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EFFECTS OF FEEDING OF BROAD MITE (ACARI: TARSONEMIDAE) ON VEGETATIVE PLANT GROWTH

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The broad mite, *Polyphagotarsonemus latus* (Banks), is a polyphagous pest that has been reported on more than 100 different plant species including crops such as cotton, beans, citrus, potatoes, mango, papaya and several ornamental plant species (Schoonhoven et al. 1978, Beattie & Gellatley 1983, Aubert et al. 1981, Hooper 1957, Nemestothy et al. 1982, Laffi 1982). Because of this mite's short generation time (approx. 5 days), high fecundity, small size and protected habitat, the injury it produces is often confused with diseases and phytotoxicity. Jeppson et al. (1975) reported that some of the plant symptoms following broad mite attack were formerly considered to be due to various diseases including plant viruses (Aubert et al. 1981). Broad mite damage has also been confused with herbicide toxicity or micronutrient deficiency (Beattie & Gellatley 1983, Cross & Bassett 1982).

Gerson (1992) stated that the variety of symptoms on different hosts reflects specific plant reactions to the pest's feeding and putative toxins. Broad mites reduce market yield and injure plants by reducing and deforming leaves, flowers and fruits (Schoonhoven et al. 1978, Gerson 1992). Plants under heavy attack cease growing and die (Moutia 1958). Despite extensive descriptions of broad mite injury (Gerson 1992) the quantitative relationship between broad mite injury and reduction of vegetative plant growth has not been studied extensively.

The objective of this study was to relate broad mite injury to vegetative growth of potato (*Solanum tuberosum* L.), bean (*Phaseolus vulgaris* L.), lime [*Citrus aurantifolia* (Christ.) Swingle] and sour orange (*Citrus aurantium* L.).

Bean, potato, lime and sour orange plants were individually grown in 1 liter containers and kept in an air conditioned greenhouse with a temperature of 26 ± 2°C and relative humidity of 85-90%. Plant age at infestation was 3 and 4 weeks for bean and potato, respectively, and 3 and 4 months for lime and sour orange, respectively. Broad mite stock colonies were reared on pinto bean plants maintained under similar conditions as the treatment plants. Ten broad mite males and female pupae were individually transferred to all apical leaves of the treated plants. A set of uninfested plants of each species was used as a control. The number of motile mites present on a bean and potato upper leaf or on a lime and sour orange apical shoot were counted 1 week after infestation and infested again if less than 20 mites appeared per leaf.

The number of leaves per plant and plant height was assessed weekly for 4 consecutive weeks. Four weeks after infestation, leaf damage indices (Table 1), leaf area, fresh

TABLE 1. EVALUATION SCALES FOR BROAD MITE INJURY TO POTATO, BEAN, LIME AND SOUR ORANGE.

Plant Species	Injury Level	Type of Injury
Potato	0	No injury
	1	Light injury, some leaves curling, leaves show bronzing.
	2	Moderate injury, curling, leaves show bronzing.
	3	Heavy, leaf curled, necrosis, wilting.
	4	Death of terminal and lateral growing points.
Bean	0	No Injury
	1	Distal and adjacent leaves with a few faint silver spots.
	2	Shoot and/or nearby leaves slightly deformed or curled.
	3	Leaves curled, lower leaf surface, silvery.
	4	Leaves curled, necrotic spots, trifoliate upper leaves, severely deformed or reduced in size.
Lime	0	No injury, no mites observed.
	1	Mites observed, leaf dark green.
	2	Leaf margins slightly rolled downward, leaf yellowish-green.
	3	Leaf light yellow and withering; shoot deformed.
	4	Leaves turning brown, defoliation, death of shoots.
Sour Orange	0	No Injury
	1	Distal leaves slightly deformed.
	2	Distortion of leaves and/or shoots.
	3	Shoots completely deformed.
	4	Distortion of terminal and lateral growing points; death of shoots.

weight and dry weight of leaves were estimated. Leaf area was determined with a leaf area meter (LI-COR, Lambda Instruments Corporation, Lincoln, NE) and water content was determined by subtracting leaf dry weight from leaf fresh weight. Amount of vegetative growth was determined by dividing the dry leaf weight by the total leaf area. The increases in height and number of leaves were determined by subtracting the plant height and number of leaves observed on a given week from the numbers recorded during the prior week.

Differences in these parameters for infested and uninfested plants were determined by student t-test and a linear regression model (SAS 1987) was used to determine the relationship between leaf injury index and leaf area, number of leaves or shoots per plant, plant height and water content.

The responses of the different plant species to broad mite injury varied. Of the physical characteristics studied, leaf area was influenced most by broad mite injury, followed by water content, plant height and numbers of leaves per plant.

Potato. Mean height of plants exposed to broad mite was significantly less than the control plants through week 4 of the post-exposure period. Two weeks after infestation, more leaves were observed on the infested plants than on the control plants. This plant response might indicate that the broad mite reduces apical dominance on the infested plant two weeks after infestation, inducing lateral shoot growth. The number of leaves produced in infested or uninfested plants was similar 3-4 weeks after treatment. The average leaf area of uninfested potatoes was 2.01 times greater than the infested ones (Table 2). The results of the regression analysis of the visual injury index on vegetative growth are shown in Table 3. The slopes of the significant regressions were all negative, showed a reduction on potato height and leaf area, but indicated a poor fit (r^2 = 0.14 and 0.41, respectively). The levels of significance associated with number of leaves per plant and water content were inadequate ($P > 0.05$). Additional studies with other variables, e.g., photosynthesis and nitrogen leaf content (Schaffer et al. 1986 , Van de Vrie et al. 1972) are necessary to confirm these results.

TABLE 2. MEAN LEAF AREA AND LEAF WATER CONTENT FROM FOUR PLANT SPECIES INFESTED WITH BROAD MITE.[1]

Plant Species	Treatment	Leaf Area[2] (cm^2 ± SE)	Leaf Water Content[2] (g ± SE)
Potato	Infested	9.85 ± 1.74	6.63 ± 1.25
	Uninfested	19.83 ± 1.81***	7.58 ± 1.34 n.s.
Bean	Infested	36.21 ± 2.25	7.69 ± 0.85
	Uninfested	47.26 ± 3.34**	6.36 ± 0.42 n.s.
Lime	Infested	51.10 ± 8.76	1.00 ± 0.17
	Uninfested	146.24 ± 14.71*****	2.78 ± 0.31*****
Sour Orange	Infested	36.91 ± 3.33	0.55 ± 0.07
	Uninfested	52.72 ± 5.99*	1.17 ± 0.15****

[1]Numbers followed by an asterisk were significantly different; t-test;
*P=0.02; **P=0.01; ***P=0.003; ****P=0.001; *****P=0.0001.

Bean. Exposure of bean to broad mites resulted in an immediate increase in plant height 1 week after exposure compared to control plants, but the infested plants were shorter than the control plants 2 through 4 weeks after treatment. The number of leaves per plant increased for infested plants two weeks after treatment and declined sharply 4 weeks after treatment for control and infested plants. In general, there were no differences in the amount of vegetative growth between infested and non-infested plants, but the mean leaf area was 1.30 times greater in non-infested plants than in the infested plants (Table 2). The results from this experiment indicated a significant ($r^2 = 0.43$; $P < 0.0001$) relationship between leaf area and injury level, and a poor fit between the visual injury index and number of leaves per plant ($r^2 = 0.12$; $P < 0.05$) (Table 3).

Lime. All lime plants exposed to broad mites grew and exhibited similar vegetative growth increases in comparison with the control plants. More leaves were observed on non-infested plants than on infested ones. The leaf area and water content per leaf was higher on mite-free lime plants than on mite-infested plants (Table 2). Linear regression analysis showed that the slopes of regression lines were negative for the different parameters, but the relationships were only significant for lime leaf area, water content and broad mite injury ($r^2 = 0.53$; $P < 0.001$ and $r^2 = 0.49$; $P < 0.0001$) (Table 3).

Sour Orange. No vegetative growth was observed for infested and non-infested sour orange plants 2 weeks and 5 weeks after treatment. Broad mite infested plants showed no increase in number of leaves 3 weeks after infestation but leaf number increased thereafter. The leaf area and water content were higher for the mite-free sour orange plants than for the infested ones (Table 2). However, a significant but poor relationship ($P < 0.05$; $r^2 = 0.20$) was only obtained between leaf water content and broad mite injury (Table 3). The results of the regressions were not significant for leaf area, leaves per plant and height.

Our investigation has shown that broad mite feeding appears to be an important factor in development of leaf area and amount of leaf water content of the plant species

TABLE 3. RELATIONSHIP BETWEEN BROAD MITE VISUAL INJURY INDEX (X) AND VEGETATIVE GROWTH OF FOUR HOST PLANTS.

Host Plant	y	a + bx	r^2	P	F
Potato	Height (cm)	23.16-1.31x	0.14	**[1]	8.54
	Leaves/plant	10.39-0.49x	0.03	ns	1.54
	Leaf area(cm^2)	21.12-3.49x	0.41	***	33.19
	Water content(g)	8.93-0.83x	0.06	ns	2.90
Bean	Height (cm)	25.26-0.32x	0.01	ns	0.67
	Leaves/plant	4.51-0.44x	0.12	**	6.48
	Leaf area(cm^2)	50.08-7.17x	0.43	***	36.17
	Water content(g)	6.94-0.18x	0.03	ns	0.19
Lime	Height (cm)	81.03-0.92x	0.01	ns	0.78
	shoots/plant	11.80-1.12x	0.01	ns	0.17
	Leaf area(cm^2)	151.00-40.81x	0.53	***	75.28
	Water content(g)	2.85-0.76x	0.49	***	63.21
Sour Orange	Height (cm)	35.29-0.99x	0.03	ns	1.55
	Leaves/plant	21.07-0.76x	0.07	ns	3.56
	Leaf area (cm^2	45.19-2.40x	0.02	ns	1.2
	Water content (g)	0.68-0.15x	0.20	**	10.64

[1]Significant level of regression; ns, not significant, $P<0.05$**, $P<0.005$***, df – 48.

studied. With the exception of potato, broad mite injury does not show a significant relationship with plant height or the number of leaves per plant. Differences in injury among the different plant species may be due to the ability of different species (i.e., woody plants versus herbaceous plants) to regenerate new leaves, to form new shoots if the species is injured or to the inherent ability of broad mites to induce damage response from these plant species. These hypotheses merit further research. We propose the delay in plant growth for some species was caused by reduction of photosynthetic area, stomatal conductance and leaf transpiration (Schaffer et al. 1986) due to feeding by broad mite. Because all experiments were terminated 5 weeks after exposure period, no effect on later stages of plant growth or yield was determined.

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Summary

Injury of vegetative growth of plants by the broad mite, *Polyphagotarsonemus latus* (Banks) has become a significant problem worldwide. A visual rating system was used to relate broad mite injury to potato, bean, lime and sour orange leaf area, height, water content and number of leaves per plant. In general, leaf area and leaf water content was reduced for most of the infested plant species, but the number of leaves per plant and plant height was not significantly related to broad mite injury.

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