

Damage potential of the spider mite *Tetranychus ludeni* (Acari: Tetranychidae) on four varieties of eggplant

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Abstract. The damage potential of the spider mite *Tetranychus ludeni* Zacher was studied on 20–65-day-old seedlings of four eggplant *Solanum melongena* varieties: Madurai (MDU₁), Coimbatore (CO₁), Annamalai and Panruti at introduction levels of 2, 5, 10 and 15 mites/leaf. The average seedling mortality among varieties was lowest at the introduction level of two mites and maximum at the introduction level of 15 mites/leaf. The overall seedling mortality was 23% when the four levels of mite population were introduced on 20-day-old seedlings, and only 14% on 30-day-old seedlings. Among the different varieties, the MDU₁ seedlings recorded higher mortality (1.6%) and Panruti the lowest (0.3%). The percentage losses in total plant height, number of leaves, number of flowers and fruits and fruit weight due to mite attack were highest (37–50%) in MDU₁ and lowest (7–11%) in the variety Panruti. The other two varieties CO₁ and Annamalai were found to be intermediate between Panruti and MDU₁. The inoculated mites at different levels multiplied greatly on the variety MDU₁ followed by CO₁, Annamalai and Panruti. The extent of damage was higher in 35-day-old plants, when mites were introduced on 35- and 65-day-old seedlings. Therefore, the variety Panruti is recommended for cultivation in the study area in view of its resistance to *T. ludeni*.

Key words: *Solanum melongena*, *Tetranychus ludeni*, damage potential, Acari, Tetranychidae

Résumé. On a étudié les dégâts potentiels de l'acarien *Tetranychus ludeni* Zacher sur des plantules d'aubergine *Solanum melongena*, âgées de 20 à 65 jours, sur les quatre variétés Madurai (MDU₁), Coimbatore (CO₁), Annamalai et Panruti et pour des niveaux d'infestation de 2, 5, 10 et 15 acariens/feuille. La mortalité moyenne des plantules est minimale pour 2 acariens/feuille et maximale pour 15 acariens/feuille. La mortalité totale des plantules est de 23% sur des plantules âgées de 20 jours et seulement de 14% sur des plantules âgées de 30 jours. Parmi les différentes variétés, on a enregistré la plus forte mortalité (1.6%) sur les plantules de MDU₁ et la plus faible (0.3%) sur les plantules de Panruti. Les pourcentages de pertes en taille, nombre de feuilles nombre de fleurs et fruits et poids des fruits sont maxima (37–50%) sur MDU et minima (7–11%) sur Panruti. Sur les deux autres variétés, CO₁ et Annamalai, on a enregistré des pertes intermédiaires. Les dégâts sont maxima sur les plantes âgées de 35 jours, lorsque les acariens ont été inoculés

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sur des plantules âgées de 35 à 65 jours. En conséquence, la culture de la variété Panruti est recommandée dans la zone d'étude compte tenu de sa résistance à *T. ludeni*.

Mots clés: *Solanum melongena*, *Tetranychus ludeni*, dégât potentiel, Acari, Tetranychidae

Introduction

The eggplant (brinjal or aubergine) *Solanum melongena* L. (Solanaceae), is native to India and is one of the most common vegetables grown throughout the country. It possesses ayurvedic medicinal properties and the white eggplant variety is especially known to be good for diabetic patients (Choudhury, 1967). The eggplant yield is affected by many pests, among which the spider mite, *Tetranychus ludeni* Zacher (Acari: Tetranychidae) is important.

Tetranychus ludeni is widespread throughout the tropics, across the southern United States, in Mexico, Central and South America, South Africa and Australia (Krantz, 1971). It has been reported as a serious pest of *Hibiscus*, bean, eggplant, potato, alfalfa, castor bean, pumpkin and other cucurbits (Moutia, 1958; Meyer and Rodriguez, 1966). These mites are exclusively phytophagous and cause substantial losses, especially of vegetable crops (Channabasavanna, 1971).

In the state of Tamil Nadu (India), eggplant, okra and green chillies are grown intensively, especially in Vallampadugai, Mutlur and Panruti. Among these crops, both eggplant and okra are often damaged by *T. ludeni* (Reddy, 2001).

Tetranychus ludeni is difficult to control chemically being resistant to all organophosphate insecticides tested (Herron *et al.*, 1998; Elzen and Hardee, 2003). Miticide sprays also gave variable control, due to the widespread resistance within pest populations and the difficulties of applying the spray to the underside of leaves (Goodwin, 1990).

Although many workers have studied the damage potential of *Tetranychus cinnabarinus* (Boisduval) on eggplant (Wang *et al.*, 2004), cucurbits (Edelstein *et al.*, 2000) and cotton (Canerday and Arant, 1964; Brito *et al.*, 1986); *Tetranychus urticae* Koch on cotton (Oliveira, 1971; Oliveira and Calcag Nolo, 1975; Reddall *et al.*, 2004) and geranium (Marchetti, 1976) and *Panonychus citri* (McGregor) on citrus (Inoune, 1968) and pear (Tetsuo and Mitsuhiro 1997), very little information on the damage potential of *T. ludeni* is available (Kumar and Sharma, 1993).

The present study on the damage potential of *T. ludeni* in different eggplant varieties was undertaken to generate information for the farming community in endemic areas.

Materials and methods

Mite cultures

An isogenic culture of *T. ludeni* was reared in the greenhouse at 14 h L:10 h D photoperiod, $34 \pm 2^\circ\text{C}$ and 50% RH, on each of four varieties of eggplant: Madurai (MDU₁), Coimbatore (CO₁), Annamalai and Panruti. The cultures were started with one potted plant per variety, maintained inside a wire mesh cage. One male and one female mite were introduced onto a 15-day-old seedling of each variety. When the seedlings were badly damaged by the mites, fresh plants were added and the damaged plants removed after the mites had migrated to the healthy plants. Approximately 10 generations were completed before use for experiments. For all investigations, mites were obtained from the culture of the respective variety.

Damage potential of mites on eggplant seedlings

The damage of egg plant by mites was assessed on 20- and 30-day-old potted seedlings of the four varieties above. In each pot (30 cm diameter \times 30.5 cm deep), five seedlings of each variety were raised. The experiment was conducted in a $2 \times 4 \times 5$ factorial design, in which groups of five 20- or 30-day-old potted seedlings formed a treatment, replicated five times. Seedlings were inoculated with one of five mite levels (control), 2 (1♀ + 1♂), 5 (3♀ + 2♂), 10 (5♀ + 5♂) or 15 (8♀ + 7♂), at the deutonymphal stage. After inoculation, each seedling was isolated with a polythene cage to prevent mites from migrating from one plant to another. Ten days later, adult mites were visually counted and the damage determined by counting the number of dead seedlings. Analysis of variance was performed on the arcsine-transformed data and means were separated using the LSD method.

Mite infestation levels on plant characters and yield at different stages of crop growth

The effect of mite load, plant growth stage and eggplant variety were studied in a factorial design. The initial levels of load were 2, 5, 10 or 15 mites per 35-, 45-, 55- or 65-day-old plants (days after transplanting). Each seedling was transplanted individually to a pot (30 cm diameter \times 30.5 cm

deep) filled with a mixture of 3 kg sand, 2 kg farmyard manure and 2 kg loamy clay soil (pH 7.3, available P_2O_5 5.3 mg/100 g, K_2O 7.5 mg/100 g), and supplied with 1.5 g nitrogen applied as NH_4NO_3 , 2.0 g phosphorous as Ca (H_2PO_4), 3.0 g potassium as KCl and K_2SO_4 (50/50) and magnesium as $MgSO_4$. All the fertilizer compounds were mixed with dry soil as solutions, except for P, which was added as pure salt. Moisture content was adjusted at about 60% of soil retention capacity and held at this level by irrigating during the experiment. The plants were grown under natural light and temperature conditions. For each treatment, five pots were used as replicates.

The plants were tagged and randomly placed, and after their inoculation they were covered with polythene cages to prevent mite migration. Twenty-five days before mite introduction, the plants had been sprayed with 0.05% methyl demeton, to protect them against other pests. Ten days after the mite introduction, all the plants, including those in the control treatments received a foliar spray of 0.1% Sevin (wp) to prevent damage from other pests.

From day 5 after inoculation and at subsequent 7-week intervals, the following parameters were assessed: mite population development, plant height, number of leaves, flowers and fruits and total weight of the fruits. The fruits were harvested at maturity and weighed. Mite population development was estimated by counting the mites on a 1 cm^2 leaf area (middle of leaf, above midrib), on the lower surface of each of 3 leaves/plant (at top, middle and bottom) (Reddy and Baskaran, 1991). These counts were made early in the morning under a $10\times$ lens. Data on mite counts were $\sqrt{(\times + 0.5)}$ -transformed and analysed by three-way analysis of variance (ANOVA), and differences between means separated using the LSD method.

Results

Damage potential of mites on seedling mortality

Considering both the seedling age at the time of mite release and all four levels of mite introduction, the MDU₁ variety suffered the highest mortality, while Panruti had least mortality ($F_{8,4} = 13.4$; $P \geq 0.05$) (Table 1). Between the two age groups, the 20-day-old seedlings suffered a higher mortality compared to the 30-day-old group ($F_{8,2} = 11.3$; $P \geq 0.05$). Among the different mite loads, mortality was lowest when the introduction level was lowest—of 2 mites/seedling, as compared to 5, 10 and 15 mites/seedling ($F_{3,1} = 21.8$; $P \geq 0.05$). The mean number of mites on the 10th day after inoculation indicated that mites preferred 20-day-old seedlings (18.0 mites/seedling) than 30-day-old ones (10.5 mites/seedling) ($F_{1,2} = 29.7$; $P \geq 0.05$). Among the four varieties, the mites multiplied more on MDU₁ (11.7 mites/seedling), than on CO₁ (8.5 mites/seedling) and Annamalai (5.4 mites/seedling) and on Panruti (3.3 mites/seedling).

Effect of different mite loads at different stages of crop growth and time of introduction on plant characters and yield components in four varieties

Mite population build up

Mites inoculated at different densities multiplied greatly on the MDU₁ variety and least on Panruti ($F_{8,4} = 2.18$; $P > 0.05$) (Table 2). The other two varieties, i.e. CO₁ and Annamalai were found to be intermediate.

Effect on plant height

The effect of different mite loads on certain plant characters such as plant height showed a significant

Table 1. Effect of initial mite infestation level and seedling age on mortality of four varieties of eggplant (mean number of five replicates)

Seedling age (days)	Infestation level (mites/leaf)	No. of dead seedlings(\pm SD)				Age mean	Mite load mean
		MDU ₁	CO ₁	Annamalai	Panruti		
20	Control	0.0	0.0	0.2 \pm 0.8	0.0	1.2 \pm 1.0 b	0.0 \pm 0.2 a
	2	1.0 \pm 0.3	0.6 \pm 0.2	0.4 \pm 1.2	0.0		0.5 \pm 0.4 b
	5	1.8 \pm 1.7	1.4 \pm 1.9	1.0 \pm 0.4	0.2 \pm 0.8		1.0 \pm 1.2 c
	10	3.0 \pm 2.8	1.8 \pm 2.6	1.4 \pm 0.7	0.8 \pm 0.5		1.8 \pm 1.6 d
	15	4.0 \pm 1.5	2.6 \pm 3.6	2.0 \pm 1.3	1.0 \pm 0.2		2.4 \pm 1.4 e
30	Control	0.0	0.2 \pm 0.5	0.0	0.0	0.7 \pm 1.1 a	0.0 \pm 0.1 a
	2	0.6 \pm 0.7	0.4 \pm 1.2	0.2 \pm 1.6	0.0		0.3 \pm 0.8 b
	5	0.9 \pm 1.4	0.8 \pm 1.8	0.4 \pm 0.2	0.0		0.5 \pm 0.8 c
	10	1.6 \pm 2.3	1.2 \pm 2.8	0.8 \pm 2.0	0.4 \pm 0.2		1.0 \pm 1.8 d
	15	2.8 \pm 1.8	2.0 \pm 3.1	1.0 \pm 1.7	0.8 \pm 1.7		1.7 \pm 2.0 e
Variety mean		1.6 \pm 1.2 d	1.0 \pm 1.7 c	0.7 \pm 0.9 b	0.3 \pm 0.3 a		

Means with similar letters do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).

Table 2. Mean number of mites on four varieties of eggplant with various initial levels of mite infestation (mean number of five replicates)

Plant age (days)	Infestation level (mites /leaf)	No. of mites/cm ² leaf area (\pm SD)				Age mean	Mite load mean
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	0.8 \pm 1.2 a	0.4 \pm 0.2 a	0.2 \pm 0.1 a	0.0 a	6.5 \pm 3.7 d	0.3 \pm 0.3 a
	2	9.2 \pm 4.3 c	7.3 \pm 3.5 b	2.8 \pm 1.4 a	2.2 \pm 1.3 a		5.3 \pm 2.6 b
	5	11.4 \pm 9.3 d	9.3 \pm 3.8 c	4.5 \pm 2.5 b	3.0 \pm 2.1 a		7.0 \pm 4.4 c
	10	14.5 \pm 6.5 d	11.4 \pm 6.2 c	6.3 \pm 3.7 b	4.2 \pm 3.1 a		9.1 \pm 4.8 d
	15	16.0 \pm 11.0 d	13.5 \pm 8.9 c	8.2 \pm 4.2 b	5.0 \pm 2.4 a		10.6 \pm 6.6 e
45	Control	0.0 a	0.0 a	0.2 \pm 0.1 a	0.0 a	4.9 \pm 3.2 c	0.0 \pm 0.0 a
	2	7.6 \pm 6.1 c	4.8 \pm 1.6 b	1.4 \pm 0.8 a	1.2 \pm 0.3 a		3.7 \pm 2.2 b
	5	10.3 \pm 11.3 c	6.0 \pm 2.2 b	2.6 \pm 1.4 a	2.0 \pm 1.1 a		5.2 \pm 4.0 c
	10	12.8 \pm 10.2 d	7.8 \pm 6.1 c	4.3 \pm 2.1 b	3.2 \pm 2.4 a		7.0 \pm 5.2 d
	15	14.5 \pm 8.6 d	9.5 \pm 4.6 c	6.2 \pm 3.3 b	4.2 \pm 2.2 a		8.6 \pm 4.6 e
55	Control	0.2 \pm 0.4 a	0.0 a	0.0 a	0.2 \pm 0.1 a	3.4 \pm 2.3 b	0.1 \pm 0.1 a
	2	5.8 \pm 2.8 c	2.6 \pm 1.2 b	1.3 \pm 1.1 a	0.8 \pm 0.2 a		2.6 \pm 1.3 b
	5	7.3 \pm 4.6 c	3.8 \pm 2.6 b	2.2 \pm 2.0 a	1.4 \pm 1.2 a		3.6 \pm 2.6 c
	10	8.5 \pm 6.6 c	5.4 \pm 4.9 b	2.8 \pm 1.8 a	2.2 \pm 2.1 a		4.7 \pm 3.8 d
	15	10.3 \pm 8.2 d	7.0 \pm 3.1 c	4.0 \pm 1.4 b	3.0 \pm 2.4 a		6.0 \pm 3.7 e
65	Control	0.6 \pm 0.4 a	0.4 \pm 0.3 a	0.0 a	0.0 a	2.5 \pm 1.2 a	0.2 \pm 0.1 a
	2	4.2 \pm 3.1 b	1.8 \pm 1.1 a	1.0 \pm 0.1 a	0.4 \pm 0.6 a		1.8 \pm 1.2 b
	5	5.3 \pm 2.8 c	2.6 \pm 1.5 b	1.6 \pm 0.0 a	1.0 \pm 0.2 a		2.6 \pm 1.1 c
	10	6.8 \pm 3.3 c	3.4 \pm 2.2 b	2.0 \pm 1.3 a	1.8 \pm 1.2 a		3.5 \pm 2.0 d
	15	7.4 \pm 1.4 d	5.3 \pm 1.9 c	3.2 \pm 2.1 b	2.0 \pm 0.8 a		4.4 \pm 1.5 e
Variety mean ⁺		7.6 \pm 5.1 d	5.1 \pm 2.7 c	2.7 \pm 1.4 b	1.8 \pm 1.1 a		

Means with similar letters do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).

⁺The values are mean percentage reduction from control.

reduction in height among the four varieties, mite loads and the age of the crop at infestation. Plants exposed to the highest mite load of 15 mites/leaf suffered highest reduction ($F_{3,1} = 13.63$; $P \geq 0.05$) (Table 3). Among the four varieties, MDU₁ showed the highest reduction in height, while Panruti the lowest ($F_{8,4} = 12.75$; $P > 0.05$). The effect of mites was more pronounced when infestations were initiated during the early crop stage. The height reduction decreased considerably with plant age at infestation and was minimal on 65-day-old seedlings. The variety, growth stage and different levels of infestation interacted and their influence on the reduction on plant height was significant ($F_{47,2} = 32.36$; $P \geq 0.05$).

Effect on the total number of leaves

The number of leaves decreased significantly with increasing mite loads (Table 4). Plant age at infestation influenced the level of damage and the percentage leaf reduction was higher in plants infested at 35 than at 65 days ($F_{4,1} = 11.73$; $P \geq 0.05$). The plants exposed to the highest mite load showed significantly ($F_{3,1} = 10.23$; $P \geq 0.05$) greatest reduction in the number of leaves compared to the control plants. Of the four varieties, MDU₁ showed the highest reduction while Panruti the lowest

($F_{8,4} = 15.56$; $P \geq 0.05$). The effect of the mites was more pronounced during the early stage of the crop, where a huge reduction in leaves was observed. The effect decreased with increasing height and age of the plants.

Effect on the total number of flowers

Plants inoculated with 15 mites/leaf showed the highest reduction in total number of flowers ($F_{3,1} = 10.76$; $P \geq 0.05$) (Table 5). The effect of mites was more pronounced during the early stage of the crop where a huge reduction in number of flowers was observed ($F_{4,1} = 14.35$; $P \geq 0.05$).

Effect on the total number of fruits

Plants inoculated with 15 mites/leaf showed a higher reduction ($F_{3,1} = 13.31$; $P \geq 0.05$) in the total number of fruits compared to that observed in control plants (Table 6). Among the four varieties, MDU₁ suffered the highest fruit reduction and Panruti the lowest ($F_{8,4} = 10.63$; $P \geq 0.05$). The effect of mites was more pronounced during the early stage of the crop where a considerable reduction in fruit number was observed ($F_{4,1} = 10.27$; $P \geq 0.05$).

Table 3. Effect of mite load and initial seedling age on plant height in four varieties of eggplant (mean number of five replicates)

Plant age (days)	Infestation level (mites/leaf)	Mean plant height (cm) (\pm SD)				Age mean ⁺	Mite load mean ⁺
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	82.2 \pm 24.3	86.8 \pm 32.7	78.0 \pm 17.2	76.4 \pm 23.1	35 d	–
	2	40.3 \pm 18.7	56.5 \pm 28.9	59.3 \pm 10.5	64.2 \pm 26.9		31 a
	5	38.7 \pm 27.9	53.9 \pm 16.2	57.8 \pm 11.9	64.2 \pm 22.6		33 b
	10	37.0 \pm 22.1	52.1 \pm 25.2	55.4 \pm 18.5	61.2 \pm 18.4		36 c
	15	35.4 \pm 19.7	49.5 \pm 27.1	53.9 \pm 21.7	60.4 \pm 25.2		38 d
45	Control	80.6 \pm 28.7	85.2 \pm 19.4	76.4 \pm 23.8	75.3 \pm 27.6	27 c	–
	2	46.8 \pm 27.1	64.8 \pm 24.1	61.9 \pm 19.3	67.7 \pm 21.9		23 a
	5	46.0 \pm 11.2	63.1 \pm 21.8	61.2 \pm 25.1	66.2 \pm 22.7		25 b
	10	43.6 \pm 26.2	62.2 \pm 19.7	59.6 \pm 16.3	64.8 \pm 19.9		27 c
	15	41.2 \pm 14.8	68.5 \pm 12.9	57.3 \pm 21.1	63.3 \pm 14.7		30 d
55	Control	79.4 \pm 23.1	88.4 \pm 21.3	79.3 \pm 22.2	76.8 \pm 11.6	19 b	–
	2	58.8 \pm 21.9	71.7 \pm 19.7	69.8 \pm 16.6	72.2 \pm 19.6		16 a
	5	56.4 \pm 15.1	70.8 \pm 16.5	67.5 \pm 23.3	70.7 \pm 14.4		18 b
	10	54.8 \pm 18.5	69.0 \pm 14.1	65.1 \pm 19.6	69.2 \pm 22.1		20 c
	15	52.5 \pm 11.2	68.1 \pm 15.3	62.7 \pm 12.2	66.9 \pm 19.2		23 d
65	Control	83.2 \pm 23.4	86.0 \pm 19.9	78.8 \pm 27.1	78.4 \pm 18.8	13 a	–
	2	69.9 \pm 21.6	75.7 \pm 11.5	72.5 \pm 22.6	77.6 \pm 15.3		9 a
	5	67.4 \pm 17.3	74.0 \pm 18.8	70.2 \pm 16.4	76.0 \pm 11.5		12 b
	10	65.8 \pm 19.4	72.3 \pm 15.3	68.6 \pm 12.8	74.3 \pm 12.0		14 c
	15	63.3 \pm 10.5	71.4 \pm 11.6	65.5 \pm 10.5	72.9 \pm 21.3		16 d
Variety mean ⁺		37 d	25 c	19 b	11 a		

Means with similar letters in the same column and row do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).
⁺The values are mean percentage reduction from control.

Table 4. Effect of mite load and initial age on number of leaves in four varieties of eggplant (mean number of five replicates)

Plant age (days)	Infestation level (mites/leaf)	Mean number of leaves (\pm SD)				Age mean ⁺	Mite load mean ⁺
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	36.4 \pm 9.4	42.2 \pm 8.7	38.0 \pm 11.2	32.8 \pm 12.6	32 d	–
	2	16.4 \pm 5.4	29.5 \pm 7.2	30.4 \pm 8.9	29.2 \pm 11.0		29 a
	5	15.7 \pm 7.2	28.7 \pm 11.3	29.2 \pm 7.5	28.5 \pm 9.6		31 b
	10	15.3 \pm 4.9	27.8 \pm 6.3	29.2 \pm 9.7	27.5 \pm 8.2		33 c
	15	14.5 \pm 3.8	26.5 \pm 8.1	28.1 \pm 7.6	27.2 \pm 9.7		35 d
45	Control	38.8 \pm 11.4	43.4 \pm 12.5	36.4 \pm 11.5	34.2 \pm 10.4	23 c	–
	2	25.2 \pm 8.7	33.4 \pm 9.7	31.3 \pm 8.7	31.4 \pm 8.9		20 a
	5	24.2 \pm 6.4	32.9 \pm 8.1	30.9 \pm 7.3	30.4 \pm 7.7		22 b
	10	23.6 \pm 10.8	31.6 \pm 11.4	30.2 \pm 4.3	30.4 \pm 13.3		24 c
	15	22.5 \pm 9.2	30.3 \pm 8.6	29.18.6	30.1 \pm 9.2		26 d
55	Control	34.2 \pm 11.5	42.0 \pm 15.3	37.2 \pm 13.1	32.0 \pm 14.2	17 b	–
	2	25.6 \pm 9.6	35.7 \pm 8.7	33.8 \pm 12.4	30.7 \pm 10.6		13 a
	5	24.6 \pm 7.7	34.8 \pm 8.9	32.3 \pm 12.6	29.4 \pm 8.7		17 b
	10	24.2 \pm 6.3	33.6 \pm 4.7	31.2 \pm 7.7	28.8 \pm 6.5		19 c
	15	23.6 \pm 8.9	32.0 \pm 12.8	30.8 \pm 9.4	28.4 \pm 8.6		21 d
65	Control	35.4 \pm 12.6	40.8 \pm 12.7	38.4 \pm 13.4	35.4 \pm 11.4	11 a	–
	2	30.0 \pm 9.5	36.7 \pm 9.6	35.7 \pm 7.6	35.4 \pm 10.7		8 a
	5	29.0 \pm 11.7	36.3 \pm 11.1	34.5 \pm 9.7	35.0 \pm 9.2		10 b
	10	28.3 \pm 7.6	35.5 \pm 13.2	33.8 \pm 11.3	35.0 \pm 7.6		12 c
	15	27.6 \pm 9.7	34.2 \pm 8.7	33.0 \pm 8.8	34.6 \pm 11.1		14 d
Variety mean ⁺		36 d	23 c	16 b	8 a		

Means with similar letters in the same column and row do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).
⁺The values are mean percentage reduction from control.

Table 5. Effect of mite load and initial age on number of flowers in four varieties of eggplant (mean number of five replicates)

Plant age (days)	Infestation level (mites/leaf)	Mean number of flowers (\pm SD)				Age mean ⁺	Mite load mean ⁺
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	62.4 \pm 18.3	58.0 \pm 13.8	71.2 \pm 21.1	65.4 \pm 12.5		–
	2	11.9 \pm 8.6	37.2 \pm 11.8	57.0 \pm 18.4	58.9 \pm 17.2	40 d	37 a
	5	11.3 \pm 11.6	35.4 \pm 14.2	54.9 \pm 13.5	57.6 \pm 21.1		39 b
	10	9.4 \pm 4.3	34.8 \pm 10.6	52.7 \pm 11.9	57.6 \pm 16.3		41 c
	15	7.5 \pm 2.1	33.7 \pm 11.5	50.6 \pm 13.3	56.9 \pm 16.3		43 d
Control	62.8 \pm 18.7	58.4 \pm 13.5	70.4 \pm 15.4	67.3 \pm 17.5	–		
45	2	30.8 \pm 9.6	46.8 \pm 10.7	59.2 \pm 13.3	62.6 \pm 16.6	26 c	23 a
	5	29.6 \pm 10.4	45.0 \pm 14.3	57.8 \pm 16.4	62.6 \pm 15.8		25 b
	10	27.7 \pm 8.5	43.8 \pm 15.4	57.1 \pm 12.2	62.0 \pm 20.5		27 c
	15	25.2 \pm 7.4	42.7 \pm 11.5	55.7 \pm 15.4	61.3 \pm 19.7		30 d
	Control	60.2 \pm 21.5	59.4 \pm 14.8	72.4 \pm 18.6	66.4 \pm 14.7		–
55	2	39.2 \pm 18.7	50.9 \pm 17.5	65.2 \pm 15.6	63.8 \pm 17.3	20 b	16 a
	5	37.4 \pm 14.4	48.8 \pm 11.7	64.5 \pm 14.3	63.1 \pm 11.5		18 b
	10	36.2 \pm 19.7	47.0 \pm 14.4	63.0 \pm 11.7	63.1 \pm 13.3		20 c
	15	28.3 \pm 13.2	46.4 \pm 10.7	61.6 \pm 12.8	62.5 \pm 15.4		24 d
	Control	63.2 \pm 22.1	58.2 \pm 16.5	70.3 \pm 15.9	65.2 \pm 14.3		–
65	2	53.8 \pm 18.7	53.6 \pm 13.9	66.8 \pm 13.3	64.5 \pm 10.5	10 a	7 a
	5	51.9 \pm 10.6	52.4 \pm 16.5	64.0 \pm 15.6	64.5 \pm 15.9		9 b
	10	50.6 \pm 8.7	51.3 \pm 17.4	64.0 \pm 18.6	63.3 \pm 13.6		11 c
	15	50.0 \pm 11.2	50.7 \pm 11.7	61.9 \pm 13.5	62.6 \pm 14.7		13 d
	Variety mean ⁺	50 d	23 c	16 b	7 a		

Means with similar letters in the same column and row do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).

⁺The values are mean percentage reduction from control.

Effect on the total fruit weight

The total weight of the fruits harvested under various mite infestation levels is shown in Table 7. The reduction in fruit weight was significantly ($F_{4,7} = 25.17$; $P \geq 0.05$) influenced by the pest load, variety and age of plants at time of exposure. The plants exposed to the highest mite load showed the highest reduction in fruit weight compared to that of control plants ($F_{3,1} = 18.43$; $P \geq 0.05$). The effect of mites was highest during the early growth stage, and lowest in 65-day-old plants ($F_{4,1} = 22.19$; $P \geq 0.05$).

Discussion

Little information is available on the damage potential of *T. ludeni* on crops. Pande *et al.* (1989) reported briefly on the nature of damage and on seasonal occurrence and host preference of *T. ludeni* on peach and *Amaranthus* spp. in the Canary Islands, west of Morocco. Reddy and Baskaran (1991) reported that eggplant variety MDU₁ appears to be susceptible to *T. ludeni* attack, followed by CO₁, Annamalai and Panruti.

In the present study, variety MDU₁ suffered the highest seedling mortality, whereas Panruti suffered the least. Mite survival and population

growth was highest on MDU₁, and lowest on Panruti. Grazzini *et al.* (1997) reported that diploid zonal geraniums (*Pelargonium* \times *hortorum*) are able to resist attack by the two-spotted spider mite, *T. urticae* when exudates produced by all the glandular trichomes contain a high percentage of unsaturated anacardic acids. These workers also pointed out that trichomes of susceptible plants exude primarily saturated anacardic acids. Zeleny *et al.* (1997) reported that the Siberian medicinal plant *Leuzea carthamoides* (Willd.) (Asteraceae) is known to be resistant to attack by many herbivorous arthropods, including mites as this plant contains a very high concentration of ecdysteroids (equivalent of 300–1000 ppm of 20-hydroxyecdysone) in the leaves. Chatzivasileiadis and Sabelis (1998) also reported that secondary plant compounds, including 2-tridecanone, mediate the resistance of tomato and cucumber plants to *T. urticae*. Goncalves *et al.* (1998) found that tomato *Lycopersicon hirsutum* f. *glabratum* is highly resistant to spider mites such as *T. urticae* and *T. ludeni* because of the high contents of 2-tridecanone (2-TD) and other methyl ketones in the leaves. Therefore, the mechanisms underlying tolerance, or resistance (antibiosis/antixenosis) to mite attack in Panruti need to be investigated. Reddy and Biradar (1990) also reported that Panruti suffered least from the

Table 6. Effect of mite load and initial age on number of fruits in four varieties of eggplant (mean number of five replicates)

Plant age (days)	Infestation level (mites/leaf)	Mean number of fruits (\pm SD)				Age mean ⁺	Mite load mean ⁺
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	43.4 \pm 10.5	38.0 \pm 11.4	48.4 \pm 13.4	50.2 \pm 15.3	42 d	–
	2	12.2 \pm 4.2	19.4 \pm 6.3	36.3 \pm 11.3	45.2 \pm 14.3		39 a
	5	11.3 \pm 2.2	19.0 \pm 8.7	35.4 \pm 12.5	44.2 \pm 17.6		41 b
	10	10.5 \pm 3.1	17.5 \pm 4.3	34.9 \pm 15.3	43.2 \pm 13.3		43 c
	15	9.6 \pm 4.5	16.8 \pm 5.4	33.4 \pm 10.1	42.7 \pm 16.1		45 d
45	Control	40.2 \pm 14.3	39.4 \pm 11.2	46.2 \pm 10.4	51.8 \pm 15.3	30 c	–
	2	16.5 \pm 8.7	27.6 \pm 9.8	38.9 \pm 12.4	47.7 \pm 18.1		28 a
	5	16.5 \pm 6.4	26.4 \pm 7.6	37.5 \pm 15.6	47.7 \pm 16.1		30 b
	10	15.3 \pm 8.9	25.7 \pm 10.5	37.0 \pm 16.5	47.2 \pm 12.6		32 c
	15	14.5 \pm 3.5	24.9 \pm 9.7	36.1 \pm 13.2	46.7 \pm 16.2		34 d
55	Control	38.5 \pm 11.1	37.2 \pm 12.3	45.8 \pm 15.5	48.2 \pm 11.6	20 b	–
	2	25.1 \pm 9.8	29.8 \pm 7.8	41.3 \pm 16.3	46.3 \pm 18.4		17 a
	5	24.3 \pm 5.6	29.1 \pm 10.7	40.4 \pm 10.4	45.8 \pm 19.3		19 b
	10	23.5 \pm 8.7	28.7 \pm 8.6	39.9 \pm 13.2	45.8 \pm 10.5		20 bc
	15	22.8 \pm 9.6	27.9 \pm 6.5	38.6 \pm 10.5	45.4 \pm 21.1		22 d
65	Control	41.4 \pm 13.3	40.8 \pm 14.3	46.4 \pm 17.4	50.4 \pm 17.5	11 a	–
	2	34.4 \pm 8.4	36.4 \pm 8.7	43.7 \pm 12.4	49.9 \pm 18.4		9 a
	5	32.8 \pm 8.7	36.0 \pm 10.7	42.7 \pm 15.4	49.4 \pm 14.4		11 b
	10	31.9 \pm 10.6	35.1 \pm 9.7	41.8 \pm 15.3	49.4 \pm 20.2		12 bc
	15	31.9 \pm 8.7	34.3 \pm 13.2	41.3 \pm 10.4	48.8 \pm 18.6		14 d
Variety mean ⁺		49 d	30 c	17 b	7 a		

Means with similar letters in the same column and row do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).
⁺The values are mean percentage reduction from control.

Table 7. Effect of mite load and initial age on fruit weight in four varieties of eggplant (mean number of five replicates)

Plant age (days)	Infestation level (mites/leaf)	Mean fruit weight (kg) (\pm SD)				Age mean ⁺	Mite load mean ⁺
		MDU ₁	CO ₁	Annamalai	Panruti		
35	Control	5.2 \pm 1.6	4.8 \pm 2.7	5.4 \pm 3.4	5.6 \pm 2.8	42 d	–
	2	1.4 \pm 0.7	2.4 \pm 1.4	4.2 \pm 1.8	5.0 \pm 3.2		39 a
	5	1.3 \pm 0.6	2.3 \pm 0.2	3.9 \pm 0.7	4.9 \pm 2.1		42 b
	10	1.2 \pm 2.1	2.1 \pm 0.6	3.8 \pm 1.0	4.8 \pm 1.8		43 bc
	15	1.0 \pm 0.8	2.0 \pm 1.8	3.6 \pm 0.8	4.8 \pm 1.5		45 d
45	Control	4.9 \pm 1.7	5.0 \pm 1.7	5.5 \pm 2.1	5.2 \pm 2.4	32 c	–
	2	2.0 \pm 1.8	3.5 \pm 2.3	4.6 \pm 1.6	4.9 \pm 1.9		29 a
	5	1.9 \pm 0.7	3.3 \pm 1.3	4.5 \pm 2.3	4.8 \pm 2.1		31 b
	10	1.8 \pm 1.2	3.2 \pm 0.8	4.3 \pm 1.6	4.8 \pm 0.7		32 bc
	15	1.6 \pm 1.4	3.0 \pm 1.3	4.1 \pm 3.2	4.7 \pm 1.7		35 d
55	Control	5.4 \pm 2.1	5.2 \pm 1.5	5.2 \pm 1.6	5.4 \pm 0.8	21 b	–
	2	3.4 \pm 1.7	4.0 \pm 1.7	4.6 \pm 2.4	5.2 \pm 2.3		19 a
	5	3.3 \pm 1.4	4.0 \pm 2.1	4.4 \pm 1.6	5.2 \pm 1.8		20 ab
	10	3.1 \pm 0.7	3.9 \pm 1.9	4.4 \pm 2.1	5.0 \pm 2.2		21 bc
	15	3.0 \pm 1.2	3.7 \pm 2.5	4.2 \pm 0.8	5.0 \pm 1.6		23 d
65	Control	4.8 \pm 1.7	4.6 \pm 1.2	5.0 \pm 2.3	5.3 \pm 3.2	12 a	–
	2	3.9 \pm 2.1	4.0 \pm 1.8	4.7 \pm 2.1	5.2 \pm 2.3		9 a
	5	3.8 \pm 1.7	4.0 \pm 2.5	4.5 \pm 1.8	5.1 \pm 1.8		11 b
	10	3.6 \pm 1.9	3.8 \pm 3.3	4.4 \pm 2.2	5.1 \pm 1.5		13 c
	15	3.5 \pm 2.3	3.8 \pm 1.8	4.4 \pm 1.6	5.0 \pm 0.6		14 cd
Variety mean ⁺		50 d	32 c	18 b	7 a		

Means with similar letters in the same column and row do not vary significantly ($P \geq 0.05$; LSD test, three-way ANOVA).
⁺The values are mean percentage reduction from control.

cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), compared to other eggplant varieties. Hence, Panruti seems the most suitable variety for cultivation in areas where this mite is a threat.

Twenty-day-old eggplant seedlings were more susceptible to mite attack than 30-day-old ones. These results agree with those of Amarnath Bapu (1980), who noted that *T. cinnabarinus* attacks mostly young eggplant leaves. A similar preference for younger leaves was found in cotton with the spider mite *T. ludeni*, by Duncombe (1977).

The present results also indicate that mite infestation during the early stage of plant growth causes more pronounced effects than infestation of mid- or late-season crops. Infestation on 35-day-old plants caused the highest reduction in plant height, number of leaves, flowers and fruits and fruit weight, compared to 45- and 65-day-old plants. The longer period of damage is likely to result in greater depletion of nutrients and a higher loss of chlorophyll. This agrees with results by Furr and Pfrimmer (1968), Mistris (1969), Schuster (1975), Duncombe (1977) and Amarnath Bapu (1980).

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References

- Amarnath Bapu T. R. (1980) Studies on the ecology and damage potential of the spider mite (*Tetranychus cinnabarinus* Boisduval) on the eggplant (*Solanum melongena* L.), MSc (Agric) Thesis. Tamil Nadu Agricultural University, Coimbatore.
- Brito R. M., Stern V. M. and Sances F. V. (1986) Physiological response of cotton plants to feeding of three *Tetranychus* spider mite species (Acari: Tetranychidae). *Journal of Economic Entomology* 79, 1217–1220.
- Canerday T. D. and Arant F. S. (1964) The effect of late season infestations of the strawberry spider mite *Tetranychus atlanticus* on cotton production. *Journal of Economic Entomology* 57, 931–933.
- Channabasavanna G. P. (1971) The present status of our knowledge of Indian plant feeding mites, pp. 201–204. In *Proceedings of the 3rd International Congress of Acarology, Prague* (Edited by M. Daniel and B. Rosicky). The Hague.
- Chatzivasilieiadis E. and Sabelis M. W. (1998) Variability in susceptibility among cucumber and tomato strains of *Tetranychus urticae* Koch to 2-tridecanone from tomato trichomes: Effects of host plant shift. *Experimental and Applied Acarology* 22, 455–466.
- Choudhury B. (1967) *Vegetables*. National Book Trust, New Delhi. 214 pp.
- Duncombe W. G. (1977) Cotton losses caused by spider mites (Acarina: Tetranychidae). *Rhodesia Agriculture Journal* 74, 141–146.
- Edelstein M., Tadmor Y., Abo-Moch F. and Mansour F. (2000) The potential of *Lagenaria* rootstock to confer resistance to the carmine spider mite, *Tetranychus cinnabarinus* (Acari: Tetranychidae) in Cucurbitaceae. *Bulletin of Entomological Research* 90, 113–117.
- Elzen G. W. and Hardee D. D. (2003) Managing insect resistance to insecticides. *Pest Management Science* 59, 770–776.
- Furr R. E. and Pfrimmer T. R. (1968) Effects of early, mid and late season infections of two spotted spider mites on the yield of cotton. *Journal of Economic Entomology* 61, 1446–1447.
- Goncalves M. I. F., Maluf W. R., Gomes L. A. A. and Barbosa L. V. (1998) Variation of 2-tridecanone level in tomato plant leaflets and resistance to two mite species (*Tetranychus* sp.). *Euphytica* 104, 33–38.
- Goodwin S. (1990) Seasonal abundance and control of spider mites Tetranychidae infesting commercial strawberries in Coastal New South Wales, Australia. *Journal of the Australian Entomological Society* 29, 161–166.
- Grazzini R., Walters D., Harmon J., Hesk D. J., Cox-Foster D., Medford J., Craig R. and Mumma R. O. (1997) Inheritance of biochemical and morphological characters associated with two-spotted spider mite resistance in *Pelargonium hortorum*. *Journal of the American Society of Horticultural Science* 122, 373–379.
- Herron G. A., Edge V. E., Wilson L. J. and Rophail J. (1998) Organophosphate resistance in spider mites (Acari: Tetranychidae) from cotton in Australia. *Experimental and Applied Acarology* 22, 17–30.
- Inoune K. (1968) Effect of infestation of the citrus red mite, *Panonychus citri* (MCG) on the growth and yield of Kawano Natsu daidai trees (in Japanese). *Proceedings of the Association of Plant Protection Kyushu* 14, 51–53.
- Krantz G. W. (1971) *A Manual of Acarology*. Oregon State University, Oregon. 335 pp.
- Kumar V. and Sharma D. D. (1993) Bio-ecology and chemical control of spider mite, *Tetranychus ludeni* Zacher on okra. *Indian Journal of Plant Protection* 21, 68–71.
- Marchetti L. (1976) A mite on geranium. *Informatore Fitopatologico* 26, 16.
- Meyer M. K. P. and Rodriguez M. (1966) Acari associated with cotton in southern Africa. *Garcia de orta* 13, 1–33.
- Mistris W. J. Jr (1969) Damage by the strawberry spider mite to cotton when infestation commenced at the beginning, middle and end of flowering period. *Journal of Economic Entomology* 62, 192–195.
- Moutia L. M. (1958) Contribution to the study of some phytophagous Acarina and their predators in Mauritius. *Bulletin of Entomological Research* 49, 59–75.
- Oliveira C. A. L. De (1971) Study of the quantitative and qualitative damage caused by the attack of the two

- spotted spider mite, *Tetranychus urticae* (Acarina: Tetranychidae) on cotton. *Biologico* 37, 341–342.
- Oliveira C. A. L. De and Calcag Nolo G. (1975) The action of the mite *Tetranychus urticae* (Koch, 1836) in reducing the yield of cotton. *Biologico* 41, 307–327.
- Pande Y. D., Carnero A. and Hernandez M. (1989) Notes on biological observations on some unrecorded species of phytophagous and predatory mites in Canary Islands, North Atlantic Ocean. *Investigación Agraria: Producción y Protección Vegetales* 4, 275–282.
- Reddall A., Sadras V. O., Wilson L. J. and Gregg P. C. (2004) Physiological responses of cotton to two-spotted spider mite damage. *Crop Science* 44, 835–846.
- Reddy G. V. P. (2001) Comparative effectiveness of an integrated pest management system and other control tactics for managing the spider mite *Tetranychus ludeni* (Acari: Tetranychidae) on eggplant. *Experimental and Applied Acarology* 25, 985–992.
- Reddy G. V. P. and Biradar S. P. (1990) Varietal resistance of eggplant to *Aphis gossypii* Glover (Homoptera: Aphididae). *Advances in Plant Science* 3, 178–182.
- Reddy G. V. P. and Baskaran P. (1991) Biology and varietal preference of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) on four varieties of eggplant, *Solanum melongena* L. *Mysore Journal of Agricultural Science* 25, 331–334.
- Schuster M. F. (1975) Relative two-spotted spider mite damage to cultivars to *Gossypium* sp. *Journal of Economic Entomology* 68, 171–172.
- Tetsuo G. and Mitsuhiro K. (1997) Population dynamics of the citrus red mite *Panonychus citri* (McGregor) (Acari: Tetranychidae) in Japanese pear orchards. *Experimental and Applied Acarology* 21, 343–356.
- Wang J.-J., Zhao Z.-M. and Zhang J.-P. (2004) The host plant-mediated impact of simulated acid rain on the development and reproduction of *Tetranychus cinnabarinus* (Acari Tetranychidae). *Journal of Applied Entomology* 128, 397–402.
- Zeleny J., Havelka J. and Jan S. K. (1997) Hormonally mediated insect-plant relationship: Arthropod populations associated with ecdysteroid-containing plant *Leuzea carthamoides* (Asteraceae). *European Journal of Entomology* 94, 183–198.