# RELATIONSHIP OF BROAD MITE (ACARI: TARSONEMIDAE) TO HOST PHENOLOGY AND INJURY LEVELS IN *CAPSICUM ANNUUM*

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Abstract

The responses of broad mite, *Polyphagotarsonemus latus* Banks (Acarina: Tarsonemidae), were studied on four phenological stages of pepper plants: vegetative (V), blossoming (B), early fruiting (EF) and late fruiting (LF) stages. All stages of the mite preferred the undersides of the leaves to the uppersides. Plants in V, B, and EF stages had higher numbers of mites per $cm^2$ of foliage than plants in the late fruiting stage. A damage index scale (0-6) was developed to assess broad mite injury to pepper plants. Eight to nine cumulative mite days/$cm^2$ were needed to reach a damage index equal to 3 for V, B and EF plant stages. The damage index was also used to relate broad mite injury to leaf area, height, water content, number of leaves, flowers, buds, fruits and fruit weight of plants infested at four different phenological stages. Plants infested when 14 weeks old (late fruiting stage), had less damage, significantly higher number of fruits and fruit weight than plants infested at earlier plant stages, i.e., vegetative, flowering or early fruiting. The relationship between the damage rating (x) and fruit numbers per plant ($y_1$) and fruit weight in grams ($y_2$) was given by $y_1$ = 2.83-0.45x and $y_2$ = 232.5-37.234x, respectively.

Key Words: *Polyphagotarsonemus latus, Capsicum annum,* injury levels, green pepper

RESUMEN

Se estudió la respuesta de cuatro estados fenológicos (vegetativo (V), floración (F), fruta pequeña (EF) y fruta madura(LF)) de pimentón verde a el ataque del ácaro blanco, *Polyphagotarsonemus latus* Banks (Acarina: Tarsonemidae). Los ácaros prefirieron el envés a el haz de las hojas. Aquellas plantas en estado V, F y EF mantuvieron un número más alto de ácaros por $cm^2$ que aquellas plantas en estado LF. Se estableció una escala de daño del 0 al 6 para evaluar la acción del ácaro blanco en las plantas de pimentón. Un rango de 8 a 9 días cumulativos de ácaros son necesarios para causar un nivel de daño igual a 3 en plantas en estado V, F y EF. Las plantas en estado LF necesitan 6 días-ácaros /$cm^2$ para alcanzar un nivel de daño igual a 1. La escala de daño fué también utilizada para relacionar el daño causado por los ácaros y el area foliar, altura de la planta, contenido líquido, número de hojas, flores, yemas, frutos, y peso de frutos por plantas en los 4 estados fenológicos. Aquellas plantas infestadas cuando tienen 14 semanas, presentaron menor daño y un número significativamente mayor de frutas y peso de fruta, que plantas en estado V, B y EF. La relación entre la escala de daño (x) y el número de frutas ($y_1$) y el peso de fruta en gramos ($y_2$) está descrita por la ecuación: $y_1$ = 2.83-0.45x y $y_2$ = 232.5-37.234x, respectivamente.

Outbreaks of plant feeding tarsonemid mites often occur in vegetative, blossoming or early fruiting stages in the host plant (Jeppson et al. 1975). Because of the tarsonemid'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, Aubert et al. 1981, Cross and Bassett 1982). The impact of the broad mite, *Polyphagotarsonemus latus* (Banks) feeding has been qualitatively described for cotton, cucumber, potatoes, tomatoes, gerberas, beans, papaya, and pepper (Aubert et al. 1981, Bassett, 1981, Beattie & Gellatley 1983, Cross & Basset 1982, Hooper 1957, Laffi 1982, Lo & Chao 1972, Peña & Bullock 1994, Schoonhoven et al. 1978, Jeppson et al. 1975, Ochoa et al. 1994). While these observations suggest a causal relation to host phenology, quantitative assessment of actual impact of feeding by broad mite on growth, leaf area and yield is apparently not well correlated with levels of visible injury and with broad mite densities (Dhoria and Bindra, 1977, Jones & Brown 1983, Peña, 1990). We observed in commercial pepper, *Capsicum annuum* L., that rapid increases of broad mite numbers coincided with early stages of the plant. However, under field conditions it is difficult to determine whether enlarged broad mite populations on early vegetative or reproductive host plant stages resulted from an enhanced mite growth rate compounded over time, or from immigration from outside sources.

Our study was designed to (1) determine under greenhouse conditions the response of mite populations to host phenology in pepper and (2) to measure the impact of mite density on total yield, fruit number, number of leaves and flowers of different developmental stages of pepper plants.

## Materials and Methods

Pepper "Early Calwonder"was grown to the stages desired for testing in 3.78 l plastic pots. Plants were fertilized with 20-20-20 NPK, plus micronutrients. Treatments consisted of 15 plants at the vegetative stage(V) (ca. 5 weeks old), 15 plants at the blossoming stage (B) (ca. 7 weeks-old), 15 plants at the early fruiting stage (EF) (ca. 10 weeks old) and 15 plants at the late fruiting stage (LF) (ca. 14 weeks old). Treatments and the untreated controls were replicated 4 times and arranged in a randomized complete block design in a greenhouse maintained at 26 ± 2°C; 75-89% RH. Twelve adult broad mite females from a colony maintained on "Podsquad" garden bean plants, were placed on 2 apical leaves of each treated plant. One leaf was collected 4 days after exposure and thereafter every 4th day until 50 days after exposure from each pepper plant and the number of mites per $cm^2$ determined under a microscope. Levels of mite populations were measured in cumulative mite-days per $cm^2$ with 1 mite-d defined as one mite (any motile stage) per leaf for 1 d. Broad mite days were calculated as the sum of the two successive counts (mean number of mites/$cm^2$) divided by two and multiplied by the number of days between evaluations, and then summed over the evaluation period. It was assumed that the amount of physical injury (removal of cell contents) increased with the number of broad mite days; thus, the term is used interchangeably with injury. Leaf area, fresh weight, dry weight of leaves, were measured weekly during the growing season. 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.

### Damage Index Among Different Plant Ages:

A second experiment consisted of 30 broad mite-infested plants and 30 uninfested plants at four phenological ages (V, B, EF, LF), where the number of leaves, buds, flowers, fruit, fruit weight and mite days and damage index per plant was assessed weekly. To establish a damage index per plant, plants were separated into 6 categories of damage. The damage categories were defined as follows: Category 0.5: apical leaves have begun to curl; the mid vein has become sinuous and the color of the leaves has changed from shiny green to opaque green. Category 1: the mesophyl of the leaf undersides sunken; the basal portion of the apical leaves showed a light green color and the apical leaves curled down. Category 2: a bronze color is present in the apical leaves. If the apical leaves were large, bronzing was a characteristic of the leaf base. If the leaves were small, the leaves were completely bronzed and their tips necrosed. Floral buds were necrosed; leaf area was reduced and damage was observed in axillary leaves. Category 3: petioles of apical leaves have elongated and are thicker than uninfested ones and when stems were necrosed and bronzed, necrosis and/or hypertrophy were observed also in floral buds. Category 4: apical and lateral floral buds have proliferated but are deformed and hypertrophied and have failed to develop. Category 5: apical leaves have become necrotic and necrotic floral buds have aborted. A damage pattern similar to categories 1 to 4 is observed in lateral leaves and floral buds. Category 6:apical and lateral leaves show lignification, floral buds and flowers are hypertrophied and new leaves are necrotic. New leaves are observed but they show symptoms similar to categories 1 and 4. No fruits are observed or if present, they are deformed. Differences in these categories for infested and uninfested plants were determined by student-t-test (SAS 1987) and analysis of variance (ANOVA) was used to determine differences among plant stages.

Damage Index and Yield Reduction:

Fruit yields were determined by harvesting and weighing all peppers grown from each plant and calculating the total weight of the fruit per plant. Regression analysis was used to determine if there was a relationship between broad mite days ($x$) and damage index ($y$). Data were combined over four plant stages. The fruit weight (dependent variable) was also regressed on the damage index (independent variable). To establish injury levels, a linear regression model was used i.e., $y = a + bx$, where $y$ is the percentage of fruit weight reduction per plant, $x$ is the damage index per plant.

## Results and Discussion

Mite Dynamics Related to the Abaxial and Adaxial Leaf Surfaces:

Mites were first observed on the underside basal portion of the leaf near the mid and lateral veins. In general, number of broad mites were significantly higher 4 to 14 days after infestation; thereafter, densities remained below 93 broad mites per leaf (F = 2.78; $P$ = 0.0073; df = 11, 47; N = 59). Oviposition was first observed near the mid and secondary leaf veins but later continued at random on the leaf. During the first 8 days following infestation, higher *P. latus* densities were observed on the leaf underside. Maximum oviposition rate and maximum number of immature and mature stages were observed on the eighth day after infestation (Fig. 1, 2). When the number of eggs was > 200/cm$^2$ on the leaf underside, the number of females increased on the leaf upperside (Fig. 1A). This population trend might suggest that females search for a new habitat after the carrying capacity of the preferred habitat on the leaf underside has been reached. However, from the 19th through the 73rd day of the evaluation period, the proportion of broad mites on the leaf underside was always higher than on the leaf upperside (Fig 1, 2). This pattern may be due to the propensity of the mites to avoid sunlight or to avoid parts of the plant with low humidity. High light intensity, low humidity and high temperature combinations are unfavorable for *P. latus* (Jeppson et al. 1975, Jones & Brown 1983).

Mite Dynamics Related to Plant Age:

The number of mites feeding varied for different plant stages (F = 8.54; $P$ = 0.0001; df = 3, 226; N = 230)(Table 1). Even though the same number of females were allocated per plant, higher numbers of eggs deposited per cm$^2$ were observed on vegetative(V), blossoming (B) and early fruiting (EF) plant stages than on late fruiting stages (LF) (Table 1). The male to female ratio varied from 5: 1 for 5 week-old plants (V) to 3: 1 for the 7-14 week old plants (B, EF, LF). Mite populations on plants in V to EF stages increased significantly more than populations on LF stages of pepper (Fig. 3). These results strongly indicate that *P. latus* responds to some physiological change in the late

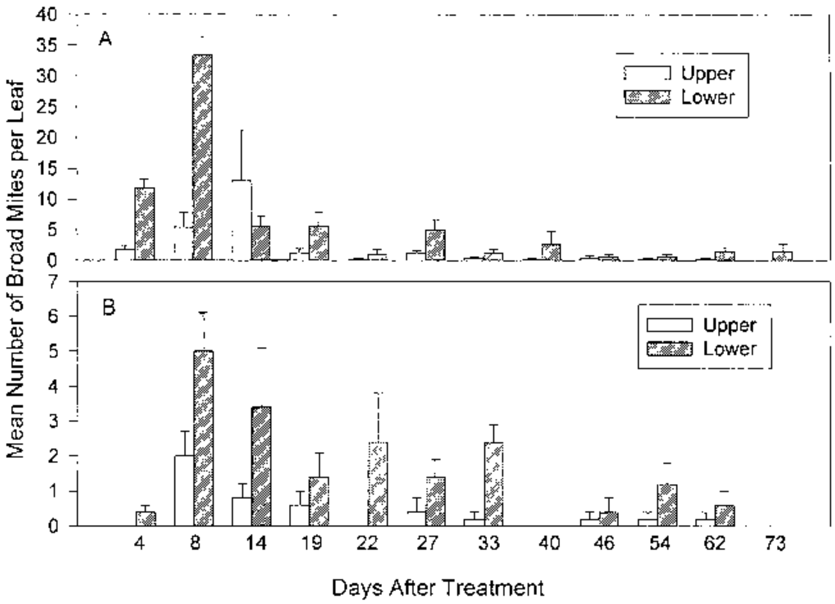


Fig. 1. Mean number of *P. latus* female(A) and male (B) on the upperside and underside of green pepper leaves recorded for 73 days after infestation.

fruiting stage of the plant. Peaks of mite abundance were observed during the first 14, 20, 7 and 20 days following infestation of vegetative, blossoming, early fruiting and late fruiting plants, respectively (Fig. 2).

Early fruiting stage plants had the highest numbers of mites/cm$^2$ and late fruiting plants had the lowest number of mites/cm$^2$. There were no significant differences in mites/cm$^2$ for V and B plant stages (Table 1). Apparently, tarsonemid mouthpart appendages are unsuitable for effective penetration of renitent tissues (Jeppson et al. 1975). Thus *P. latus* may not be able to puncture the more lignified tissues found in 14 week-old plants as opposed to those tissues in 5-10 week old plants. These data may

TABLE 1. COMPARISON OF AVERAGE NUMBER OF DIFFERENT BROAD MITE STAGES PER CM $^2$ ON THE LEAF UPPERSIDE AND LOWERSIDE ON FOUR GROWTH STAGES OF PEPPER.

| Plant Age (weeks) | Plant Stage | Mites /cm$^2$ | Eggs | Nymphs | Female | Male |
|---|---|---|---|---|---|---|
| 5 | V | 23.87b | 42.68a | 10.79b | 7.92ab | 2.05b |
| 7 | B | 24.19b | 39.84a | 11.22b | 7.36ab | 2.64b |
| 10 | EF | 45.13a | 52.27a | 23.38a | 13.29a | 4.88a |
| 14 | LF | 9.60c | 4.57b | 6.49b | 1.34c | 0.51c |

Numbers within the same column followed by the same letter were not significantly different (P > 0.05).

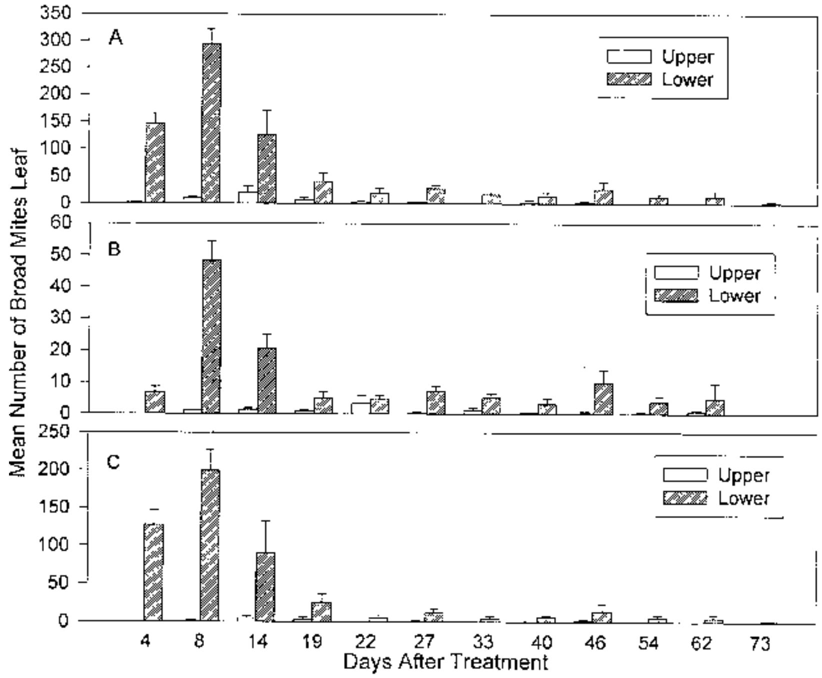


Fig. 2. Mean number of *P. latus* prelarvae (A), nymphs(B) and eggs (C) on the upperside and underside of green pepper leaves recorded for 73 days after infestation.

be of value in programs for evaluating resistance of peppers to *P. latus.* Thus, assessments of plant resistance to *P. latus* made at early growth stages of peppers would be particularly effective for identifying highly resistant plants.

Relationship between damage index and mite-day/cm$^2$:

The greenhouse experiment indicated that 9.24, 8.24 and 9.24 cumulative mite days/cm$^2$ are needed for 5, 7 and 10 day-old plants (V, B, EF stages) to reach an average damage index equal to 3.59, 2.56 and 3.02, respectively, whereas 6.31 mite days/cm$^2$ are necessary to reach a damage index equal to 0.98 for 14 week-old plants (LF stage) (Table 3).

Broad mites significantly reduced the increment in leaf sizes of infested plants compared to the control (Table 4). Fresh leaf weight was reduced for all plant stages, but significant reductions in dry weight were observed only for V and B plant stages. The levels of significance associated with soluble solids were reduced for V, B and EF plant stages. (Table 4). Table 5 shows that the numbers of leaves per plant, plant heights and numbers of fruit per plant were also affected by mite injury during all plant stages. The data suggest that broad mites reduce height in the infested plants, and that they induce lateral shoot growth (Table 5). The number of flowers and buds in V, B and EF plant stages was significantly reduced compared with the uninfested check plants, but corresponding reductions were not observed on LF plants (Table 5).

TABLE 2. CUMULATIVE NUMBER OF BROAD MITE DAYS AND AVERAGE DAMAGE RATING OF PEPPER PLANTS AT FOUR DIFFERENT PLANT STAGES.

| Plant Age (weeks) | Plant Stage | Cumulative Number of Mite Days | | | | | | | | Average Damage Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 7 | 14 | 20 | 26 | 33 | 46 | 50 DAI | |
| 5 | V | 1.40 | 5.08 | 7.42 | 8.12 | 8.14 | 8.99 | 9.13 | 9.24 | 3.59 |
| 7 | B | 1.33 | 3.52 | 5.17 | 6.77 | 7.96 | 8.21 | 8.22 | 8.24 | 2.56 |
| 10 | EF | 1.36 | 4.96 | 8.96 | 9.08 | 9.20 | 9.21 | 9.21 | 9.21 | 3.02 |
| 14 | LF | 1.12 | 2.24 | 6.24 | 6.28 | 6.29 | 6.31 | 6.31 | 6.31 | 0.98 |

DAI = Days after infestation.

TABLE 3. COMPARISON OF MEAN DAMAGE RATING, LEAF AREA, LEAF WATER CONTENT AND GROWTH OF PEPPER PLANTS INFESTED WITH BROAD MITE AT FOUR PLANT STAGES.

| Plant Age (weeks) | Plant Stage | Damage Rating | | Leaf Area/ leaf ($cm^2$) | | Leaf Fresh weight (g) | | Leaf Dry weight (g) | | Soluble Solids (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Infested | Control | Infested | Control | Infested | Control | Infested | Control | Infested | Control |
| 5 | V | 3.59a | 0.0b | 1.76b | 5.20a | 0.12b | 0.16a | 0.04b | 0.05a | 0.08b | 0.11a |
| 7 | B | 2.56a | 0.0b | 2.12b | 5.04a | 0.08b | 0.09a | 0.02b | 0.01a | 0.07b | 0.08a |
| 10 | EF | 3.02a | 0.0b | 5.22b | 9.94a | 0.18b | 0.25a | 0.03a | 0.02a | 0.16b | 0.23a |
| 14 | LF | 098a | 0.0b | 5.10b | 7.23a | 0.18b | 0.20a | 0.05a | 0.04a | 0.14a | 0.16a |

Means for each parameter within rows for each parameter, followed by the same letter are not significantly differently (t-test; P = 0.05)

TABLE 4. COMPARISON OF MEAN NUMBER OF LEAVES, PLANT HEIGHT, BUDS, FLOWERS, FRUITS AND FRUIT WEIGHT FROM FOUR PEPPER PLANT STAGES INFESTED WITH BROAD MITE.

| Plant Age | Plant Stage | Leaves /plant | | Plant Height (cms.) | | No. Buds /plants | | No. Flowers /plant | | No. Fruits /plant | | Fruit weight/plant (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Infested | Control | Infested | Control | Infested | Control | Infested | Control | Infested | Control | Infested | Control |
| 5 | V | 17.68b | 29.62a | 11.97b | 20.63a | 2.17b | 6.79a | 0.12b | 0.80a | 0.08b | 1.88a | 10.67b | 270.51a |
| 7 | B | 14.44b | 19.33a | 11.76b | 16.11a | 1.15b | 5.31a | 0.01b | 0.50a | 0.02b | 0.37a | 3.90b | 50.78a |
| 10 | EF | 18.03b | 30.49a | 14.50b | 22.54a | 2.58b | 10.83a | 0.09b | 1.31a | 0.34b | 0.98a | 16.87b | 55.62a |
| 14 | LF | 37.52b | 41.39a | 30.82b | 32.54a | 4.41a | 5.28a | 0.83a | 0.93a | 2.48b | 3.10a | 333.17a | 346.07a |

Means for each parameter within rows followed by the same letter are not significantly different (t-test, P=0.05)

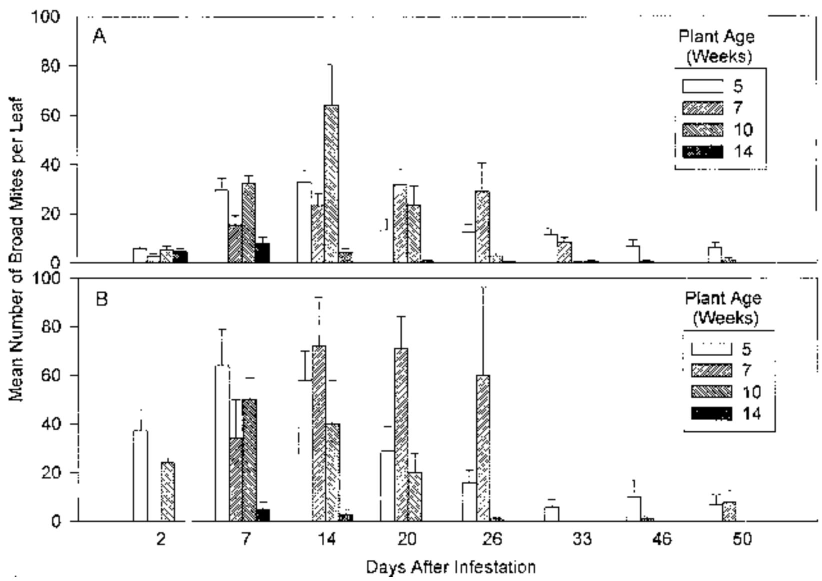


Fig. 3. Densities of *P. latus* motile and prelarva stages (A) and eggs (B) in 5, 7, 10 and 14 week-old pepper plants recorded for 50 days after infestation.

Mean fruit weight on LF plants did not differ significantly between infested and control plants. However, mean fruit weights of V, B, EF plants exposed to broad mite were significantly lower than those of control plants. Fruit weight was consistently lower from V, B and EF broad mite-stressed plants compared to uninfested plants at the same growth stage. Lower fruit numbers were recorded from mite-stressed plants compared to the untreated check.

Relationship between damage index and plant yield:

The damage caused by broad mites appears to be dependent on the stage of development of the pepper plant. Plants infested when 14 weeks-old (LF) had significantly more fruits than plants infested at an earlier plant stage. This experiment indicated an intermediate ($y = 2.83 - 0.45x$; $r^2 = 0.46$; $P = 0.0001$) relationship between damage index ($x$) and the number of fruits per plant ($y$). However, the relationship between fruit weight per plant ($y$) in grams and damage index ($x$) was less than intermediate ($y = 232.50 - 37.23x$; $r^2 = 0.38$; $P = 0.0001$). Nevertheless, these relationships may be used to predict yield loss for *P. latus* infested pepper plants. For example, using the intercepts of the above equations, and the damage index is 0, the yield of undamaged plants would be 2.83 fruits or 232.50 grams per plant. However, if the damage index ($x$) is 5, the yield will be reduced by 80%.

High levels of stress induced by *P. latus* feeding resulted in reductions in quantity and quality of fruit, reduction in vegetative growth and flower development responds to some anatomical, physiological or biochemical differences between vegetative and reproductive stage plants. This reductions were due to chronic feeding on plants with younger leaf tissue, which appear to be more susceptible than plants with greater numbers of mature leaves. This effect has been shown to vary with the phenological development of hedera (Nemestothy et al. 1982). Plants with younger hirsute leaves suffered the strongest damage compared to older plants with leaves with less hairs and where cell differentiation has already occurred. These results are in agreement with the reports of Smith (1935) who stated that the broad mite cannot survive long on the tough, mature leaves of most plants.

Regardless of the causative factors, our results help to explain why outbreak populations of *P. latus* are observed only in vegetative and early reproductive stages of the crop. The response of *P. latus* to pepper phenology appears to be an important component of the broad mites pest potential in the pepper ecosystem. In pepper, flowering and fruit formation induce a significant increase in the growth rate of *P. latus* populations. This rapid increase in mite density, together with the production of new lateral growth, may stimulate mite movement onto new lateral leaves. However, when the leaves are mature (LF), the plants seem to be unable to support broad mite populations. Thus, mites invading plants younger than 14 weeks encounter a potential host suitable for colonization and favorable rapid growth. The sequence of motile mites observed every 8 days, explains why plants at these early ages have the potential for inducing damaging mite outbreaks. This potential is often realized under the exacerbating effects of hot humid weather and certain pesticide programs. The knowledge that the potential of damage arises from mite responses to the phenological stage of the crop can enhance the efficiency and value of broad mite monitoring programs and control strategies by focusing attention on the critical periods prior to flowering and fruiting in pepper. However, yield responses to broad mite damage under field conditions may differ from those observed under controlled conditions in the greenhouse.

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