARS, GKVK, Bangalore (Table 19).

Mean mite damage score in different chilli entries ranged from zero (14 entries) to 2.33 (North Assam), whereas the percentage of yellow mite infested

Table 17. Evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during kharif 2008 (*July to November 2008* - Polyhouse experiment)

Sl. No.	Entries	Mean number/6 leaves			Mite damage	
		Eggs	Active stages	Total	Mean damage score	Percentage of plants infested by mites
1	KDC -2	12.75	2.85	15.60	2.00	40.00
2	KDSC -1	23.5	6.10	29.60	3.25	82.50
3	S 112-4	34.25	8.75	43.00	0.00	0.00
4	20-1	45.00	16.05	61.05	3.25	70.83
5	132-2	50.25	19.95	70.20	2.25	22.50
6	149-2	52.78	21.63	74.41	0.75	18.75
7	G 4	57.87	22.13	80.00	3.50	75.00
8	133-5	66.40	26.60	93.00	3.25	32.50
9	101-3	67.80	27.25	95.05	2.00	20.00
10	107-1	70.10	25.90	96.00	0.00	0.00
11	101-4	74.30	31.75	106.05	3.25	72.50
12	94-1	78.69	27.66	106.35	3.50	35.00
13	101-1	74.10	35.30	109.40	0.50	6.25
14	65-1	80.25	35.25	115.50	0.50	50.00
15	S 65-3	86.50	33.20	119.70	3.00	37.50
16	S 20-1	85.80	34.60	120.40	3.75	62.50
17	4—4	87.60	33.10	120.70	3.75	47.50
18	S 120-1	100.95	40.80	141.75	3.50	35.00
19	HMT-1	109.98	45.05	155.03	2.25	82.50
20	S 112-1	119.75	64.00	183.75	0.25	25.00
21	132-2-2	150.50	68.25	218.75	1.25	62.50

Table 18. Field evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during late kharif 2008 (*August to December 2008*)

Sl. No.	Entries	Mean number/6 leaves			Mean damage score	Percentage of plants infested by mites
		Eggs	Active stages	Total		
1	CNS 1	0.00	0.00	0.00	0.00	0.00
2	CNS 8	0.00	0.00	0.00	0.00	0.00
3	Falatkal local	0.00	0.00	0.00	0.00	0.00
4	KA 2	0.00	0.00	0.00	0.00	0.00
5	GVC 111	0.00	0.00	0.00	0.00	0.00
6	SB 1	0.00	0.00	0.00	0.00	0.00
7	AVNPC 131	0.00	0.00	0.00	0.00	0.00
8	GVC 101	0.00	0.00	0.00	0.00	0.00
9	S 49	0.20	0.40	0.60	0.00	0.00
10	CH 1	0.27	0.33	0.60	0.00	0.00
11	CO – 2	0.53	0.13	0.67	0.00	0.00
12	BCSL 4	1.40	0.40	1.80	0.00	0.00
13	*Cluster suryamukhi*	7.60	2.27	9.87	0.33	0.00
14	SB 3	10.20	2.20	12.40	0.33	7.50
15	CNS 2	10.27	3.13	13.40	0.55	5.00
16	*Arka lohit*	13.73	5.33	19.07	0.00	8.50
17	GVC 121	17.60	3.20	20.80	0.33	40.00

Table 19. Field evaluation of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* during summer 2009 (*February to June 2009*)

Sl. No.	Entries	Mean number/6 leaves			Mean damage score	Percentage of plants infested by mites
		Eggs	Active Stages	Total		
1	S-49	6.20	3.30	9.50	0.00	53.33
2	ICPN-14	10.50	3.57	14.07	2.00	60.00
3	CA-2	11.40	5.67	17.07	0.00	73.33
4	KDC-2	11.53	6.13	17.66	1.13	86.67
5	BVC-47	13.10	6.33	19.43	1.00	80.00
6	Aparna	14.33	7.43	21.76	0.50	66.67
7	Koira	17.07	7.43	24.50	0.00	93.33
8	BVC-53	18.83	6.00	24.83	0.00	93.33
9	CA-10	18.43	6.63	25.06	0.00	86.67
10	PMR-21	19.87	7.97	27.84	1.00	80.00
11	CA9	20.03	7.83	27.86	1.00	73.33
12	LCA-336	21.30	9.20	30.50	0.00	80.00
13	GVC-101	20.97	9.80	30.77	1.30	73.33
14	LCA-334	22.50	10.37	32.87	1.00	60.00
15	AVNPC-131	23.97	9.20	33.17	0.00	40.00
16	KNG-1	21.53	11.80	33.33	0.00	33.33
17	Pant C-1	23.60	10.03	33.63	0.00	80.00
18	GVC-111	25.27	10.00	35.27	0.00	73.33
19	CMS7B	23.33	12.03	35.36	0.67	86.67
20	HMT-2	25.97	11.23	37.20	0.00	60.00
21	PBC-631	25.40	14.70	40.10	0.00	86.67
22	North assam	28.70	11.43	40.13	2.33	53.33
23	*Phule Jyothi*	27.27	13.37	40.64	1.20	73.33
24	GVC-121	26.90	14.50	41.40	0.50	86.67
25	KDC-1	29.80	13.87	43.67	1.00	60.00
26	PBC-142	38.07	14.83	52.90	0.00	33.33
27	G-4	39.77	14.50	54.27	0.50	86.67
28	Vamsi	34.33	21.90	56.23	1.00	93.33
29	*Bydagi kaddi*	44.00	20.63	64.63	2.17	80.00
30	*Oothgod local*	45.00	22.10	67.10	0.00	73.33

plant ranged from 33.33 (KNG 1 and PBC 142) to 93.33 per cent in entries namely Koira, BVC 53 and Vamsi. Mite population data recorded ranged from 9.50 mites/6 leaves (S 49) to 67.10 mites/6 leaves (*Oothgod local).*

4.5.7. Evaluation of chilli entries for their reaction to yellow mite infestation (Pooled from six different screening trials)

Pooled data from 107 chilli entries evaluated for their response to *P. latus* infestation at GKVK, Bangalore revealed per cent mite infestation (number of plants with mite infestation based on visual symptoms of mite damage *i.e.* downward curling) to range from zero (46 entries) to 82.50 (1 entry KDSC-1). The mite damage score in these entries varied from zero (40 entries) to 3.75 (Entry 4-4 & S 20-1 from Dharwad). Since there was differential reaction among the entries with respect to the expression of symptoms due to mite feeding, the ascending order of mean mite population (eggs+ motile stages) from different screening periods was prepared. Ten entries *viz*., CMS2B, CMS7A, CNS1, CNS8, Falatkal local, KA2, SB1, CH1, CO-2 and CCA336B recorded less than 1 mite/6 leaves, of which first seven entries were absolutely free from mite infestation except CMS7A and this was also evident with respect to the number of mite infested plants (Table 20).

The number of entries which recorded up to 10 mites, 10.1 to 20 mites, 20.1 to 30 mites, 30.1 to 40 mites, 40.1 to 50 mites and 50.1 to 100 mites/6 leaves was 14, 34, 11, 9, 6 and 23, respectively (Table 20). About 12 entries harboured >100 mites/6 leaves, of which the entry 132-2-2 from Dharwad recorded maximum number of mites, 218.75/6 leaves.

Table 20. Reaction of chilli entries to yellow mite, *Polyphagotarsonemus latus* (*Pooled from six different screening trials*)

Sl. No.	Entries	Mean number/6 leaves			Mite damage	
		Eggs	Active stages	Total	Mean damage score	Percentage of plants infested by mites
1	CMS 2B	0.00	0.00	0.00	0.00	0.00
2	CMS 7A	0.00	0.00	0.00	1.33	26.67
3	CNS 1	0.00	0.00	0.00	0.00	0.00
4	CNS 8	0.00	0.00	0.00	0.00	0.00
5	Falatkal local	0.00	0.00	0.00	0.00	0.00
6	KA 2	0.00	0.00	0.00	0.00	0.00
7	SB 1	0.00	0.00	0.00	0.00	0.00
8	CH 1	0.27	0.33	0.60	0.00	0.00
9	CO – 2	0.53	0.13	0.67	0.00	0.00
10	CCA336B	0.00	1.40	0.70	0.00	0.00
11	CMS 6B	1.05	0.11	1.16	0.00	0.00
12	CMS 8A	1.00	0.18	1.18	0.00	0.00
13	BCSL 4	1.40	0.40	1.80	0.00	0.00
14	CMS 6A	0.56	1.83	2.39	0.33	6.67
15	PBC 81	1.75	1.25	3.00	0.00	0.00
16	CA 14	3.47	0.73	4.20	0.00	0.00
17	Scoul I	2.40	2.00	4.40	0.00	0.00
18	S 49	3.20	1.85	5.05	0.00	0.00
19	*Susceptible baccatum*	3.71	1.57	5.28	0.67	6.67
20	LCA 335	1.00	6.00	7.00	0.00	0.00
21	PBC 80	3.95	3.65	7.60	0.00	0.00
22	CMS 2A	6.82	0.81	7.63	0.33	5.56
23	*Capsicum frutescence*	6.05	2.63	8.68	0.33	4.76
24	*Cluster suryamukhi*	7.60	2.27	9.87	0.33	0.00
25	LCA 336	7.10	3.10	10.20	0.00	26.70
26	Aparna	7.17	3.72	10.88	0.25	0.00
27	CMS 8B	5.55	5.74	11.29	0.67	13.33
28	LCA 273	9.76	2.37	12.13	0.17	2.78
29	CO – 1	8.40	3.80	12.20	0.00	0.00
30	SB 3	10.20	2.20	12.40	0.33	7.50
31	*Pusa sadabahar*	8.35	4.50	12.85	0.80	7.50
32	CNS 2	10.27	3.13	13.40	0.55	5.00
33	PMR 21	9.94	4.11	14.05	1.20	25.00

34	KNG 2	9.50	4.85	14.35	0.00	0.00
35	LCA 334	9.83	4.72	14.56	0.33	0.00
36	CA 3	10.35	4.25	14.60	0.00	0.00
37	GVC 101	10.49	4.90	15.39	0.65	0.00
38	Chiagmai local	11.55	3.95	15.50	0.00	0.00
39	CA 9	11.09	4.69	15.78	0.75	4.70
40	CA 2	10.95	4.99	15.94	0.00	0.00
41	Darpung	12.50	3.78	16.28	0.67	8.33
42	AVNPC 131	11.99	4.60	16.59	0.00	0.00
43	KDC -2	12.14	4.49	16.63	2.57	20.00
44	LCA 353	11.80	5.00	16.80	0.50	8.33
45	BVC 53	12.82	4.15	16.97	0.00	0.00
46	BVC 47	11.15	5.92	17.07	0.50	0.00
47	Koira	11.76	5.54	17.30	0.00	0.00
48	ICPN 14	11.53	5.79	17.31	1.00	0.00
49	GVC 111	12.64	5.00	17.64	0.00	0.00
50	CMS 5B	12.91	5.22	18.13	0.33	6.67
51	HMT 2	12.99	5.62	18.60	0.00	0.00
52	CMS 7B	12.67	6.22	18.88	0.34	0.00
53	*Arka lohit*	13.73	5.33	19.07	0.00	8.50
54	Lampong local short	14.39	4.72	19.11	0.00	0.00
55	Vietnam	13.30	5.85	19.15	0.50	10.00
56	CA 12	14.85	4.55	19.40	1.30	50.00
57	LCA 424	13.60	5.80	19.40	1.00	14.29
58	CMS 1A	16.11	3.39	19.50	1.33	16.67
59	CA 6	12.80	8.15	20.95	0.00	0.00
60	CA 10	15.47	5.84	21.31	0.00	0.00
61	PBC 1752	13.68	7.94	21.62	2.33	46.67
62	KDC 1	15.75	7.11	22.86	1.10	27.50
63	CMS 3A	16.54	6.47	23.01	0.00	0.00
64	PBC 631	15.80	8.35	24.15	0.00	0.00
65	*Phule jyothi*	16.46	8.06	24.52	0.85	5.00
66	*Punjab gucchedhar*	18.70	6.25	24.95	0.00	0.00
67	Minchalli betta	15.60	9.40	25.00	0.50	8.33
68	PBC142	19.04	7.52	26.55	0.00	0.00
69	KDSC -1	23.50	6.10	29.60	1.10	82.50
70	PL 3	22.05	8.50	30.55	1.80	12.50
71	Vangara	21.25	9.80	31.05	1.50	13.90
72	GVC 121	22.25	8.85	31.10	0.42	20.00

73	Vamsi	19.24	12.08	31.32	0.50	0.00
74	KNG 1	22.44	11.43	33.87	0.00	0.00
75	CMS 1B	30.83	3.11	33.94	1.67	16.67
76	North Assam	27.75	10.09	37.84	1.17	0.00
77	*Utkad rashmi*	31.90	7.07	38.97	1.67	33.33
78	Lampong local long	31.71	7.38	39.09	1.00	12.50
79	PL 5	28.50	11.75	40.25	1.10	35.00
80	S 112-4	34.25	8.75	43.00	0.00	0.00
81	G- 4	33.18	12.83	46.01	2.77	29.17
82	CMS 5A	39.07	8.30	47.37	0.67	13.33
83	CMS 3B	40.61	7.55	48.16	0.67	13.33
84	Tiwari	34.40	13.80	48.20	1.30	15.00
85	Pant C-1	37.55	12.97	50.52	0.34	4.17
86	Gowribidanur	43.50	16.45	59.95	1.00	50.00
87	20-1	45.00	16.05	61.05	3.25	70.83
88	Chikkaballapur local	50.15	17.35	67.50	0.90	30.00
89	132-2	50.25	19.95	70.20	2.25	22.50
90	149-2	52.78	21.63	74.41	0.75	18.75
91	HMT 1	54.99	22.53	77.52	3.13	41.25
92	*Oothgod local*	66.37	23.07	89.44	0.50	27.15
93	133-5	66.40	26.60	93.00	3.25	32.50
94	101-3	67.80	27.25	95.05	2.00	20.00
95	107-1	70.10	25.90	96.00	0.00	17.15
96	101-4	74.30	31.75	106.05	3.25	72.50
97	94-1	78.69	27.66	106.35	3.50	35.00
98	*Byadgi dabbi*	87.32	20.90	108.22	2.67	26.67
99	101-1	74.10	35.30	109.40	0.50	6.25
100	*Byadgi kaddi*	78.10	36.64	114.74	3.25	11.67
101	65-1	80.25	35.25	115.50	0.50	50.00
102	S 65-3	86.50	33.20	119.70	3.00	37.50
103	S 20-1	85.80	34.60	120.40	3.75	62.50
104	4 – 4	87.60	33.10	120.70	3.75	47.50
105	S 120-1	100.95	40.80	141.75	3.50	35.00
106	S 112-1	119.75	64.00	183.75	0.25	25.00
107	132-2-2	150.50	68.25	218.75	1.25	62.50

4.5.8. Final screening of short listed chilli entries during March – Aug. 2010

Out of 107entries, 32 entries were short listed based on the mite population data (and also on the availability of seeds) for further intensive screening during March to August 2010. The short listed entries represented to harbour mite population ranging from <5 mites (6 entries), 6-10 mites (6 entries), 11-50 mites (18 entries) and more than 50 mites (2 entries) per six leaves (Table 20).

The final screening data in respect of short listed entries are presented in Table 21. These entries were screened in open field conditions at GKVK, Bangalore during late summer season (March to August, 2010). The percentage of mite infested plants ranged from 0 (S 49) to 94.44 per cent (*Byadgi kaddi* & CMS 5 B). The mean damage score ranged from 0 (Aparna and S 49) to 3 (KNG 1). The total mite population including eggs and active stages ranged from 0.9 mites/6 leaves (Aparna) to 87.20 mites/6 leaves (*Byadgi kaddi)* (Table 21).

32 entries were grouped based on total mite population (eggs + active stages)/6 leaves as below.

<5 mites	2 entries (Aparna & S 49)
5-10 mites	1 entry (BVC 47)
10-20 mites	2 entries (BVC 53, *C. frutescens*)
20-30 mites	3 entries (CA 2, KDC 2 and CA 9)
>30 mites	24 entries (PMR 21, KNG 2, KDC 1, G 4, PBC 631, CMS1B, LCA 273, PBC 142, CA 960, CMS7B, *Phule jyothi*, LCA 334, KNG 1, Vamsi, LCA 336, CA 10, Koira, AVNPC 131, CMS5B, ICPN 14, *Pusa sadabahar* and *Punjab gucchedhar*, *Oothgod local, Byadgi kaddi)*

Further, these entries were subjected to biochemical analysis to relate them to resistance mechanism or reaction to mite infestation.

Table 21. Reaction of chilli entries (short listed) to yellow mite, *Polyphagotarsonemus latus* (Banks) during late summer 2010 (*March to August 2010*)

Sl. No.	Entries	Mean number/6 leaves			Mean damage score	Percentage of plants infested by mites
		Eggs	Active stages	Total		
1	Aparna	0.40	0.80	0.90	0.00	5.56
2	S 49	0.50	0.60	1.10	0.00	0.00
3	BVC 47	4.50	2.60	6.80	0.40	11.11
4	BVC 53	10.40	6.60	16.50	0.80	61.11
5	*Capsicum frutescens*	11.20	6.80	18.00	1.60	19.44
6	CA 2	17.10	10.40	27.50	1.00	83.33
7	KDC 2	18.40	13.30	27.50	1.20	72.22
8	CA 9	17.80	12.20	28.70	1.20	69.44
9	PMR 21	20.80	11.00	30.30	1.20	77.78
10	KNG 2	20.30	13.50	30.50	1.40	88.89
11	KDC 1	18.10	12.50	30.60	1.40	88.89
12	G 4	22.90	13.60	30.90	1.60	63.89
13	PBC 631	24.60	12.10	31.00	1.80	69.44
14	CMS 1B	20.90	12.20	31.30	2.40	91.67
15	LCA 273	22.60	12.30	31.40	1.60	66.67
16	PBC 142	20.70	13.90	32.90	2.40	58.33
17	CA 960	25.20	12.60	33.10	1.80	75.00
18	CMS 7B	21.10	15.70	34.00	1.60	69.44
19	*Phule jyothi*	25.20	12.90	34.60	1.80	63.89
20	LCA 334	21.70	14.50	34.70	1.40	91.67
21	KNG1	23.80	14.80	35.20	3.00	77.78
22	Vamsi	26.90	13.20	35.50	2.00	61.11
23	LCA 336	24.30	14.10	35.80	2.20	88.89
24	CA10	23.90	16.00	36.90	2.20	86.11
25	Koira	25.90	14.60	37.50	1.40	80.56
26	AVNPC 131	26.20	15.20	38.00	1.40	86.11
27	CMS 5B	25.10	21.00	38.10	1.40	94.44
28	ICPN 14	22.50	15.60	38.20	2.00	88.89
29	*Pusa sadabahar*	29.20	14.60	40.30	2.80	38.89
30	*Punjab gucchedhar*	33.60	15.00	46.10	1.90	91.67
31	*Oothgod local*	38.50	21.10	59.60	2.40	91.67
32	*Bydagi kaddi*	65.20	91.60	87.20	2.90	94.44
F test		*	*	*	*	-
SEM±		7.37	14.99	9.76	0.13	-
CD at P=0.05		16.06	32.65	21.27	0.28	-

***** *significant at 5% probability***

4.6. Biochemical analysis of chilli entries screened for their reaction to yellow mite, *Polyphagotarsonemus latus*

Thirty two chilli entries evaluated and shortlisted based on their reaction to yellow mite infestation were analysed for biochemical constituents like chlorophyll, total sugars, total proteins, proline, total phenols, capsaicin and activity of enzymes like peroxidases & phenylalanine ammonia lyase and were also compared based on the levels of these constituents before and after mite infestation or damage by the mites.

4.6.1. Chlorophyll content

The data pertaining to total chlorophyll content in shortlisted chilli entries are presented in Table 22. Total chlorophyll content ranged from 2.92 (CMS 7B) to 3.85mg/g (S 49). The entries S 49, PBC 631, *Pusa sadabahar*, CMS 5B, Aparna and CA 10 were on par with each other with respect to their chlorophyll content in leaves (Table 22).

The entries like Aparna, S 49 and BVC 47 which harboured <10 mites/6 leaves had a total chlorophyll content ranging from 3.54 to 3.85 mg/g.

4.6.2. Total Sugars content

Total sugar content in the leaves of different chilli entries ranged from 21.60 to 58.50 mg/g in CA 9 (lowest) and *Byadgi kaddi* (highest). The top three entries, Aparna, S 49 and BVC 47 harbouring <10 mites/6 leaves had 26.50, 28.50 and 29 mg/g of total sugars, respectively in their leaves (Table 22).

4.6.3. Proteins content

It is evident from the data in Table 22 that as the concentration of total proteins in the leaves increased, the number of mites recorded on these entries also increased. Entries which harboured <30 mites/6 leaves contained total proteins in

Table 22. Chlorophyll, Sugars and Protein contents in leaves of selected chilli entries

Sl. No.	Chilli entries	Total Chlorophyll (mg/g)	Total Sugars (mg/g)	Protein (mg/g)
1	Aparna	3.78	26.50	14.05
2	S 49	3.85	28.50	14.38
3	BVC 47	3.54	29.00	13.26
4	BVC 53	3.36	25.00	14.43
5	*Capsicum frutescens*	3.51	28.00	15.93
6	CA 2	3.35	30.50	15.37
7	KDC 2	3.19	27.00	14.47
8	CA 9	3.33	21.60	14.50
9	PMR 21	3.23	33.50	16.93
10	KNG 2	3.32	30.94	17.18
11	KDC 1	3.59	31.75	16.36
12	G 4	3.39	30.64	15.37
13	PBC 631	3.84	31.42	16.12
14	CMS 1B	3.23	32.12	15.86
15	LCA 273	3.26	34.64	17.32
16	PBC 142	3.08	32.29	16.34
17	CA 960	3.49	32.46	15.45
18	CMS 7B	2.92	32.27	15.68
19	*Phule jyothi*	3.37	31.45	16.88
20	LCA 334	3.54	32.89	17.28
21	KNG 1	3.36	33.18	18.32
22	Vamsi	3.16	35.67	18.86
23	LCA 336	3.11	34.89	17.68
24	CA 10	3.64	32.58	17.36
25	Koira	3.25	35.86	17.14
26	AVNPC 131	3.29	39.16	17.48
27	CMS 5B	3.75	38.79	17.86
28	ICPN 14	3.40	42.00	16.36
29	*Pusa sadabahar*	3.80	44.34	18.25
30	*Punjab gucchedhar*	3.23	48.87	18.42
31	*Oothgod local*	3.56	53.35	18.68
32	*Byadgi Kaddi*	3.45	58.50	19.52
F test		*	*	*
SEM±		0.08	0.26	0.11
CD at P=0.05		0.24	0.82	0.34

**** significant at 5% probability***

leaves ranging from 13.26 to 15.93mg/g. Most of the other entries harbouring >30 mites/6 leaves showed higher levels of proteins exceeding 16mg/g and the highest protein content was noticed in most susceptible variety *Byadgi kaddi* which recorded the maximum number of 87.20 mites/6 leaves (Table 22).

4.6.4. Capsaicin content

Capsaicin content in leaves of different chilli entries ranged from 0.044 (CA 9) to 0.14 per cent (*Capsicum frutescens*). No definite trend was evident between mite population and the leaf capsaicin contents (Table 23).

4.6.5. Total proline

Thirty two shortlisted chilli entries when analysed for their proline content in leaves, it was lowest (1.9 µmoles/g) in entry CA 9, and it was highest (4.2 µmoles/g) in the most susceptible line *Byadgi kaddi* and these entries harboured 28.7 and 87.2 mites/6 leaves, respectively. Also no definite trend could be observed between proline content and mite population except in few entries like *Oothgod local* (3.88 µmoles/g), LCA 336 (3.98 µmoles/g) and *Phule jyothi* (3.98 µmoles/g), with higher levels of proline and more number of mites *i.e.* >30 mites/6 leaves.

It was also observed that yellow mite infestation increased proline content in the leaves in all the entries (Table 24) and increased proline content after mite infestation ranged from 50.46 µmoles/g (Aparna) to 121.26 µmoles/g (ICPN 14). In susceptible cultivar *Byadgi kaddi* proline content of 4.2 µmoles/g in mite free leaves got increased to 8.96 µmoles/g as a result of mite infestation and this accounted for an increase in proline content by 113.33 per cent.

Table 23. Capsaicin content in selected chilli entries before and after infestation by yellow mite, *Polyphagotarsonemus latus* (Banks)

Sl. No.	Chilli entries	Capsaicin (%) in leaves		Change in capsaicin content after mite infestation (%)
		Mite free	Mite infested	
1	Aparna	0.110	0.131	19.09
2	S 49	0.104	0.127	22.12
3	BVC 47	0.093	0.117	25.81
4	BVC 53	0.101	0.121	19.80
5	*Capsicum frutescens*	0.146	0.177	21.23
6	CA 2	0.092	0.114	23.91
7	KDC 2	0.084	0.099	17.86
8	CA 9	0.044	0.057	22.73
9	PMR 21	0.068	0.082	20.59
10	KNG 2	0.060	0.075	25.00
11	KDC 1	0.076	0.089	17.11
12	G 4	0.092	0.116	26.09
13	PBC 631	0.134	0.171	27.61
14	CMS 1B	0.108	0.131	21.30
15	LCA 273	0.078	0.096	23.08
16	PBC 142	0.096	0.117	21.88
17	CA 960	0.110	0.132	20.00
18	CMS 7B	0.067	0.084	25.37
19	*Phule jyothi*	0.080	0.100	25.00
20	LCA 334	0.105	0.136	29.52
21	KNG 1	0.072	0.088	22.22
22	Vamsi	0.075	0.096	28.00
23	LCA 336	0.086	0.107	24.42
24	CA 10	0.089	0.105	17.98
25	Koira	0.094	0.118	25.53
26	AVNPC 131	0.082	0.104	26.83
27	CMS 5B	0.131	0.170	29.77
28	ICPN 14	0.058	0.072	24.14
29	*Pusa sadabahar*	0.088	0.109	23.86
30	*Punjab gucchedhar*	0.110	0.138	25.45
31	*Oothgod local*	0.093	0.112	20.43
32	*Byadgi Kaddi*	0.096	0.118	22.92
F test		*	*	-
SEM±		0.002	0.009	-
CD at P=0.05		0.006	0.030	-

**** significant at 5% probability***

Table 24. **Proline activity in selected chilli entries before and after infestation by yellow mite, *Polyphagotarsonemus latus* (Banks)**

Sl. No.	Chilli entries	Proline (µ moles/g tissue) in leaves		Change in proline content after mite infestation (%)
		Mite free	Mite infested	
1	Aparna	3.25	4.89	50.46
2	S 49	3.73	6.18	65.68
3	BVC 47	2.73	4.42	61.90
4	BVC 53	3.63	6.54	79.95
5	*Capsicum frutescens*	3.11	5.36	72.18
6	CA 2	3.29	5.67	72.34
7	KDC 2	2.08	4.15	100.16
8	CA 9	1.90	3.78	98.62
9	PMR 21	2.58	4.82	86.82
10	KNG 2	2.59	5.42	108.87
11	KDC 1	2.77	5.71	106.21
12	G 4	2.94	6.12	107.99
13	PBC 631	2.42	4.64	91.51
14	CMS 1B	3.63	6.00	65.10
15	LCA 273	2.94	5.71	94.15
16	PBC 142	3.11	6.32	102.92
17	CA 960	3.29	6.06	84.21
18	CMS 7B	2.42	4.98	105.43
19	*Phule jyothi*	3.98	7.27	82.63
20	LCA 334	2.59	5.44	109.64
21	KNG 1	2.94	5.61	90.66
22	Vamsi	4.15	8.48	104.22
23	LCA 336	3.98	8.52	113.97
24	CA 10	3.50	7.09	102.51
25	Koira	2.59	5.67	118.50
26	AVNPC 131	4.15	8.01	92.83
27	CMS 5B	3.19	6.32	98.12
28	ICPN 14	2.25	4.98	121.26
29	*Pusa sadabahar*	3.63	7.09	95.14
30	*Punjab gucchedhar*	2.25	4.34	92.83
31	*Oothgod local*	3.88	7.87	102.84
32	*Byadgi Kaddi*	4.20	8.96	113.33
F test		*	*	-
SEM±		0.48	0.10	-
CD at P=0.05		1.53	0.33	-

***** *significant at 5% probability***

4.6.6. Phenol content

Total phenol content in 32 chilli entries ranged from 8.25 mg/g (PBC 631) to 15.6 mg/g (LCA 273) and both these entries harboured almost similar number of mites (31 mites/ 6 leaves). However, the top 2 entries Aparna and S 49 which harboured <5 mites/6 leaves recorded the total phenol content of 12.80 mg/g and 14 mg/g compared to susceptible *Byadgi kaddi* with 11.6 mg/g of phenol and with the maximum number of mites (Table 25). In all the entries phenol content of leaves improved with yellow mite infestation, but to varying levels. Compared to all other entries, Aparna and S 49 recorded the higher phenol contents of 21.6 and 22.8 mg/g after mite infestation, with 63 to 69 per cent increase in total phenol content with mite infestation. The improvement in the phenol content of *Byadgi kaddi* was only 36 per cent (Table 25).

4.6.7. Activity of enzymes

4.6.7.1. Peroxidase activity

Peroxidase activity in different chilli entries before mite infestation ranged from 234 (CA 10) to 775 units/g of leaf tissue (*Capsicum frutescens*). Top 3 entries, Aparna, S 49 and BVC 47 had peroxidase levels of 417, 514and 487 units/g of tissue, respectively and these entries harboured <10 mites/6 leaves. However, susceptible *Byadgi kaddi* with higher mite population also had similar peroxidase activity of 487 units/g of tissue (Table 26). Though yellow mite infestation improved peroxidase activity in all the entries, it was more evident in entries like Aparna, S 49, BVC 47, BVC 53 and *Capsicum frutescens* and this elevated phenol levels encouraged the mite population to a lesser extent. In all these entries peroxidase activity increased by more than 75 per cent compared to 34 per cent increased activity in chilli variety *Byadgi kaddi*.

Table 25. Total phenols content in selected chilli entries before and after infestation by yellow mite, *Polyphagotarsonemus latus* (Banks)

Sl. No.	Chilli entries	Total phenols (mg/g) in leaves		Change in phenol content after mite infestation (%)
		Mite free	Mite infested	
1	Aparna	12.80	21.60	68.75
2	S 49	14.00	22.80	62.86
3	BVC 47	11.85	18.00	51.90
4	BVC 53	12.50	21.45	71.60
5	*Capsicum frutescens*	9.00	16.80	86.67
6	CA 2	12.00	15.00	25.00
7	KDC 2	11.00	13.80	25.45
8	CA 9	10.50	13.00	23.81
9	PMR 21	10.50	12.50	19.05
10	KNG 2	9.75	12.34	26.56
11	KDC 1	10.00	13.00	30.00
12	G 4	13.00	15.40	18.46
13	PBC 631	8.25	10.00	21.21
14	CMS 1B	14.00	16.75	19.64
15	LCA 273	15.60	18.50	18.59
16	PBC 142	13.40	16.48	22.99
17	CA 960	12.60	14.80	17.46
18	CMS 7B	13.00	17.36	33.54
19	*Phule jyothi*	11.32	14.76	30.39
20	LCA 334	10.60	14.32	35.09
21	KNG 1	11.67	14.54	24.59
22	Vamsi	12.75	17.42	36.63
23	LCA 336	11.40	14.78	29.65
24	CA 10	9.80	12.54	27.96
25	Koira	11.25	13.54	20.36
26	AVNPC 131	11.50	14.60	26.96
27	CMS 5B	12.40	16.34	31.77
28	ICPN 14	8.96	13.24	47.77
29	*Pusa sadabahar*	11.25	12.80	13.78
30	*Punjab gucchedhar*	13.50	15.80	17.04
31	*Oothgod local*	10.80	14.96	38.52
32	*Byadgi Kaddi*	11.60	15.78	36.03
F test		*	*	-
SEM±		0.05	0.10	-
CD at P=0.05		0.15	0.33	-

**** significant at 5% probability***

Table 26. Peroxidase activity in selected chilli entries before and after infestation by yellow mite, *Polyphagotarsonemus latus* (Banks)

Sl. No.	Chilli entries	Peroxidase (units/g of tissue) in leaves		Change in peroxidase activity after mite infestation (%)
		Mite free	Mite infested	
1	Aparna	416.66	883.00	111.92
2	S 49	514.28	960.00	86.67
3	BVC 47	487.00	900.00	84.80
4	BVC 53	460.00	825.00	79.35
5	*Capsicum frutescens*	775.00	1362.00	75.74
6	CA 2	362.50	612.00	68.83
7	KDC 2	237.50	367.50	54.74
8	CA 9	335.00	520.00	55.22
9	PMR 21	425.00	675.50	58.94
10	KNG 2	450.00	678.00	50.67
11	KDC 1	314.28	486.50	54.80
12	G 4	362.50	512.34	41.34
13	PBC 631	440.00	674.00	53.18
14	CMS 1B	300.00	487.50	62.50
15	LCA 273	366.66	575.00	56.82
16	PBC 142	362.50	578.50	59.59
17	CA 960	380.50	587.00	54.27
18	CMS 7B	450.00	650.00	44.44
19	*Phule jyothi*	375.00	537.50	43.33
20	LCA 334	213.00	322.60	51.46
21	KNG 1	300.00	498.00	66.00
22	Vamsi	512.50	767.00	49.66
23	LCA 336	387.50	468.00	20.77
24	CA 10	234.00	338.00	44.44
25	Koira	460.00	678.00	47.39
26	AVNPC 131	462.50	687.00	48.54
27	CMS 5B	350.00	512.00	46.29
28	ICPN 14	471.42	678.00	43.82
29	*Pusa sadabahar*	298.00	428.00	43.62
30	*Punjab gucchedhar*	525.00	698.00	32.95
31	*Oothgod local*	362.50	514.28	41.87
32	*Byadgi Kaddi*	487.00	654.00	34.29
F test		*	*	-
S.EM±		1.63	2.55	-
CD at P=0.05		5.22	8.16	-

**** significant at 5% probability***

4.6.7.2. Phenylalanine ammonia lyase (PAL) activity

With respect to activity of phenylalanine ammonia lyase, entries namely Aparna and S 49 which harboured single mite/6 leaves had the higher activity of PAL *i.e.* 3.20 and 3.1µmoles/min/ml of enzyme extract. Most of the other entries with varying number of mites showed PAL activity within 3 µmoles/min/ml except in entries like BVC 53, PBC 142, CA 960 and *Punjab gucchedhar* (Table 27). Interestingly susceptible *B. kaddi* which normally recorded higher mite infestation showed the least activity of PAL *i.e.* 2µmoles/min/ml.

Phenylalanine ammonia lyase activity increased with mite infestation in all the chilli entries but to varying extents. S 49 and *Capsicum frutescens* showed more prominent increase in the activity of PAL *i.e.* 48 to 51 per cent with mite infestation. In *Byadgi kaddi* level of PAL which was 2µmoles/min/ml in healthy leaves could increase to 2.22µmoles/min/ml with mite infestation and the extent of increase was only 11 per cent, being the lowest of all the entries.

4.7. Relationship between the total mite population and biochemical constituents in different chilli cultivars

The data from Table 28 revealed certain relationship between yellow mite population and biochemical constituents in 32 chilli cultivars. Only total sugars and total protein content in leaves showed positive significant relationship with mite population, while the relationship between mite population and phenylalanine ammonia lyase was negative and significant. Thus total sugars and proteins content in leaves of chilli varieties encouraged mite population, while phenylalanine ammonia lyase content adversely influenced the buildup of yellow mites. Chlorophyll, proline, phenols, capsaicin and peroxidase content in leaves were not observed to influence yellow mite infestation significantly.

Table 27. Activity of phenylalanine ammonia lyase (PAL) in selected chilli entries before and after infestation by yellow mite, *Polyphagotarsonemus latus* (Banks)

Sl. No.	Chilli entries	Phenylalanine ammonia lyase ($x 10^{-3}$ µmoles /min/ml)		Change in PAL activity after mite infestation (%)
		Mite free	Mite infested	
1	Aparna	3.20	4.34	35.63
2	S 49	3.10	4.67	50.65
3	BVC47	2.30	3.20	39.13
4	BVC53	3.00	3.90	30.00
5	*Capsicum frutescens*	2.30	3.40	47.83
6	CA 2	2.20	2.90	31.82
7	KDC 2	2.30	2.97	29.13
8	CA 9	2.90	3.40	17.24
9	PMR 21	2.70	3.40	25.93
10	KNG 2	2.70	3.08	14.07
11	KDC 1	2.60	3.28	26.15
12	G 4	2.90	3.40	17.24
13	PBC 631	2.70	3.10	14.81
14	CMS 1B	2.40	2.98	24.17
15	LCA 273	2.60	3.12	20.00
16	PBC 142	3.00	3.63	21.00
17	CA 960	3.00	3.47	15.67
18	CMS 7B	2.30	2.70	17.39
19	*Phule jyothi*	2.80	3.40	21.43
20	LCA 334	2.50	2.94	17.60
21	KNG1	2.90	3.45	18.97
22	Vamsi	2.80	3.24	15.71
23	LCA 336	2.60	3.00	15.38
24	CA10	2.90	3.50	20.69
25	Koira	2.40	3.02	25.83
26	AVNPC 131	2.30	2.67	16.09
27	CMS 5B	2.80	3.18	13.57
28	ICPN 14	2.90	3.24	11.72
29	*Pusa sadabahar*	2.40	2.78	15.83
30	*Punjab gucchedhar*	3.00	3.40	13.33
31	*Oothgod local*	2.70	3.08	14.07
32	*Byadgi Kaddi*	2.00	2.22	11.00
F test		*	*	-
S.EM±		0.09	0.10	-
CD at P=0.05		0.29	0.33	-

**** significant at 5% probability***

Table 28. Relationship between yellow mite population and biochemical constituents in short listed chilli entries

Biochemical constituents	'r' value	Regression equation	R^2 value
Total chlorophyll	-0.17^{NS}	-	-
Total sugars	0.81**	Y=-180.89+278.42X	0.656
Proteins	0.78**	Y=-336.49+600.39X	0.624
Proline	0.18^{NS}	-	-
Total phenols	-0.11^{NS}	-	-
Capsaicin	-0.12^{NS}	-	-
Peroxidase activity	-0.11^{NS}	-	-
Phenylalanine ammonia lyase activity	-0.35*	Y=97.10-259.16X	0.126

NS-Non significant, *Significant ; ** Highly significant

4.8. Genetic variation in chilli entries evidenced by Simple Sequence Repeat (SSR) primers for parental polymorphism

Chilli entries Aparna, S 49, BVC 47, BVC 53, *Capsicum frutescens* and *Byadgi kaddi* were screened with 20 SSR primers to identify for polymorphic primer combinations, if any (Table 2, Plate 9a,b & c).

Out of 32 short listed chilli entries based on the population density of yellow mite they encouraged six genotypes were selected and analysed for parental polymorphism. These six genotypes were Aparna and S 49 (<5 mites/6 leaves); BVC 47 (<10 mites/6 leaves); BVC 53 and *Capsicum frutescens* (< 20 mites/ 6 leaves) and *Byadgi kaddi* (>50 mites/6 leaves). Twenty SSR primers were used against these six chilli genotypes from resistant to susceptible reactions to ascertain the polymorphism. In all the six entries studied, out of 20 SSR polymorphic primers 15 primers showed only one allele with no distinct variation in their genomic region. However, five primers namely Hpms E 140, Hpms E 142, Hpms E 143, Hpms E 144 and Hpms E 148 sparsely differentiated two or more alleles in few of the entries (Plate 9 b & c), while primer Hpms E 58 did not align with any of these entries. Thus few more primers along with those primers which differentiated two or more alleles in the present study may be utilized for further genotypic studies to identify the polymorphism, if any.

4.9. Coexistence of yellow mite, *Polyphagotarsonemus latus* and thrips, *Scirtothrips dorsalis* on chilli variety *Byadgi kaddi*

A preliminary study was conducted using 30 potted plants with chilli variety *Byadgi kaddi* in the glasshouse of Department of Agricultural Entomology, GKVK, Bangalore. Infested (by mites or thrips) plants were placed at equal distance from the centrally placed 30 healthy chilli plants free from mites and thrips providing a free choice for both mites as well as thrips to infest the healthy plants placed at the central region. Observations on the buildup of mites and thrips

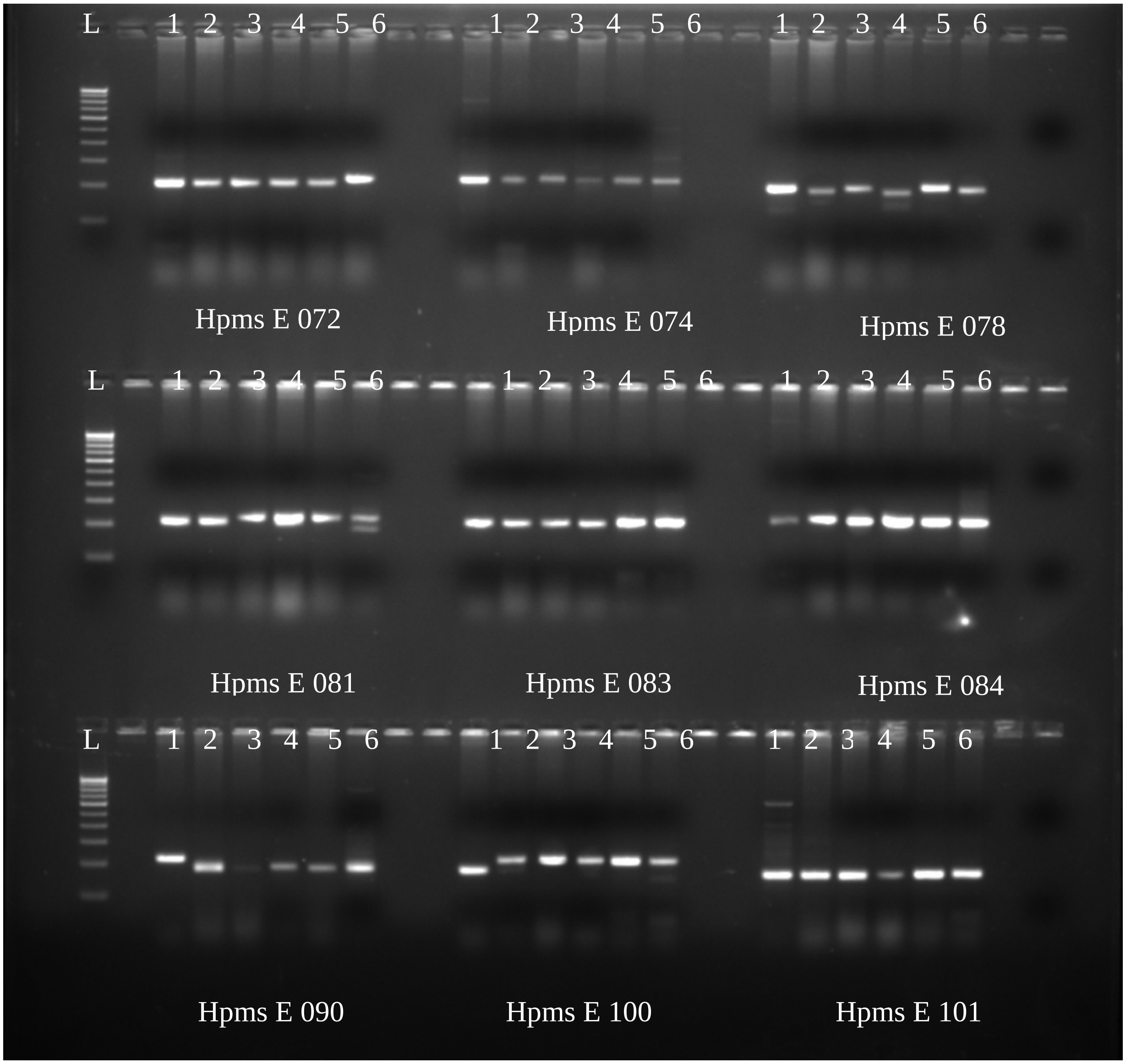


Plate 9a. Amplified PCR product of chilli entries with SSR primers

L – 100bp DNA ladder; 1 – Aparna ; 2- S 49; 3- BVC 47; 4-BVC – 53; 5 – Capsicum frutescens; 6 – Byadgi kaddi

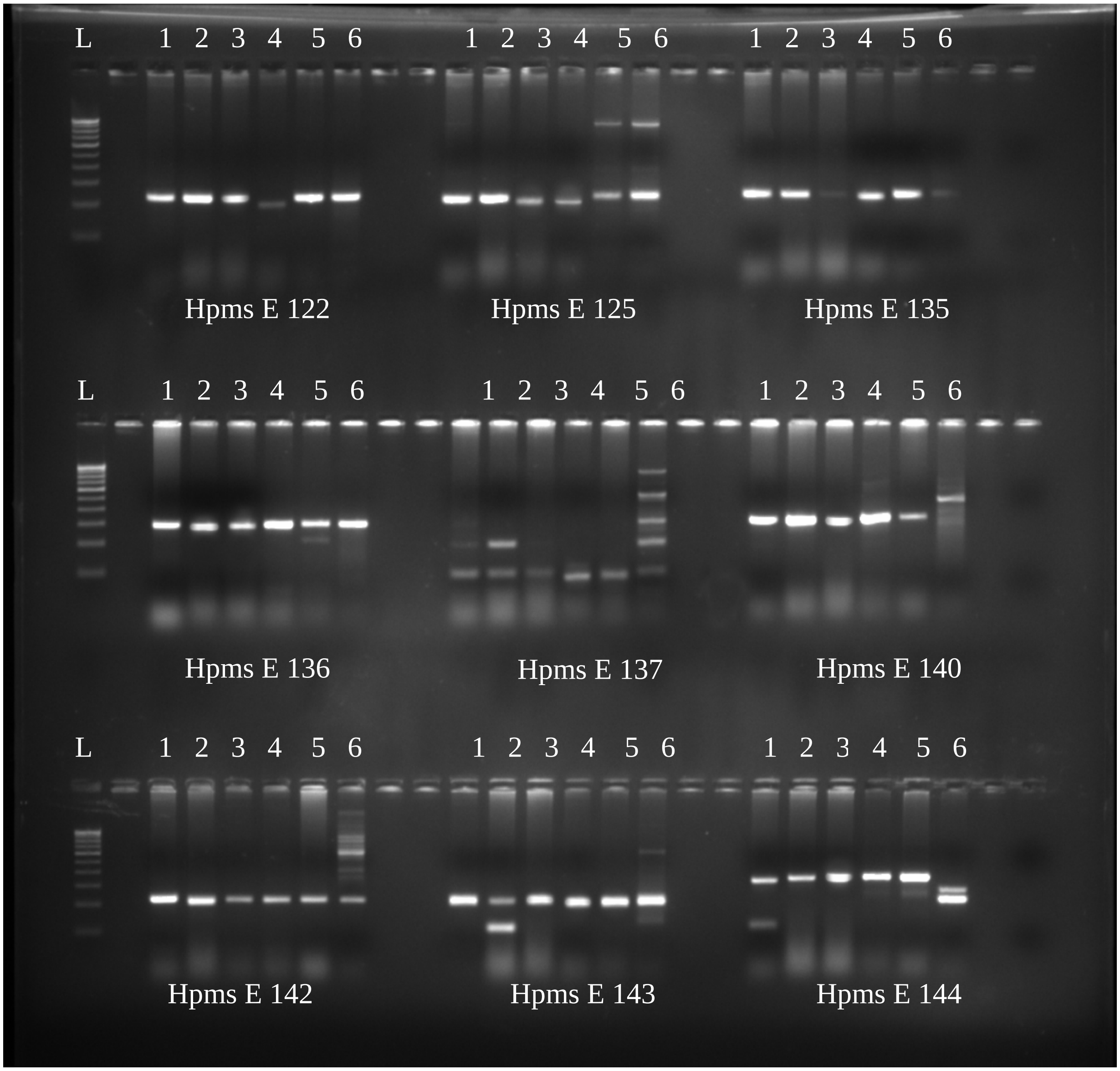


Plate 9b. Amplified PCR product of chilli entries with SSR primers

L – 100bp DNA ladder; 1 – Aparna ; 2- S 49; 3- BVC 47; 4-BVC – 53; 5 – Capsicum frutescens; 6 – Byadgi kaddi

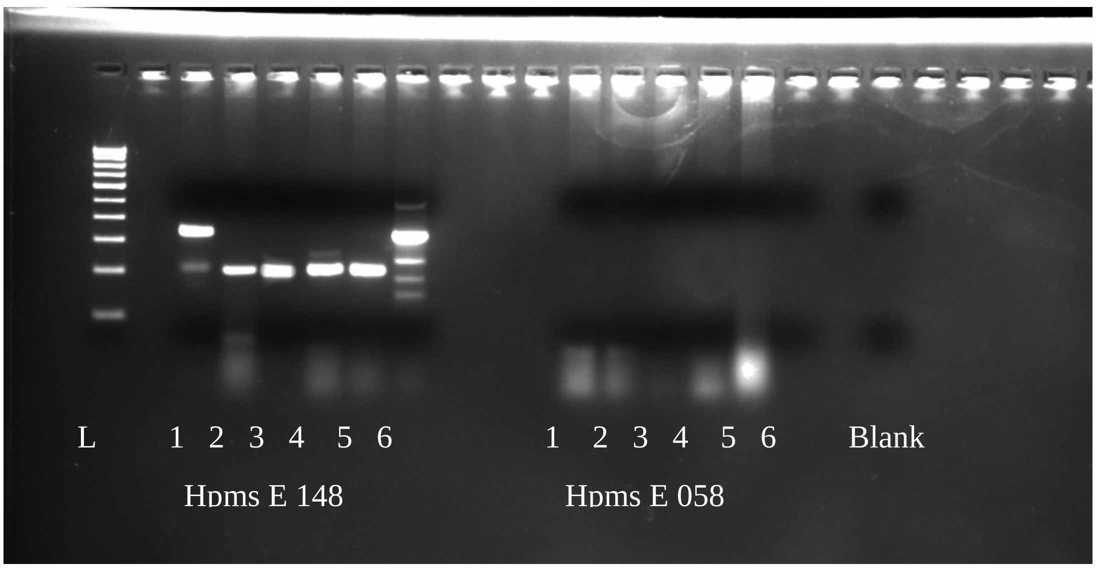


Plate 9c. Amplified PCR product of chilli entries with SSR primers

L – 100bp DNA ladder; 1 – Aparna ; 2- S 49; 3- BVC 47; 4-BVC – 53; 5 – Capsicum frutescens; 6 – Byadgi kaddi

on the centrally placed plants were recorded at weekly intervals up to 7 weeks (Table 29).

Yellow mites started colonizing healthy chilli plants (cv. *Byadgi kaddi*) soon after one week, as a result of which mite population gradually increased from 2.01mites/6 leaves in the first week to 8.9 mites/6 leaves by the 3rd week. However, the mite population remained more or less at the same level up to 7 weeks (Table 29). Also the damage by these mites further increased and by 3rd week nearly 25 per cent of leaves in mite infested plants (with a damage score of 1.07) showed downward curling symptom (up to 7 weeks).

Thrips also dispersed from infested plants to healthy plants from first week onwards, their number being 0.51 thrips/plant in the first week increased to 2.02 thrips/plant by the 4th week. Further, thrips population increased but at a lower level of 0.53 to 0.85 thrips/plant. Thrips infestation resulted in the upward curling of leaves with a damage score ranging from 0.17 in the first week to 0.63 by the 4th week. The further damage by thrips remained between 0.33 and 0.43 score.

The data from Table 29 revealed that though both thrips and mites inhabit chilli leaves simultaneously, the mites would be more in number compared to thrips, so also the damage by these mites. In some of the plants, damage symptoms due to both thrips (upward curling) and mites (downward curling) were apparently seen in the same plant (Plate 10).

Table 29. Co-occurrence of yellow mite *Polyphagotarsonemus latus* (Banks) and thrips *Scirtothrips dorsalis* (Hood) on chilli cv. *Byadgi kaddi*

Period	Mean number of mites/6 leaves	Mite damage score (Number of plants with mite damage)	Mean number of thrips/plant	Thrips damage score (Number of plants with thrips damage)
After one week	2.01	0.13(4)	0.51	0.17(5)
After 2 weeks	5.14	0.73(19)	1.46	0.57(16)
After 3 weeks	8.90	1.07(24)	1.55	0.57(15)
After 4 weeks	6.74	0.87(23)	2.02	0.63(18)
After 5 weeks	8.55	0.97(24)	0.85	0.43(12)
After 6 weeks	7.14	0.77(19)	0.53	0.37(11)
After 7 weeks	7.58	0.77(19)	0.61	0.33(10)

**** Initially 4 weeks old seedlings were allowed for simultaneous infestation by mites as well as thrips***

Plate 10. Chilli plant infested by thrips and yellow mites

Discussion

V. DISCUSSION

Chilli, an important spice crop of India is grown in almost all the states in the country under diverse situations and is attacked by a variety of insect and mite pests right from sowing till harvest. The present study on the key mite pest, *Polyphagotarsonemus latus* (Banks) carried out during the period 2008 – 2011 included the assessment of damage and yield loss due to *P. latus*, screening of chilli entries for probable host plant resistance mechanisms *etc*. The results from these investigations are discussed hereunder in the light of the available reports.

5.1. Pest complex and succession of insect and mite pests on chilli crop

The chilli crop raised during *kharif* 2008 at the Zonal Agricultural Research Station, GKVK, Bangalore served as a prefered habitat for good number of insects and mites. The checklist comprising of pests and natural enemies on the chilli crop was prepared (Table 4).

The chilli crop harboured 26 species of insects and one species of mite as pests and four species of natural enemies represented insects and mites (two each). Of these, the potential pests were *Spodoptera litura* Fabricius, thrips *Scirtothrips dorsalis* Hood, aphids *Myzus persicae* Sulzer and mite *Polyphagotarsonemus latus* (Banks) during seedling to vegetative stage and gall midge *Asphondylia capsici* Barnes and fruit borer *Helicoverpa armigera* Hubner at flowering to fruiting stage. Butani (1976) recorded 20 species of insects menacing the chilli crop, while Reddy and Puttaswamy (1983) reported 35 species as pests including a mite, a snail species and two species of millipedes damaging chilli crop in the nursery. In 1993 Karappuchamy *et al*. recorded 33 species of pests on chilli crop in Tamil Nadu, of which 21 were insects and 12 were non-insects.

Insects and mites which occur in succession on chilli crop *Capsicum annuum* L. presented in Table 4 indicated relationship between the phenology of crop and the pests. *S. litura*, *M. persicae*, *S. dorsalis* and *P. latus* were observed feeding and damaging the seedlings. Of these, only aphids continued to damage the crop in the vegetative stage, while damage by thrips and mites was evident up to the fruiting stage. In vegetative stage seven species of bugs, eight species of beetles (weevils and flea beetle) and four species of short horned grasshoppers appeared, but caused no significant damage to the crop. At flowering to fruiting stage, thrips and mites continued to ravage the foliage resulting in upward and downward curling of leaves, respectively. Also gall midge *A. capsici* caused galls on flowers which were associated with flower dropping occasionally. Fruit borer, *H. armigera* damaged the maturing fruits bearing a characteristic symptom of a large entry hole, such damaged fruits later were found rotten due to secondary infection. As observed in the present study, Kareem *et al*. (1977) attributed the failure of chilli crop due to infestation by *P. latus* at flowering and fruiting stage. Similarly, Reddy and Puttaswamy (1983) opined that the mite *P. latus*, thrips *S. dorsalis* and fruit borer *H. armigera* were the major pests infesting chilli crop between seedling and fruiting stages.

5.2. Crop loss due to yellow mite, *Polyphagotarsonemus latus* (Banks) on chilli

Crop loss due to mite, *P. latus* was assessed in farmer's fields in Haveri district by paired plot technique (protected and unprotected plots) during *kharif* 2008 and *kharif* 2009 seasons. The plots to be protected from yellow mite infestation were sprayed with acaricides like dicofol, fenazaquin and propargite, alternatively at 15 days intervals from 6 to 8 weeks after planting.

During *kharif* 2008, mean mite population (eggs and active stages) of 29.15 mites/6 leaves was recorded from protected plots against 48.43 mites/6 leaves from unprotected plots. The mean dry fruit yield from protected plot (567 kg/acre) was significantly different from the yield from unprotected plot (400 kg/acre). The extent of loss in dry fruit yield due to mite infestation was 29.45 per cent (Table 5).

During *kharif* 2009, mean mite population of 4.60 mites/6 leaves was from protected plots and 6.73 mites/6 leaves from unprotected plots. The fruit yields from protected and unprotected plots differed significantly with the 't' value of 4.19. As a result corresponding mean fruit yields per acre were 634 kg/acre and 448 kg/acre. The potential loss in the yield of dry fruits due to yellow mite infestation was 29.33 per cent (Table 6).

Thus mean yield loss over two seasons in the present study was around 30 per cent. According to Butani (1976) who recorded as many as 20 species of pests, yellow mite was considered as a most destructive pest of chilli crop accounting for 25 per cent loss in fruit yield. The extent of loss with respect to yield of dry fruits due to yellow mite varied from region to region in the country, which ranged from 40 per cent in Kalyani region of West Bengal to a high of 65 per cent in Coimbatore region of Tamil Nadu (Anonymous, 2009). 40 per cent loss in the yield of chilli crop due to yellow mite accounted for a monetary loss of 4950 per hectare in Gujarat (Anonymous, 1999).

5.3. Critical assessment of damage due to yellow mite on chilli

5.3.1. Damage due to yellow mite infestation prevailed from different growth stage till maturity

Glasshouse study with mite infestation from 15/30/45/60/75/90 days after planting till maturity clearly showed that when chilli plants were infested early *i.e.* from 15 – 45 days till maturity, the yield loss was 100 per cent compared to mite free conditions (Table 7, Fig.1). Severe attack of chilli crop by *P. latus* which resulted in complete failure of the crop has been reported by Kulkarni as early as 1922. Mite infestation beyond 60 days (till maturity) resulted in 40 – 45 per cent

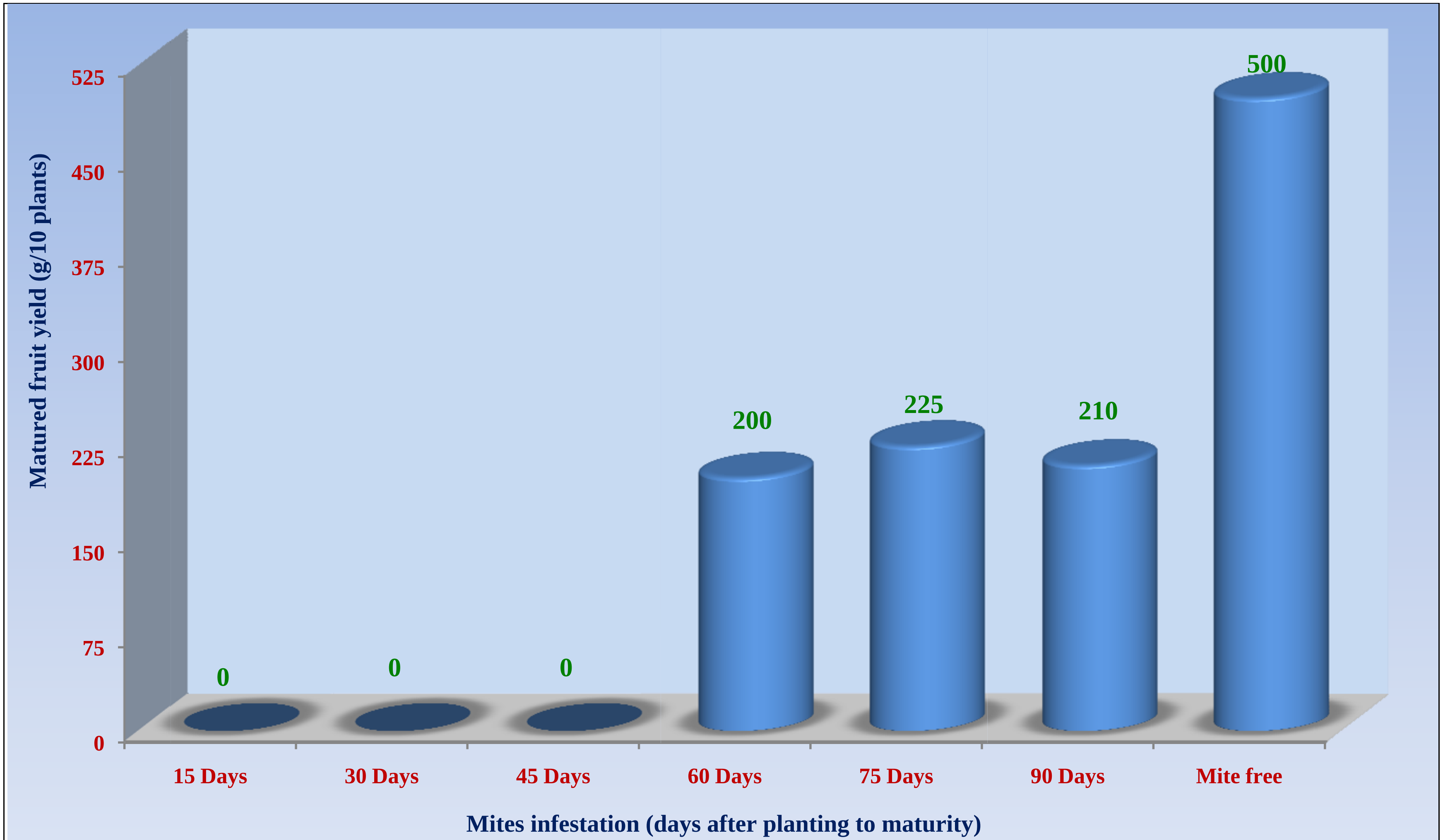


Fig. 1. Matured fruit yield in chilli cv. *Byadgi kaddi* when infested by yellow mite at different growth stages (in glasshouse)

of the potential yield, as a result an yield of 500g of chilli fruits was recorded from 10 mite free plants against 200 to 225g from10 plants when mite infestation prevailed beyond 60 days.

Data from similar experiment in the field revealed that with yellow mite infestation from 15 days till maturity, from 30 days till maturity, from 45 days till maturity, from 60 days till maturity and from 75 days till maturity, the corresponding matured fruit yields were 533kg, 800kg, 1333kg, 1733kg and 2222kg per acre, while it was highest, 3199kg per acre when the crop was apparently mite free throughout (Table 9). These yield records corresponded to a potential yield of only 17% (loss 83%), 25% (loss 75%), 42% (loss 58%), 54% (loss 46%) and 69% (loss 31%). Thus it was evident that contiguous mite infestation from 15 days or 30 days or 45 days till maturity accounted for an yield loss of 83, 75 and 58 per cent, respectively. The corresponding cumulative mite population was highest (404.71 mites) when the crop was infested from 15 days till maturity and it was lowest (54.20 mites) when infested beyond 60 days till maturity (Table 8). This showed that as the mean mite population decreased over different treatments, the fruit yield per acre showed an increasing trend (Fig. 2), with an inverse relationship between mite population and the fruit yield. As observed in the present study, Sudharma and Madhavan Nair (1999) noticed similar relationship between mite population from 6 weeks after planting and the resulting fruit yield, showed inverse relationship between yellow mite population or damage score and the dry fruit yield. Also Borah (1987) from Dharwad region of Karnataka established significant negative effect of mite damage on plant growth as well as the yield and he recorded almost complete loss (96.39 per cent) in dry fruit yield due to 100 per cent mite infestation because of which the entire crop failed to set any fruits.

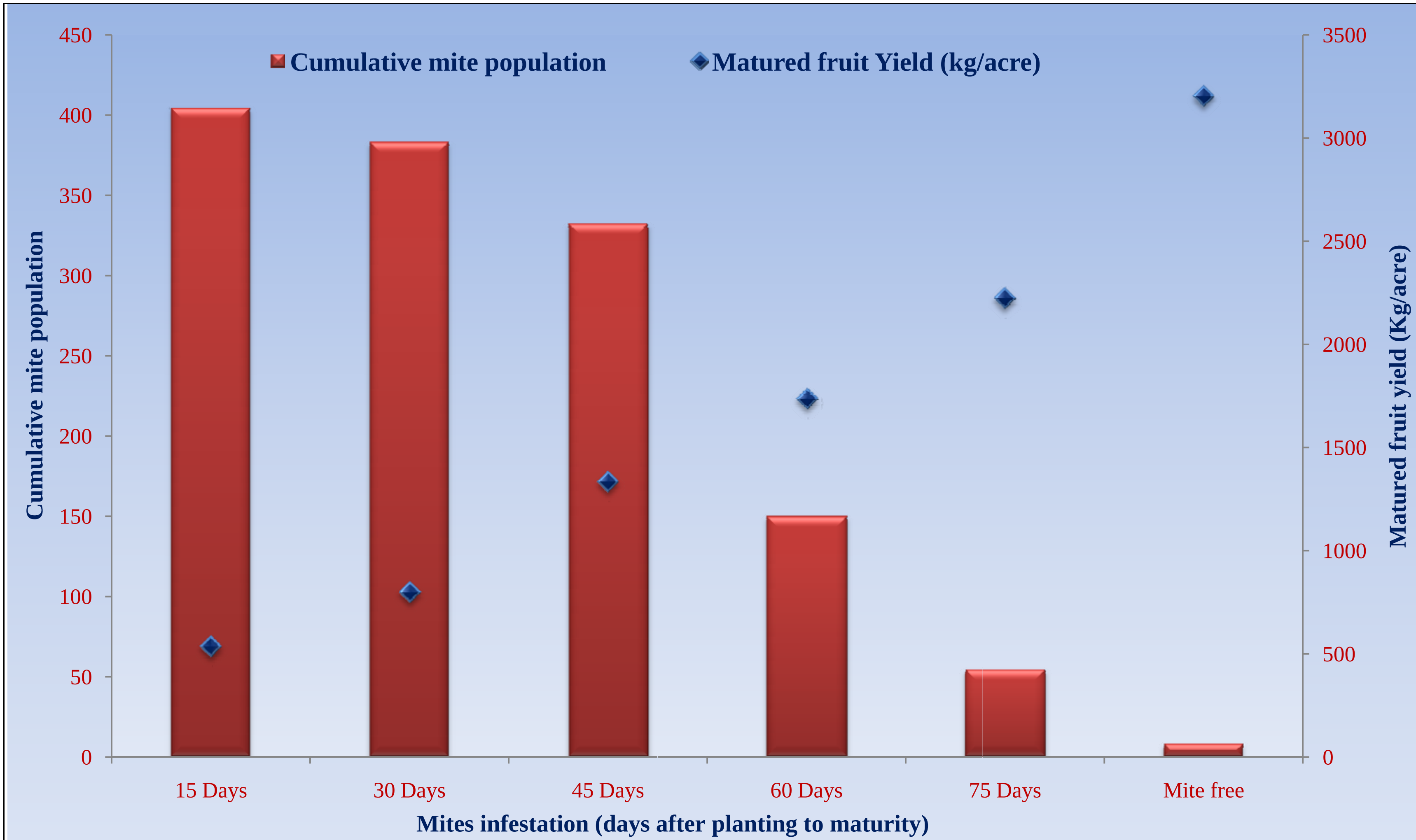


Fig. 2. Yellow mite infestation at different stages of chilli cv. *Byadgi kaddi* and matured fruit yield (Field experiment)

5.3.2. Damage due to yellow mite infestation of different durations (2 to 4 weeks) at various growth stages of chilli crop

In the glass house study chilli plants of definite age (4 to 10 weeks after planting) were systematically allowed for yellow mite infestation for a period of 2 to 4 weeks and further mite population buildup, damage and the biomass/ red ripe fruit yield were recorded and compared with mite free check treatment. It was evident that restricting yellow mite infestation for a period of 4 weeks compared to 2 weeks period always encouraged the buildup of mite population, particularly on 4 weeks old plants (4 weeks after planting) followed by 6 and 8 weeks old plants. As a result maximum cumulative mite population of 714.4 mites per 6 leaves was recorded when 4 weeks old plants were allowed for colonization by mites for the next 4 weeks (*i.e.* from 4 to 8 weeks). As the age of plants advanced incremental buildup of mites also recorded a decline and correspondingly 401.60 and 346.80 mites/6 leaves were observed on 6 and 8 weeks old plants. Also this higher mite population mostly accounted for lower turn out of biomass by such infested plants (Table 10, Fig 3). However, this was not reflected in the corresponding mean damage score recorded. This is probably attributed to the ability of younger plants to recover or withstand the damage by yellow mites compared to the older plants (particularly under glasshouse conditions) and because of this 10 weeks old plants allowed for colonization by mites for a period of 2 or 4 weeks scored higher mite damage of 3.25 to 3.50 (Table 11).

In the field experiment the mite load was relatively low compared to the study in the glasshouse, but the trend in cumulative as well as mean mite population was similar (Table 12). Allowing mite colonization for 4 weeks period on 4 weeks old plants accumulated maximum number of mites (361.90 mites) followed by that on 8-12 weeks, 6-10 weeks and 10-14 weeks mite infestation treatments (with 200.10, 154.60 and 111.80 mites, respectively). Such mite populations corresponded to more damage due to mite feeding as evidenced by the

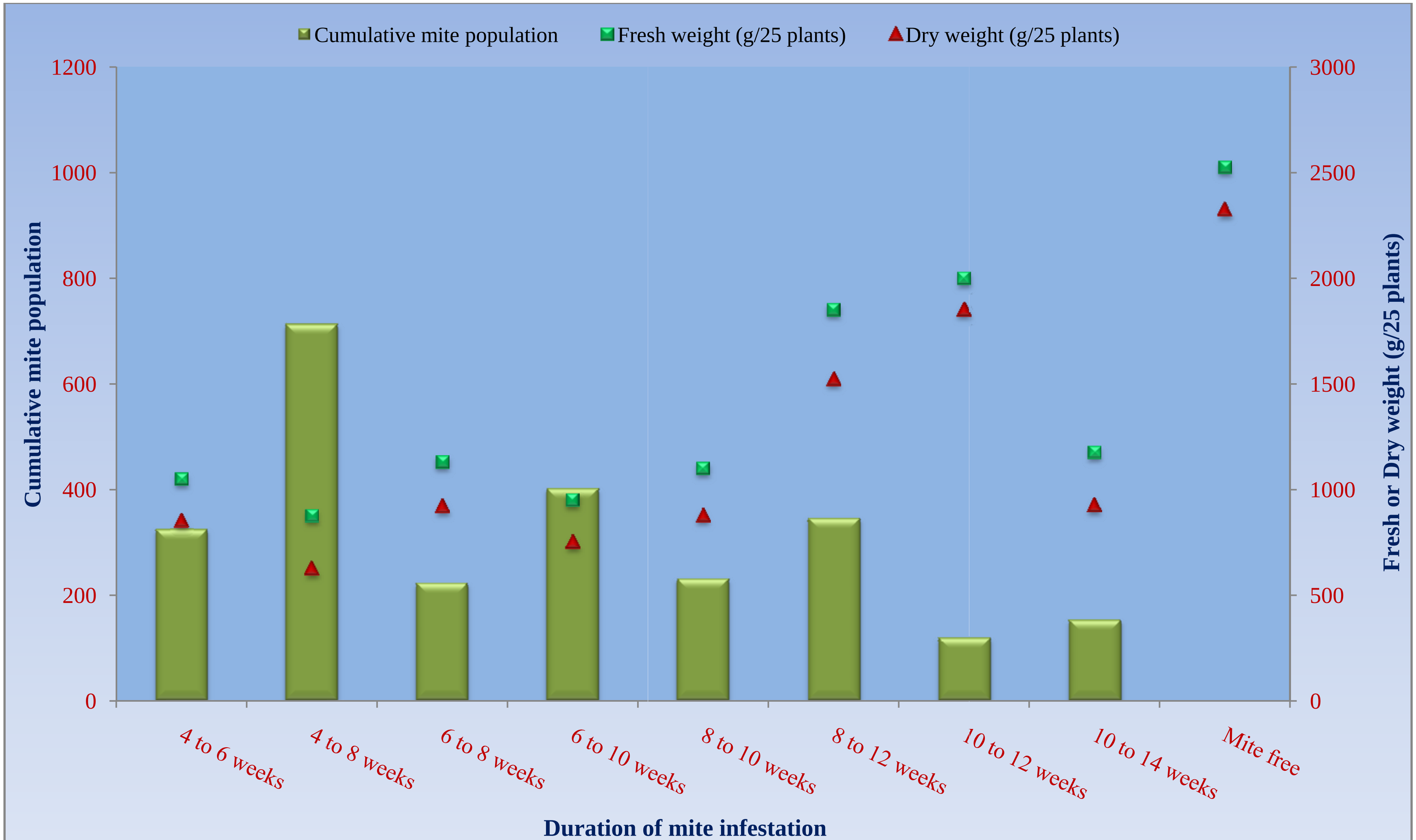


Fig. 3. Mite infestation at different stages, cumulative mite population and biomass yield in chilli cv. *Byadgi kaddi* (in glasshouse)

damage scores, maximum of 2.36 mean damage score (with at least 35 per cent leaves in a plant with downward curling due to mite feeding) was associated with a cumulative population of 361.90 mites and with a mean population of 72.38 mites with the mite infestation treatment from 4 to 8 weeks (Table 12). The mean damage score was 3.20 with 6 to 10 weeks mite infestation treatment. It was apparent that mite colonization for a period of 4 weeks on 4 weeks and 6 weeks old plants further resulted in higher buildup of mites in the following weeks, as a result plants were damaged more severely and fruit yields were also significantly low (Table 13, Fig 4). Hence, 4 to 6 weeks infestation treatment recorded the lowest yield of 555kg/acre followed by the yield of 1111kg/acre in 6 to 10 weeks infestation treatment. The mite free check plot recorded the highest yield of 3311kg/acre. Mites infestation treatment beyond 10 weeks (10-12 or 10-14 weeks) did not record higher mite population further as a result mite damage scores were low, which also did not reduce the fruit yield more evidently.

No information or documented literature is available on systematic study of crop stage *versus* mite infestation and its negative influence either on plant biomass or fruit yield in chilli crop. Earlier studies in Tamil Nadu by Kareem *et al.* (1977) and Karappuchamy *et al.* (1994) have reported severe damage leading to complete failure of chilli crop when yellow mite *P. latus* infested the crop at flowering and fruiting stages (probably between 6 and 10 weeks after planting) as evidenced in the present study. Also Ukey *et al.* (1999) suggested 1 mite/leaf as the economic threshold level of yellow mite between 6^{th} and 10^{th} week after planting of chilli crop (*cv.* CA 960) and any effective plant protection intervention during this stage would result in a favourable cost benefit ratio of 1: 3.82 in Akola region of Maharashtra. Sudharma and Madhavan Nair (1999) also considered 6 weeks after planting (*cv.* Jwalamukhi) as critical and crucial stage of chilli crop for infestation and damage by yellow mites in Vellayani region of Kerala. They released 10, 25, 50 and 100 mites/plant 6 weeks after planting and noticed its

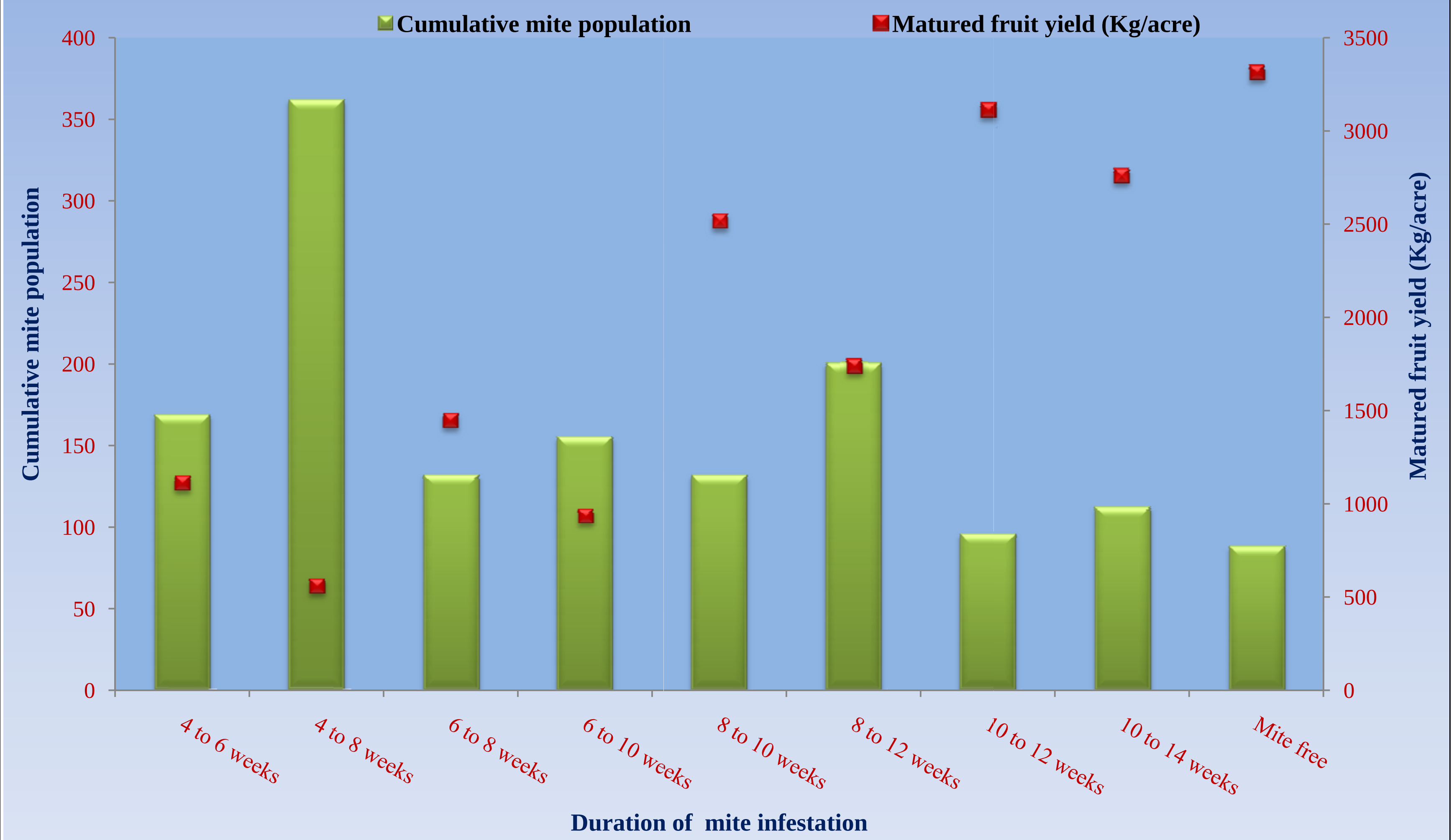


Fig. 4. Yellow mite infestation and matured fruit yield in chilli cv. *Byadgi kaddi* (Field experiment)

negative relationship with the fruit yield (per plant) and positive relationship with the mite damage score.

5.4. Screening of chilli entries for their reaction to yellow mite, *Polyphagotarsonemus latus* (Banks)

Over a period of 3 years (2008-2010) 107 chilli entries were evaluated for their reaction to yellow mite, *P. latus* both under glasshouse and field conditions. Data pooled from six different screening trials revealed a mean mite infestation ranging from zero (46 entries) to 82.50 per cent (KDSC 1), while the damage score ranged from zero (40 entries) to as high as 3.75 (S 20-1 and 4-4 with > 75% of leaves in a plant with downward curling). Mean mite population (eggs + active stages) ranged from zero mites/6 leaves (seven entries) to 218.75 mites/6 leaves (132-2-2) (Table 20). Out of these 107 entries, 32 entries were shortlisted and subjected to final screening during summer 2010 and data from this final screening experiment revealed that percentage of mite infested plants in different chilli entries ranged from 0 (S 49) to 94.40 per cent (*Byadgi kaddi* & CMS 5B) and the mite population (including eggs and active stages) of 0.9 mites/6 leaves (Aparna) to a maximum of 87.20 mites/6 leaves (*Byadgi kaddi*) (Table 21, Fig 5).

In most of the entries since there was no consistency in mite damage scoring data (probability due to recovery from the symptom) mean mite population was considered for assessing the reaction of different chilli entries for mite infestation. Thus 32 shortlisted entries were categorized into 5 major reaction groups based on mean mite population (including eggs and active stages recorded from 5 fortnightly intervals between 15 and 75 days from planting) (Table 21). Two entries which harboured <5 mites/6 leaves namely, Aparna & S 49 were designated as highly resistant; 1 entry BVC 47 with 5 to 10 mites/6 leaves as resistant; 2 entries BVC 53 and *Capsicum frutescens* as moderately resistant with 11 to 20 mites/6 leaves; 3 entries namely CA 2, KDC 2 and CA 9 which recorded

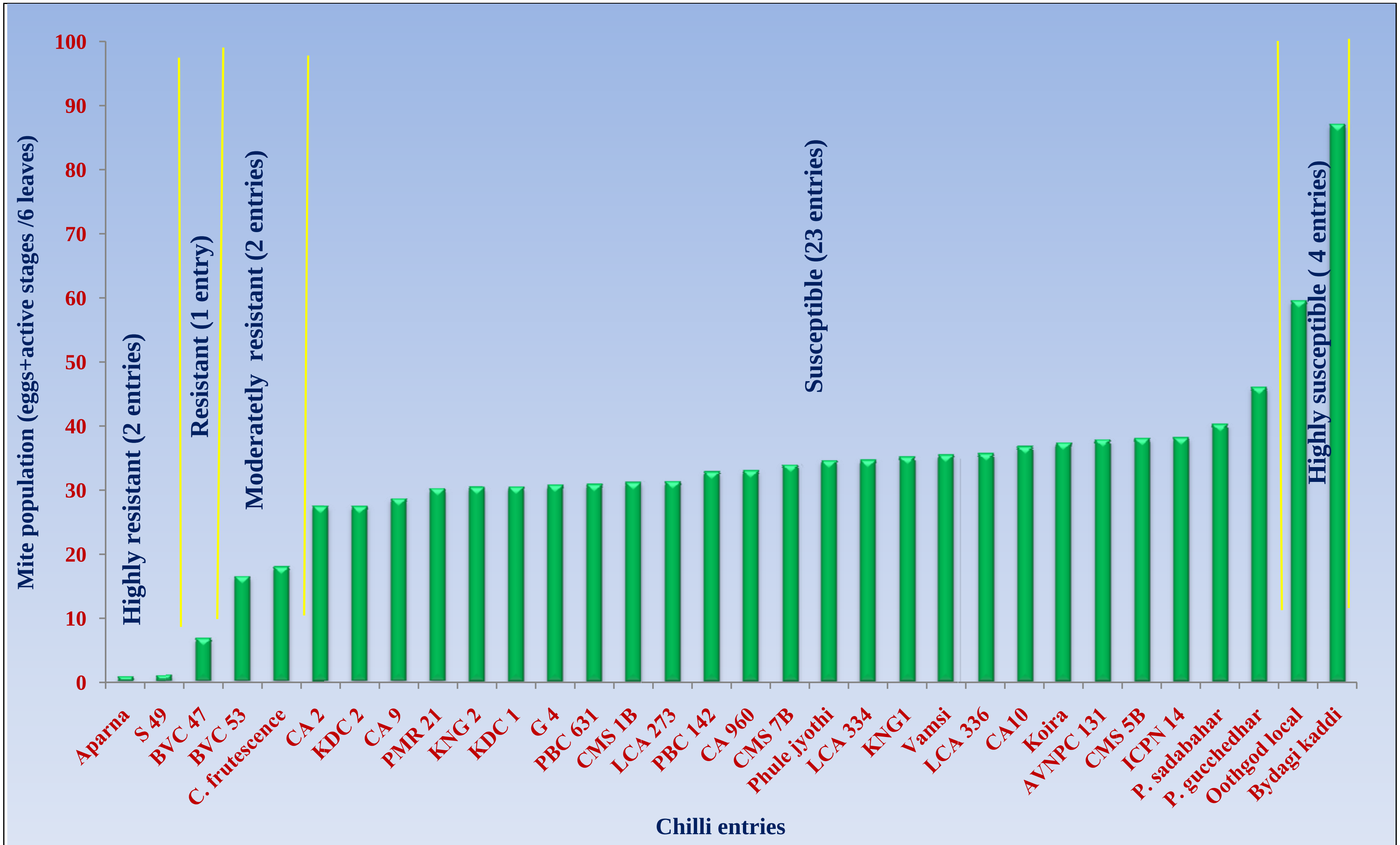


Fig. 5. Reaction of selected chilli entries to yellow mite, *Polyphagotarsonemus latus* (Banks)

21 to 30 mites/6 leaves as susceptible; remaining 22 entries including *Byadgi kaddi* (87.20 mites/6 leaves) were categorized as highly susceptible with >30 mites/6 leaves.

In earlier studies varying number of entries have been evaluated for their reaction to yellow mite in different regions of the country (Sarathbabu *et al*. 2002). Ningappa (1972), who screened 19 entries against yellow mite in Dharwad region of Karnataka, of which variety S 7 was found least affected (3.91 mites/leaf with damage index of 0.53) and variety Byadgi was most susceptible (14.40 mites/leaf with damage index of 1.72). Reddy *et al.* (2000) who evaluated 33 accessions in Ghataprabha area of Northern Karnataka found lowest damage in entry 4-1 (1.6 leaf damage index) followed by 7-11, 11-9 and 1-12 (with 1.80, 1.90 and 2.2 leaf curl indices on 1-10 scale, respectively) and the damage was highest in *Byadgi* variety with a leaf curl index of 5.83. Of these entries 1-12 and 7-11 were observed as high yielders. Ahmed *et al.* (2001) in Guntur region of Andhra Pradesh evaluated 77 entries and categorized them to three reaction groups as resistant (9 entries), susceptible (31 entries) and highly susceptible (37 entries). Entries LCA 34, CA 960 and G4 which they grouped as susceptible/highly susceptible harboured 5.6, 10.6 and 11.5 mites/6 leaves, respectively. Interestingly these entries also recorded higher mean mite population of 30.9 to 34.7 mites/6 leaves and categorized under highly susceptible group in the present study.

5.5. Biochemical basis of resistance to yellow mite, *Polyphagotarsonemus latus* (Banks) in chilli entries

Variation in mite infestation among the chilli entries may be attributed to biochemical constituents of plants. In the present investigation in addition to biochemical constituents in the healthy plants (free from mites/infestation) subsequent effects on the quantity or levels of certain biochemicals and enzymes due to mite feeding (induced) were also determined. In wounded plants due to mite feeding quantitative changes in the levels of biochemicals was observed (Table 22-27).

Chlorophyll, total sugars and protein

Among the 32 chilli entries there was no much difference in chlorophyll content. Total sugars and proteins content was high in susceptible entries (like *Byadgi kaddi*, *Oothgod local*) which might supported mite infestation compared to the resistant entries (like Aparna, S 49, BVC47, BVC 53 and *Capsicum frutescens*) with lower levels of sugars and proteins (Table 22, Fig 6). Nawalagatti *et al.* (1999) also reported that the resistant entries (especially hybrids H1 & H2) had high total chlorophyll and lower sugar content compared to susceptible entries namely Byadgi and Sankeshwar.

Capsaicin

There was no definite trend between accumulation of capsaicin in leaves and the mite infestation, as capsaicin content ranged from 0.044 to 0.140 per cent, which was fairly low compared to that in fruits as evidenced from the earlier studies of Zhen *et al*. (2006) who showed the production of capsaicin in chilli plant mostly beyond 50 days *i.e.* after flowering and according to them the site of capsaicin synthesis was placenta. Since capsaicin content in leaves was low, no definite relationship was observed with mite infestation between resistant and susceptible entries.

Proline

Among the genotypes studied for proline profile and the yellow mite infestation, there was significantly higher and rapid accumulation of proline after mite infestation in all the susceptible entries. The proline content ranged from 1.9 to 3.25 µmoles/g in resistant and 2.25 to 4.2 µmoles/g in susceptible entries and

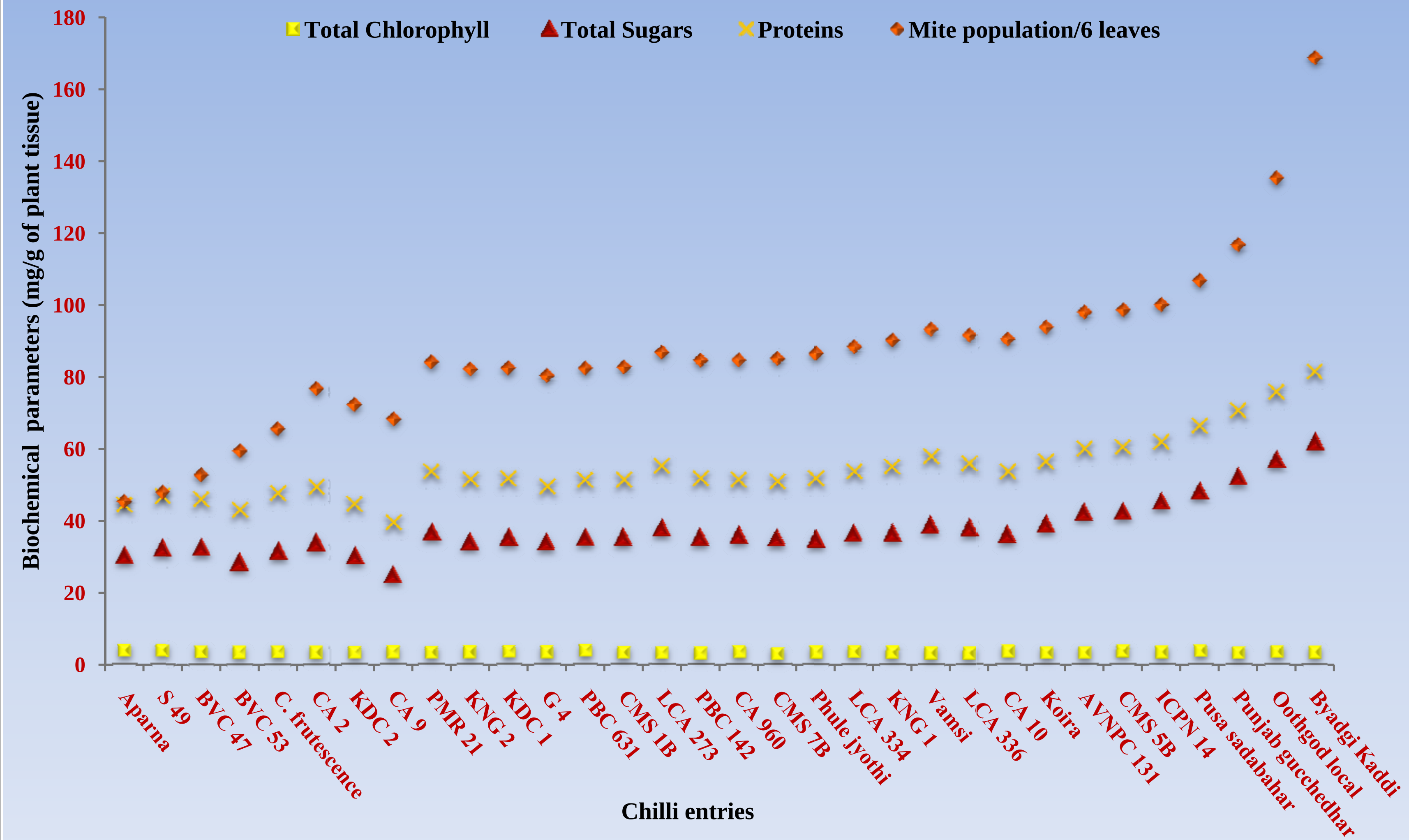


Fig. 6. Relationship between mite population and biochemical constituents in selected chilli entries (*Total chlorophyll, Total sugars and Protiens (mg/g)*)

was found to increase as 3.78 to 6.54 and 4.34 to 8.96 µmoles/g of leaf tissues. The incremental change in proline content after mite infestation was 50.46 to 113.33 per cent, which was more apparent with entries harbouring mites >20 mites/6 leaves (Table 24, Fig 7). This rapid accumulation of proline with mite infestation in susceptible entries indicated distinct improvement in proline content under mite infestation conditions. Leaves with downward curling (caused by mite infestation) contained higher levels of proline than the healthy leaves (free from mite/damage).

Phenols

Among the entries studied for total phenols profile, mite infested plants had significantly higher quantity of phenol (16.80 to 22.80 mg/g) in all the entries which were resistant or highly resistant to mite attack and these entries also recorded lower number of mites (Table 25, Fig.8). In susceptible entries (with 10 to 18.50 mg/g phenols) this trend was not so evident. Thus in resistant genotypes increase in the levels of total phenol observed with mite infestation, might have been induced to enhance the synthesis of phenolic precursors and their further oxidation into toxic quinones which prevented the further buildup of mite population as a hypersensitive reaction or induced resistance. Sequestration of phenolic compounds has been a major defensive mechanism in host plants against insects and mites. These substances are toxic and detrimental to the development of mites by adversely affecting the enzymes and nutrients (Goldstein and Swain, 1965). Higher tannin content (phenolic compounds) imparted resistance in chilli varieties against *P. latus* as reported by Borah (1987) and in cotton varieties against spider mites as reported by Lane and Schuster (1981). Nawalgatti *et al.* (1999) reported higher phenol levels in chilli entries resistant to yellow mite compared to susceptible entries. Also Ahmed *et al.* (2000) noticed that chilli entries which were resistant had higher mean phenol content of 16.07 mg/g (like in LCA 235, LCA 330) compared to susceptible ones with 7.68 mg/g (like in CA

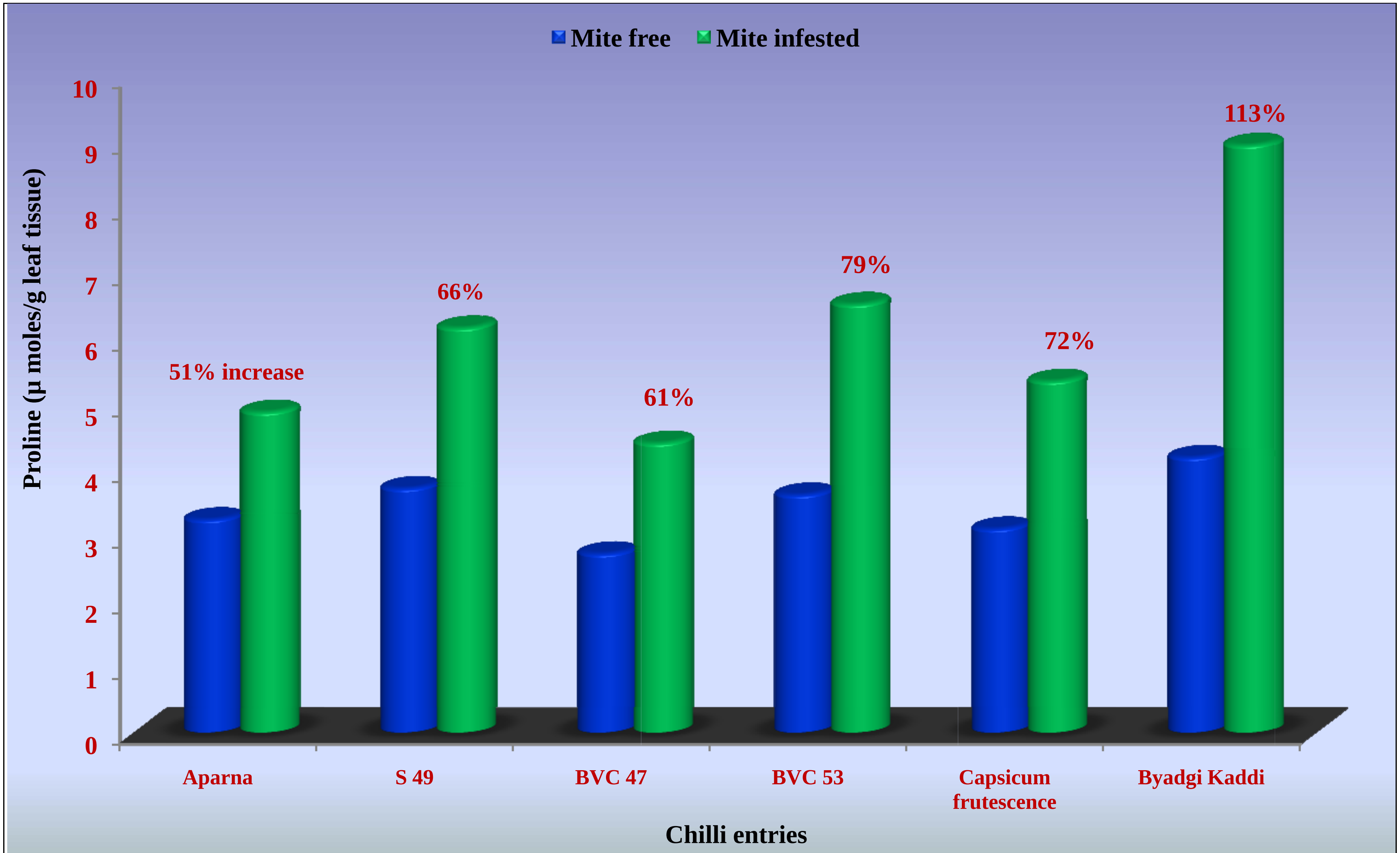


Fig. 7. Proline activity before and after yellow mite infestation in selected chilli entries

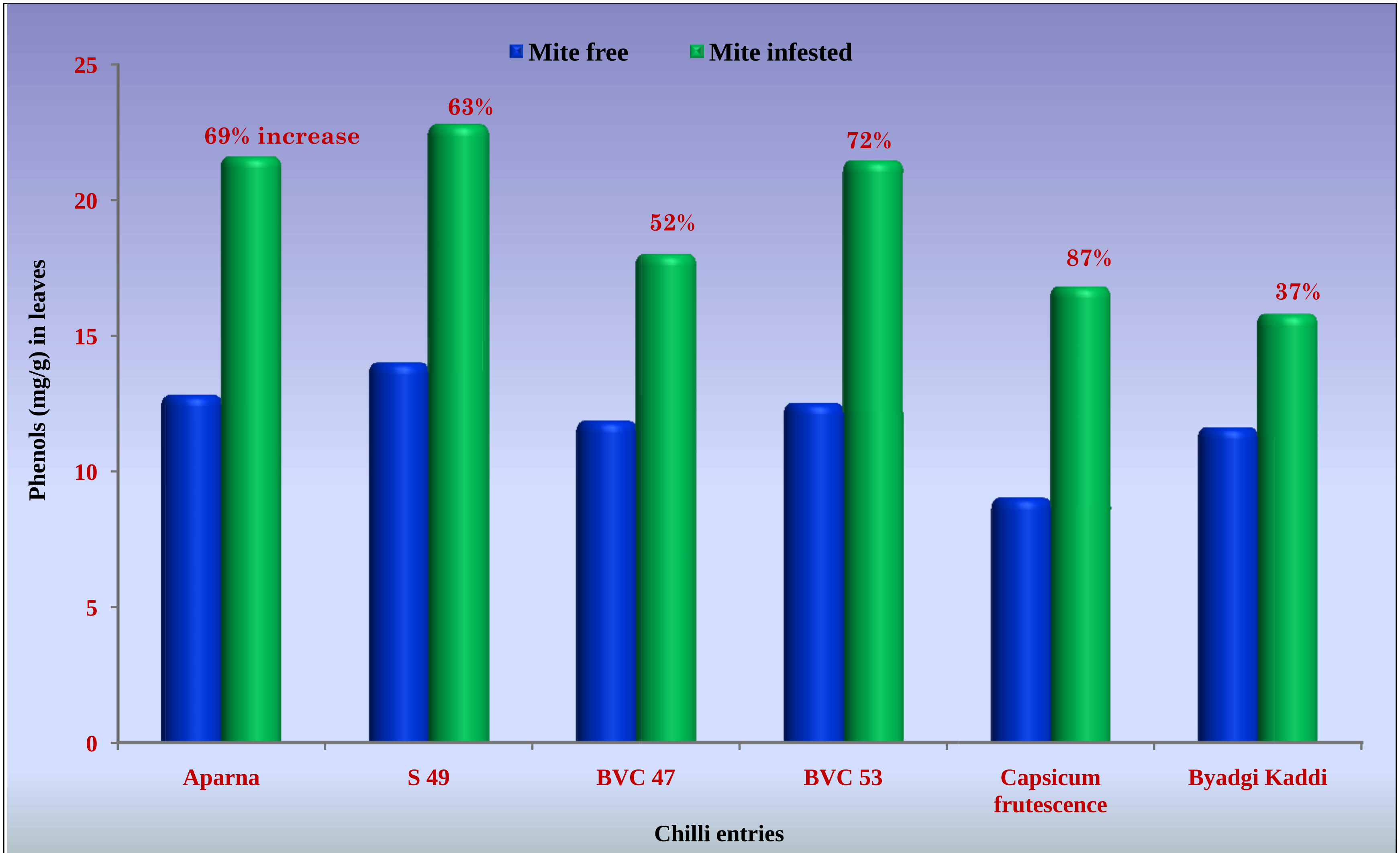


Fig. 8. Total phenols (mg/g) before and after yellow mite infestation in selected chilli entries

960, G4 and LCA 334). In the present study also highly resistant entries like Aparna and S 49 had higher phenol content of 12.80 to 14.00 mg/g as compared to susceptible ones like LCA 334, CA 960 and *Byadgi kaddi* with lower phenol levels of 10.60 to 12.60 mg/g. Rani (2001) reported susceptible potato entry TPS 2/67 to have lower phenol content (6mg/g) compared to resistant TPS 1/67 with higher phenol content of 14 mg/g, as a defensive mechanism against yellow mite *P. latus.*

Enzyme activity

The peroxidase level which was initially 416 to 775 units/g of tissue in different entries before mite infestation increased to 825 to 1362 units/g of tissue after infestation particularly in resistant entries (5 entries), the extent of increase was >75 per cent with mite infestation. In other entries improvement in enzyme activity did not exceed 68.80 per cent (CA 2) (Table 26, Fig 9) and the increase was 34.29 per cent in *Byadgi*, a highly susceptible entry. Thus the activity of peroxidase in relation to mite infestation clearly indicated its negative impact on the further buildup of mites. Hidlebrand *et al.* (1986) observed the activity of prooxidant enzyme, lipooxygenase and peroxidase to increase with spider mite (*Tetranychus urticae* Koch) feeding in resistant soybean cultivars. Increase in peroxidase activity is rather considered as a common phenomenon of induced plant responses and such activity in herbivore damaged plants may be attributed to the fact that these are the key enzymes involved in cell wall building processes (Chittoor *et al*., 1999). Product(s) from such enzymes would be antinutritive because of their poor digestibility and assimilation by insects and mites (Constable, 1999). These adverse enzyme related activities might have affected further buildup of mites or their continued damage in resistant cultivars in the present study.

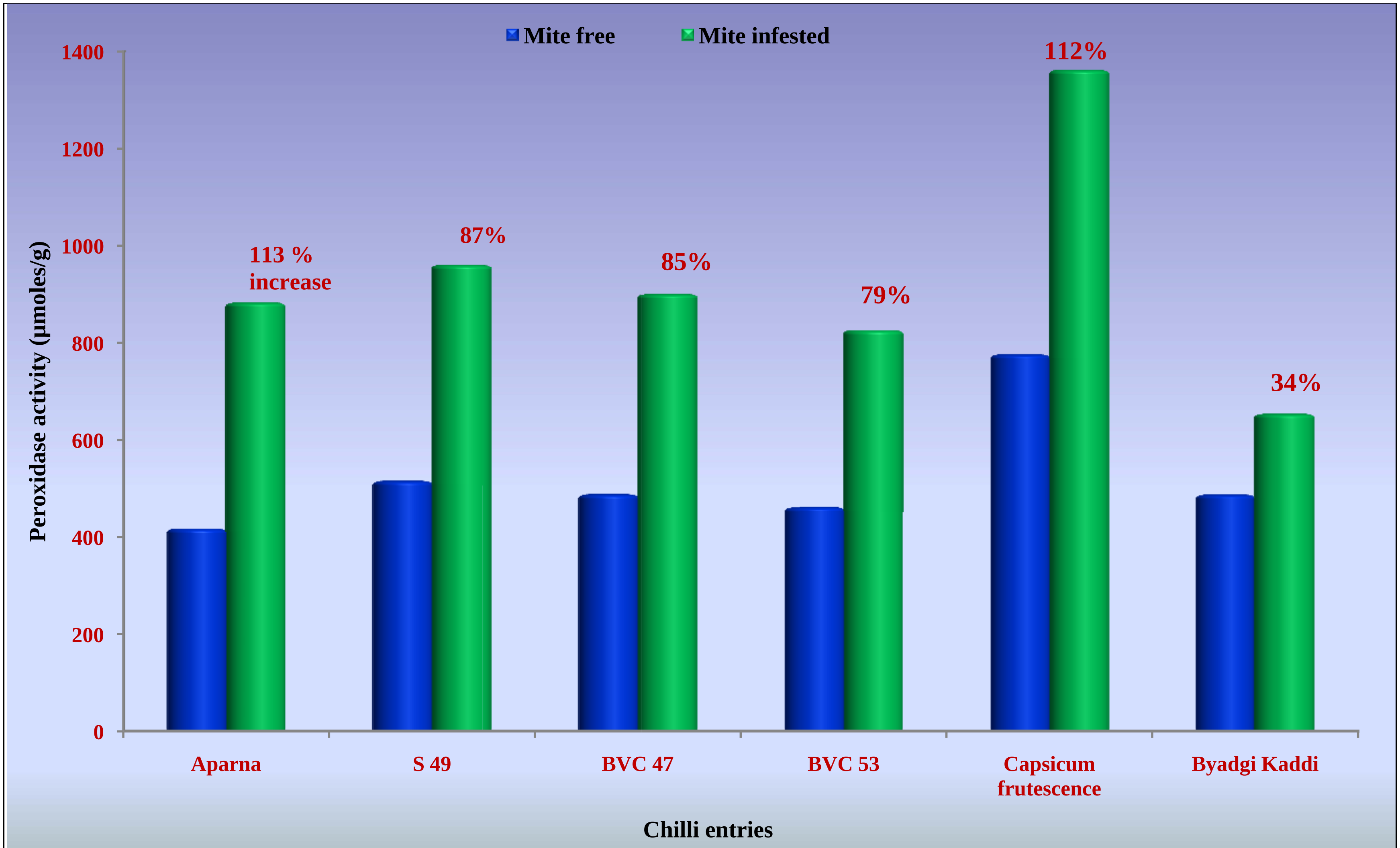


Fig. 9. Peroxidase activity before & after mite infestation in selected chilli entries

When phenylalanine ammonia lyase activity was studied, its level also got increased in mite damaged plants, enhancement in their activity ranged from 11.00 to 50.65 per cent after mite infestation (Table 27, Fig. 10). Induced synthesis of enzymes such as PAL catalyzes the production of plant defensive compounds such as phytoalexins or it directly synthesizes pest resistance compounds like trypsin inhibitors (Brown and Ryan, 1984). Such systemic signals conferred induced resistance in cotton seedlings to mites (Karbon and Cary, 1984). Such translocated signals may be attributed to induced resistance in chilli entries resistant to *P. latus* in the present study.

5.6. Genetic diversity of chilli entries against yellow mite, *Polyphagotarsonemus latus* (Banks)

Six chilli entries namely S 49 and Aparna (highly resistant), BVC 47 (resistant), BVC 53 and *Capsicum frutescens* (moderately resistant) and *Byadgi kaddi* (highly susceptible) were screened for primary linkage map based on 20 SSR primers. None of these primers showed polymorphism to designate them for mite resistance (Plate 9a, b & c). The primers, Hpms E140, Hpms E 142, Hpms E 143, Hpms E 144 and Hpms E 148 showed few polymorphic bands which might be due to the heterozygosity in the plant material used. Ghosh *et al*. (2010) who screened 88 SSR markers in jute for yellow mite damage observed only 2 markers, HK 64 and J-170 to show 100% selection efficiency. By increasing the number of markers, a marker dense saturated linkage map of chilli genome may be constructed, which would help to identify the location of genes responsible for yellow mite resistance trait in chilli crop.

5.7. Coexistence of yellow mite, *Polyphagotarsonemus latus* (Banks) and thrips, *Scirtothrips dorsalis* (Hood)

When healthy chilli plants were allowed for colonization by both mites and thrips simultaneously, within one week both mites and thrips were observed

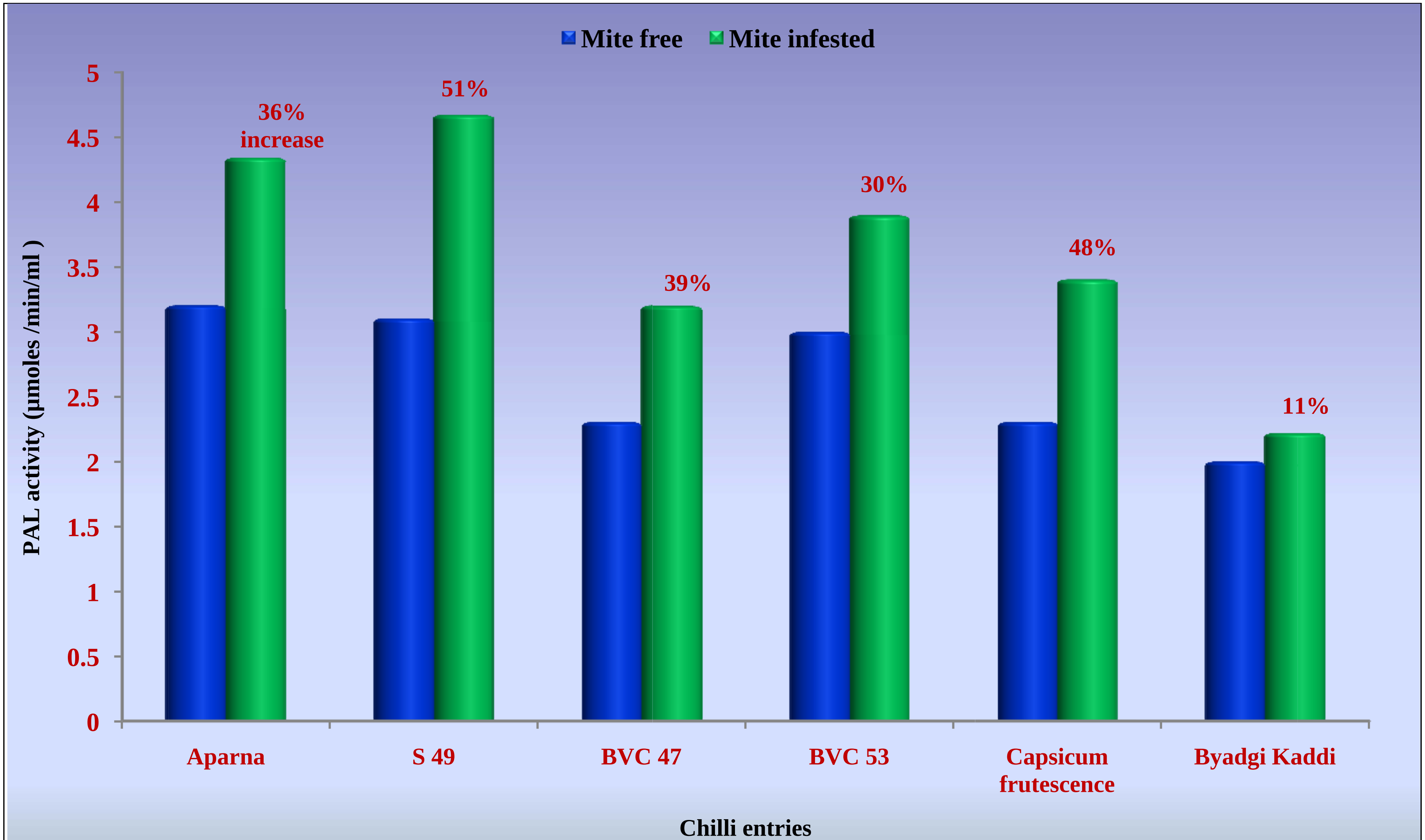


Fig. 10. Phenylalanine ammonia lyase activity before and after yellow mite infestation in selected chilli entries

inhabiting the healthy leaves. Though the number of mites (2.0/6 leaves) was slightly more than the number of thrips (0.51/plant) in the first week, still symptoms due to thrips as well as mite feeding were apparent. Further both mites and thrips continued to inhabit and damage the same plants from 2nd to 7th week, hence both the symptoms of downward curling (due to mites) and upward curling (due to thrips) of leaves were observed on the same plant. This evidently showed their coexistence with similar potentiality to damage the plants which they inhabit or infest. Joint occurrence of yellow mite *P. latus* and thrips *S. dorsalis* is not a new phenomenon, but it was evident that on the same plant some leaves with mite infestation showed downward curling symptom and other leaves with thrips infestation showed upward curling symptoms simultaneously.

Summary

VI. SUMMARY

The present investigations carried out during 2008-2011 at UAS, GKVK, Bangalore on key mite pest of chilli crop, *Polyphagotarsonemus latus* (Banks) mainly comprised of critical assessment of damage and loss in yield due to yellow mite and evaluation of chilli germplasms for biochemical basis of resistance against yellow mite infestation. The results from these investigations are summarized hereunder.

The chilli crop in field at Bangalore harboured 26 species of insect pests, one species of mite pest and four species of natural enemies (2 each of insects and mites). Of these, potential pests were *Spodoptera litura* Fabricius, thrips *Scirtothrips dorsalis* Hood, aphids *Myzus persicae* Sulzer and mites *Polyphagotarsonemus latus* (Banks) during seedling to vegetative stage and gall midge *Asphondylia capsici* Barnes and *Helicoverpa armigera* Hubner during flowering and fruiting stages.

Spodoptera litura, Myzus persicae, Scirtothrips dorsalis and *Polyphagotarsonemus latus* damaged the chilli crop in seedling stage, of which only aphids continued to damage the crop in the vegetative stage, while damage by thrips and mite was evident upto fruiting stage. Damage by 7 species of bugs, 8 species of beetles (weevils and flea beetles) and 4 species of short horned grasshoppers in the vegetative stage was insignificant.

Loss in dry fruit yield due to yellow mite, *P. latus* in Haveri district was 29.45 per cent during kharif 2008 and it was 29.33 per cent during kharif 2009, thus the mean yield loss over two seasons was 29.39 per cent.

Critical mite damage studies revealed that under glasshouse conditions yellow mite infestation for a period of 4 weeks on 4 and 6 weeks old plants (*i.e.* 4

and 6 weeks after planting) recorded a cumulative mite population of 714.40 and 401.60 mites/6 leaves, respectively, which accounted for lower turnout of plant biomass (625 and 750 g/25 plants) compared to a biomass production of 2325g/25 plants under mite free conditions. Under field conditions yellow mite colonization for 4 weeks period on 4 weeks and 8 weeks old plants (4 and 8 weeks after planting) accumulated more number of mites (361.90 and 200.10 mites/6 leaves, respectively) and the damage was relatively severe particularly on 4 weeks old plants (mite damage score of 2.36). As a result these mite infestation treatments recorded the lower yields of red ripe chilli fruits (533 and 933 kgs/acre) against the highest yield of 3313 kg/acre in relatively mite free control conditions.

Continuous infestation of yellow mite on chilli crop from 15 days after planting till maturity under glasshouse conditions resulted in complete loss (100 per cent) in the yield of chilli fruits. When chilli crop in the field was exposed to mite infestation from 15 days/30 days/45 days/60 days/75 days after planting till maturity, the corresponding matured red ripe fruit yields were 533, 800, 1333, 1733, 2222 kg/acre and the yield was highest (3199 kg/acre) in virtually mite free conditions. The corresponding yield losses of 83%, 75%, 58%, 46% and 31% were attributed to higher cumulative mite population, which evidently showed inverse relationship between mite population or damage and the fruit yield.

107 chilli entries evaluated over 6 screening trials advanced 32 entries, which harboured 0.9 mites/6 leaves (Aparna) to 87.20 mites/6 leaves (*Byadgi kaddi*). These 32 entries were categorized into 5 major reaction groups based on the mean mite population data as,

i. Highly resistant – 2 entries, Aparna & S 49 which harboured <5 mites/6 leaves
ii. Resistant – BVC 47 with 5 to 10 mites/6 leaves

iii. Moderately resistant – BVC 53 & *Capsicum frutescens* with 11 to 20 mites/6 leaves

iv. Susceptible – CA 2, KDC 2 & CA 9 with 21 to 30 mites/6 leaves

v. Highly susceptible – 22 entries (including *Byadgi kaddi)* with >30 mites/6 leaves

Differences in the levels of biochemical constituents in chilli entries were attributed to the corresponding mite infestation levels. The chlorophyll content decreased after mite infestation in susceptible entries compared to the resistant ones, while in susceptible entries higher total sugars and protein content encouraged the mite infestation. Capsaicin content in leaves did not show any relationship with the levels of yellow mite infestation in different entries. After mite infestation, the levels of phenols, proline, peroxidase and PAL were high (16.80 – 22.80 mg/g; 4.42 – 6.54 µ moles/g tissue; 825 - 1362 units/g of tissue; 3.20 – 4.67x10^3 µmoles /min/ml) in resistant entries compared to susceptible entries (18.50 mg/g in LCA 273; 8.96 µ moles/g tissue in *Byadgi kaddi*; 767 units/g of tissue in Vamsi; 3.63x10^3 µmoles/min/ml in PBC 142). This is attributed to the phenomenon of induced resistance/hypersensitive reaction particularly with resistant entries namely Aparna, S 49, BVC 47, BVC 53 and *Capsicum frutescens*.

Genetic diversity study of 6 chilli entries namely Aparna, S 49, BVC 47, BVC 53, *Capsicum frutescens* and *Byadgi kaddi* with 20 SSR primers did not designate any polymorphism to yellow mite infestation. However, five primers namely Hpms E 140, Hpms E 142, Hpms E 143, Hpms E 144 and Hpms E 148 showed few polymorphic bands and thus suggested to use more number of SSR primers for gene mapping and further selection for desired trait of resistance to yellow mite.

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