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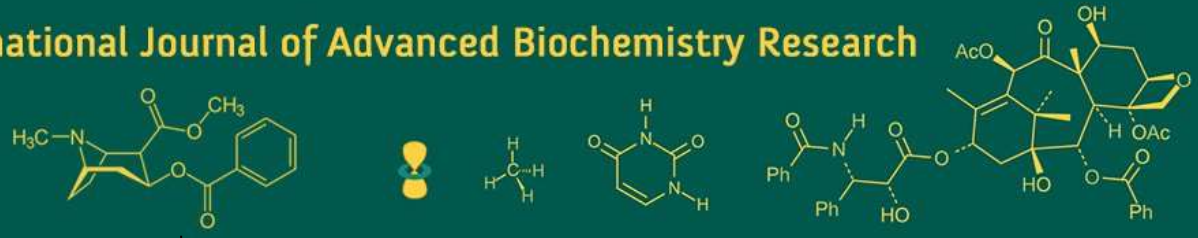

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Developmental biology and impact on yield loss by two-spotted spider mite, (*Tetranychus urticae*) in brinjal crop

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Abstract
Under lab conditions, the developmental biology of the brinjal-infested two-spotted spider mite, *Tetranychus urticae*, was investigated. The study revealed notable differences in the developmental characteristics of male and female mites, including the incubation period, larval, protonymphal, and deutonymphal periods. For females, the overall developmental time was 11.27±0.55 days, whereas for males it was 10.47±0.20 days. Furthermore, there was a difference in adult longevity: males lived 5.76±0.17 days, whereas females lived 20.95±0.60 days. Pre-oviposition, oviposition, and post-oviposition times were reported as 2.64±0.08 days, 17.71±0.51 days, and 0.60±0.02 days, respectively, for the reproductive parameters. The observed female fecundity was 48.99±1.41 eggs, and the reported sex ratio of the progeny was 1:5.03 (Male: female). Using a paired plot technique, more research into the damage assessment produced by the two-spotted spider mite on brinjal crop cv. Green Long revealed a 21.08% loss of fruit production owing to mite infection.

Keywords: *Tetranychus*, biology, brinjal, loss

Introduction
Tetranychus urticae Koch, often known as the two-spotted spider mite, is a worldwide agricultural pest that is a member of a group of mites that spin webs (Jeppson *et al.*, 1975) [7]. The term "spider" refers to their capacity to spin silk-like webbing, which they utilise to create a micro-habitat for their colonies, defend against abiotic stimulants, hide from predators, communicate through pheromones, and act as a means of dispersal (Gerson, 1985) [6]. These microscopic mites feed by piercing and sucking plant cells and tissues. They are found in enormous colonies on the underside of leaves beneath delicate silky webs. This activity causes the distinctive yellow chlorotic dots to emerge on leaves. The flower and flower buds are likewise webbed by it.

The quality and quantity of crop yield are ultimately impacted by the slow destruction of chloroplasts in leaves due to an increase in feeding mite population, which also causes a loss in photosynthesis, stomata closure, and transpiration (Brandenburg and Kennedy, 1987; Martinez *et al*., 2006) [5, 10]. *T. urticae* can quickly reach harmful population levels due to their fast rate of development, short generation period, and high net reproduction rate. This causes the quality of the host plant to rapidly decrease.

One of the most polyphagous arthropod herbivores, Tetranychus urticae consumes around 1,100 plant species from over 140 distinct plant families, including those that are known to create poisonous substances on their own. It is a serious pest that destroys both annual and perennial crops under greenhouse conditions and on field crops. Brinjal (*Solanum melongena* L.), often known as aubergine, is one of its hosts and a valuable solanaceous vegetable that is highly valued. This mite seriously threatens this produce and results in a notable reduction in crop yield. Spider mites were identified by Basu and Pramanik (1968) [3] as the second most common pest after shoot and fruit borer in brinjal, causing yield reductions of up to 31% in Varanasi, Uttar Pradesh, and Bangalore, Karnataka (Anonymous, 1992 & 1994) [1-2]. This study aims to explore the developmental biology of the brinjal mite and evaluate its possible influence on yield loss in brinjal crops.

Materials and Methods

Tetranychus urticae developmental biology on brinjal:

Under laboratory circumstances (24 °C–25 °C and 70%–75% Relative Humidity), the biological characteristics of Tetranychus urticae were investigated on brinjal plants of the cultivar Green Long. A fine camel hair brush was used to individually transfer a cohort of approximately 800 eggs, laid by around 100 to 150 gravid female T. urticae in a period of 2 to 6 hours on brinjal leaf bits measuring 5 cm by 5 cm, to 30 distinct leaf bits (2.5 cm by 2.5 cm) of the brinjal plant.

These leaf fragments were kept in 6-inch Petri dishes on a moist cotton wad. Periodically wetting the cotton wad with clean water ensured that it remained adequately moist. The development of the mite, including the duration of the incubation period and each of the various immature stages, such as larva, quiescent 1 (nymphochrysalis), protonymph, quiescent 2 (deutochrysalis), deutonymph, and quiescent 3 (teliochrysalis), was monitored by looking at the leaf bits every 6 hours under a stereo-binocular microscope. When needed, the immature stages were moved to new leaf fragments, and the observations were kept up to date. The observations for the life history data included the length of the incubation phase, the larva's duration, the protonymph, deutonymph, and quiescent stages, as well as the adult's (male and female) longevity. The subsequent offspring's sex was also noted. For both male and female subjects, the mean duration of various immatures and developing stages was calculated.

Twenty five female deutonymphs of *T. urticae* were randomly selected from the mite culture kept in the polycarbonate house on potted brinjal plants and were individually transferred on to fresh leaf pieces (2.5cm X 2.5cm) in order to analyse the reproductive characteristics of T. urticae on brinjal. Two adult males and a female deutonymph were positioned on each of these parts to guarantee mating. The preoviposition time was recorded by observing the leaf pieces every six hours after the adult female emerged. Until the female naturally passed away, observations were made every 24 hours regarding the quantity of eggs she deposited each day. Fresh males replaced any dead males as soon as they were discovered to guarantee that mating continued for at least four to five days following the emergence of the female. Every three days, the ovipositing female was carefully moved to the appropriate leaf piece, and the eggs she produced were stored for later development until the adults appeared and their sex was noted.

Estimation of yield loss

In the Gandhi Krishi Vigyan Kendra farm of the Zonal Agricultural Research Station in Bangalore, a "paired treatment experiment" (Paired Plot Technique) was conducted to determine the potential for the spider mite Tetranychus urticae to reduce the yield of brinjal crop cv. Green Long. The two treatments in the experiment, Protected and Unprotected, each had seven replications and a 5 m × 5 m plot size (48 plants per plot).

With the exception of the plant protection techniques against the spider mite, the suggested agronomic procedures for cultivating a brinjal crop were followed for both Protected and Unprotected plots. By stapling parts of infected brinjal leaf, a month-old crop of brinjal was artificially infected with spider mites in the unprotected plots. Effective acaricides were applied to the shielded plots on a fortnightly basis from the time of planting until maturity, providing total protection against spider mite infestation. In the protected plots, acaricides such as propargite (570 g a.i/ha) and fenazaquin (125 g a.i/ha) were applied alternately.

Every two weeks, starting 15 days after planting and continuing until crop maturity, observations on the mite population were made on ten randomly chosen plants from each plot. Three leaves were sampled from the top, middle, and bottom canopies of each plant. Six 1 cm2 leaf areas were marked on each leaf in order to count the number of eggs and active stages (larvae, nymphs, and adults) of the mite under a stereo binocular microscope in the lab.

From each picking, the marketable fruit yield (kg) for each plot was noted. To estimate the yield loss from spider mites, marketable fruit yield data from several pickings in Protected and Unprotected plots were combined. By comparing calculated "t" with the table "t" at (n-2) df, the statistical significance of the pooled brinjal fruit yield across Protected and Unprotected plots was determined using the "t" test as follows:

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

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

{Calculated or Observed 't' = $\frac{\sqrt{\overline{X1}-\overline{X2}}}{sd}$

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}

Results and Discussion

On brinjal leaves, the incubation period, larval and nymphal (protonymphal, and deutonymphal) periods of female (*Tetranychus urticae*) were observed to be 4.34±0.19 days, 2.72±0.49 days, 2.17±0.22 days, and 2.04±0.27 days, respectively. For males, these periods were 4.30±0.07 days, 2.00±0.22 days, 1.79±0.21 days, and 2.38±0.27 days, respectively. The combined periods were 4.32±0.39 days, 2.36±0.97 days, 1.98±0.44 days, and 2.21±0.53 days, respectively, when taking into account specimens that were male and female. The total developmental period for females was 11.27±0.55 days, while for males, it was 10.47±0.20 days.

The reproductive characteristics of T. urticae on brinjal were 2.64±0.08 days, 17.71±0.51 days, and 0.60±0.02 days, respectively. These values included the preoviposition, oviposition, and post-oviposition phases. Male adult longevity was just 5.76±0.17 days, while female adult longevity was found to be 20.95±0.60 days. The females were found to be fecund at 48.99±1.41 eggs, and the male: female sex ratio of the progeny was noted as 1:5.03.

According to Liu (1989) [9], T. urticae took between 4.3 and 6.23 days to fully grow at a temperature of 27 °C and a relative humidity of 60% to 70%. In the Junagadh district of

Gujarat, Kaneria (1988) [8] investigated the biology of *T. cinnabarinus* on brinjal under laboratory circumstances with temperatures ranging from 30.58 °C to 34.42 °C and relative humidity between 64.87% and 67.71%. It was discovered that the average egg period was 4.08±0.51 days, and 83.39% of the eggs hatched. The mean durations of 2.56±0.71, 2.69±0.65, and 2.75±0.67 days were recorded for the larval, protonymphal, and deutonymphal stages, respectively. Males and females that were not mated had average life spans of 9.36±2.98 and 8.78±2.53 days, respectively, whereas mature males and females had average life spans of 3.08±0.86 and 11.53±2.36 days, respectively. With a sex ratio of 1:11.46, the mean fecundity of mated and unmated females was 38.88±8.22 and 8.72±5.04 eggs per female, respectively. *T. cinnabarinus* biology was investigated by Bhagat and Singh (1999) [4] on brinjal at 26.2±1.0 °C and 60% relative humidity. At a rate of 4.41±1.14 eggs per day, each female laid 59.80±9.36 eggs. The duration of the incubation phase was 5.6±1.4 days. The duration of the protonymphal and deutonymphal phases was 3.40±0.54 and 7.60±1.14 days, in that order. The adult females' mean lifespan was measured at 12.80±1.92 days during their entire developmental phase, which spanned 13 to 20 days.

The mean mite population (eggs and active stages) in the protected plots was 3.24 mites/cm2 leaf area, compared to 15 mites/cm2 leaf area in the unprotected plots, according to data from the crop loss experiment (Table 31). Plots with and without protection produced different amounts of fruit: 85.32 kg/25 m2 and 67.29 kg/25 m2, respectively. The amount of fruit output lost as a result of mite infection was 21.08%. There were statistically significant differences in the brinjal fruit output between the protected (free from mite infection) and unprotected (with mite infestation) plots, as indicated by the paired "t" value of 2.75.

Red spider mites were listed by Basu and Pramanik (1968) [3] as the second most significant pest in brinjal, behind fruit borer and shoot. T. cinnabarinus is regarded by Palanisamy and Chelliah (1987) [11] as the most damaging pest of the brinjal crop in Tamil Nadu, causing a loss of 28.08 percent in the average fruit yield. The amount of fruit production loss attributed to spider mites differed by area in the nation: in Bangalore, it was 31.09 percent; in Varanasi, it was 13.64 to 30.22 percent (Anonymus, 1992 & 1994) [1-2]; and in Andhra Pradesh, it was 30 to 35 percent (Tabassum and Maruthi, 2004) [12]. The differences in ecological conditions, the degree of spider mite infestation, the severity of the occurrence, and the crop variety in each location could all contribute to the variability in yield loss across different regions.

Table 1: Development (in days) of two spotted spider mite, *Tetranychus urticae* on brinjal leaves.

Sex	Egg stage	Larva stage	Protonymph stage	Deutonymph stage	Total
Female	4.34±0.19	2.72±0.49	2.17±0.22	2.04±0.27	11.27±0.55
Male	4.30±0.07	2.00±0.22	1.79±0.21	2.38±0.27	10.47±0.20
Both male and female	4.32±0.39	2.36±0.97	1.98±0.44	2.21±0.53	10.87±1.11

Table 2: Reproductive parameters of two spotted spider mite, *Tetranychus urticae* on brinjal leaves.

{Pre oviposition period (days)}	{Oviposition Period (days)}	{Post Oviposition Period (days)}	{Female longevity (days)}	{Male longevity (days)}	(Mean no. of eggs per female)	(Mean no. of female off springs /female)	(Mean no. of male off springs /female)	Sex ratio (♂:♀)
2.64±0.08	17.71±0.51	0.60±0.02	20.95±0.60	5.76±0.17	48.99±1.41	40.87±1.18	8.12±0.23	1:5.03

Table 3: Yield loss estimation of brinjal due to two spotted spider mite (*Tetranychus urticae*)

Paired plot number	Protected plot (X1)		Unprotected plot (X2)		(*d*)	(d^2)
	Mean (mites/cm^2 leaf area)	Yield (kg/plot*)	Mean mites/cm^2 leaf area	Yield (kg/plot*)		
1	11.09	77.26	21.32	52.17	7.12	50.69
2	4.26	79.12	20.01	61.53	-0.38	0.14
3	2.94	80.23	17.97	64.79	-2.53	6.40
4	1.77	80.66	17.37	66.01	-3.32	11.02
5	0.94	89.13	13.94	67.91	3.25	10.56
6	0.90	89.38	12.57	71.00	0.41	0.17
7	0.77	101.06	1.77	87.61	-4.52	20.43
Mean	3.24	85.26	15.00	67.29		99.41

(*Plot size 5m x 5m)

Mean yield of fruits in protected plot $(\overline{X1})$ – (85.26 kg)

Mean yield of fruits in untreated plot $(\overline{X2})$ – (67.29 kg)

Standard deviation (s) = $\sqrt{\frac{Sum\ of\ d^2}{n-1}} = \sqrt{\frac{99.41}{7-1}} = 4.07$

sd = $\frac{s}{\sqrt{n}} = \frac{4.07}{\sqrt{7}} = 1.54$

Calculated or Observed 't' = $\frac{\sqrt{\overline{X1} - \overline{X2}}}{sd} = \frac{\sqrt{85.26-67.29}}{1.54} = 2.75$

The paired't' value 2.75*- significant.

The extent of loss (%) due to mite infestation = $\frac{\overline{X1} - \overline{X2}}{\overline{X1}}$ X 100 = $\frac{85.26-67.29}{85.26}$ X100 = 21.08%

Conclusion

In conclusion, the study provides valuable insights into the developmental and reproductive characteristics of Tetranychus urticae on brinjal leaves. The research sheds light on the intricate life cycle of these mites, revealing distinct periods for egg, larval, nymphal, and adult stages, as well as reproductive parameters and population dynamics.

Moreover, the experiment underscores the significant impact of mite infestation on brinjal yield, with protected plots showing significantly higher fruit production compared to unprotected ones. These findings underscore the importance of effective pest management strategies to mitigate losses caused by spider mites, which have been identified as a major threat to brinjal cultivation in various regions. Further research and implementation of targeted interventions are warranted to address this agricultural challenge and ensure sustainable brinjal production.

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