Plant architecture and prey distribution influence foraging behavior of the predatory mite Phytoseiulus persimilis (Acari: Phytoseiidae)

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Plant architecture and prey distribution influence foraging behavior of the predatory mite *Phytoseiulus persimilis* (Acari: Phytoseiidae)

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Running head: Plant architecture and prey distribution affect predator foraging behavior
Abstract  The arrangement, number, and size of plant parts may influence predator foraging behavior, either directly, by altering the rate or pattern of predator movement, or, indirectly, by affecting the distribution and abundance of prey. We report on the effects of both plant architecture and prey distribution on foraging by the predatory mite, *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae), on cucumber (*Cucumis sativus* L.). Plants differed in leaf number (2- or 6-leafed), and there were associated differences in leaf size, plant height, and relative proportions of plant parts; but all had the same total surface area. The prey, the twospotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae), were distributed either on the basal leaf or on all leaves. The effect of plant architecture on predator foraging behavior varied depending on prey distribution. The dimensions of individual plant parts affected time allocated to moving and feeding, but they did not appear to influence the frequency with which predators moved among different plant parts. Overall, *P. persimilis* moved less, and fed upon prey longer, on 6-leafed plants with prey on all leaves than on plants representing other treatment combinations. Our findings suggest that both plant architecture and pattern of prey distribution should be considered, along with other factors such as herbivore-induced plant volatiles, in augmentative biological control programs.

Keywords  Plant architecture; prey distribution; predator foraging behavior; *Tetranychus urticae*; *Phytoseiulus persimilis*; biological control
Introduction

Foraging efficiency in predators and parasitoids is determined by multiple behaviors associated with finding and handling prey or hosts (Vinson 1984; O'Brien et al. 1990). Environmental factors, including the host plant, have an important effect on how natural enemies forage. Host plant effects are mediated by both phytochemical cues and physical structures (Price et al. 1980; Boethel and Eikenbary 1986; Cortesero et al. 2000). Phytochemicals may be released in response to infestation, thus serving as cues for natural enemies while searching for hosts/prey. For example, in phytoseiid mites foraging behavior is modified by herbivore-induced plant volatiles, both in and out of prey patches (Dicke and Sabelis 1988; Dicke 1994; Maeda and Takabayashi 2001). Whether or not plant chemical cues are present, physical structures associated with the plant, broadly described as plant architecture, are known to play a significant role in local foraging behavior (e.g., Thorpe 1985; Kareiva and Sahakian 1990; Grevstad and Klepetka 1992; Clark and Messina 1998a,b; Legrand and Barbosa 2003). Many definitions of plant architecture have been offered (e.g., Andow and Prokrym 1990), but the one we prefer is the spatial arrangement and dimensions of leaves, stems, and branches at a point in time (Cloyd and Sadof 2000). Plant architectural characteristics may influence the direction and rate of natural enemy search, thus affecting searching time and encounter rate with prey or hosts (Legrand and Barbosa 2003; Cloyd and Sadof 2000).
We have been studying the foraging behavior of the predatory mite *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) on cucumber plants (*Cucumis sativus* L.) to understand variation in biological control efficiency (Gontijo et al. 2010). *P. persimilis* is a small (< 0.5 mm long) non-flying predator often used for biological control of the twospotted spider mite (*Tetranychus urticae* Koch, Acari: Tetranychidae) in greenhouses (Gould and Light 1971; Hamlen 1978). Because this predator is so small and must move along a surface to reach its prey, we expected that differences in plant architecture would have a measurable impact on its foraging behavior. Besides plant architecture, prey distribution may affect the foraging success of *P. persimilis* (Zhang et al. 1992; Zhang and Sanderson 1993; Ryoo 1996; Stavrinides and Skirvin 2003). In previous work (Gontijo et al. 2010), we measured prey finding time, consumption, and oviposition rates of *P. persimilis* foraging on either six-leafed or two-leafed cucumber plants on which spider mites were distributed in two patterns: on the basal leaf only or on all leaves. We observed that, while prey distribution affected predator foraging success, under similar prey distributions more predators found prey patches, they found them faster, and they consumed more and laid more eggs on six-leafed plants than on two-leafed plants. In this study we examined specific movement patterns of *P. persimilis* to better understand differences observed in its foraging efficiency.

Our focus was to investigate the effects of plant architecture in conjunction with prey distribution on movement patterns of *P. persimilis* on cucumber plants (*Cucumis sativus* L.). We were particularly interested in the potential effects these factors would have on initial prey-finding because, once prey are found on a plant, a predator generally will intensify local searching and therefore be more likely to find prey on other plant
parts. Our specific objectives were to: 1) quantify the effects of plant architecture on
duration and pattern of movement, resting, and feeding by *P. persimilis* on and among
plant parts; 2) measure these same variables under different prey distributions; and 3)
investigate the possible interaction between plant architecture and prey distribution. We
specifically designed our experiment to maintain an equal total plant surface area in order
to focus on the impact of plant architectural features, including the sizes and proportions
of stems and leaves.
Materials and Methods

Constructing Plant Architectures

Seeds of the cucumber cultivar ‘Cumlaude’ were obtained from Hydrogarden Company, Inc. (Colorado Springs, CO) and sown individually into 6.25-cm² pots containing FAFARD® Super-Fine Germinating Mix (Conrad Fafard, Inc., Agawam, Massachusetts, USA). Prior to transplanting, seedlings were watered daily and a 20-10-20 fertilizer (Scotts Peters Professional General Purpose 20-10-20, Scotts Company, Marysville, Ohio, USA) was applied three times a week through the irrigation system by dissolving 1,048 g of 20-10-20 solid fertilizer into a 75.7 l container of water, which was delivered through a Hozon siphon mixer at a ratio of 1:16 (fertilizer solution:tap water).

Thereafter, plants were fertilized whenever watering was required. To avoid competition for light, seedlings were spaced (stem center to stem center) 30 cm apart on a greenhouse bench when the first true leaf was completely expanded. Depending on treatment (see below), seedlings were transplanted at different times and into different sized pots.

To create experimental plants with different architectures, we manipulated pot size and transplant date. Specifically, plants assigned to the 2-leafed treatments were transplanted as seedlings into 15.2-cm diam pots when they had four true leaves fully expanded. Plants assigned to the 6-leafed treatments were transplanted as seedlings into 10.1-cm diam pots when they had six true leaves fully expanded. The plants transplanted into larger pots at an early stage became taller with larger leaves than those transplanted into smaller pots later in their growth. We removed leaves (petiole and leaf blade) from
the taller, larger-leafed plants so that only 2 leaves remained. New growth was removed
from the apex of 6-leafed plants to ensure that all plants were subject to pruning; all
pruning was done approximately 4 days after final transplant of the 6-leafed plants.

We equalized total plant surface area for the two plant treatments. To attain
approximately the same total plant surface area but two different architectures, we
estimated areas for different plant parts. For the leaves (leaf blades excluding petioles),
we established a mathematical relationship between leaf surface area and mid-rib length
by scanning leaves for a range of leaf sizes and then generating a regression equation, \( y = 
1.091x^2 - 5.817x + 19.477 \) (\( R^2 = 0.99, P<0.0001 \)). The leaves were scanned using an HP
Scanjet 4850® scanner (Hewlett-Packard Company, Palo Alto, California, USA), and the
images were converted to surface areas with Scion Image® software (Scion Corporation,
Frederick, Maryland, USA). Based on this relationship, we created a one-way table in
which entering any leaf mid-rib length value would provide an estimate of leaf surface
area. Leaf surface areas were multiplied by a factor of two because estimated values
were for one side of the leaf only. To measure the surface area of stems and petioles, we
constructed a two-way table based on the formula of a cylinder \( 2\pi r h \) (\( \pi =3.14, r = 
radius of the cylinder, \( h = \) height of the cylinder). By substituting length and diameter
measurements for petioles and stems into the formula, we could estimate surface areas for
those plant parts. To measure total plant surface area, we summed the surface areas of all
plant parts. Differences in surface areas for total plant and plant parts between 2-leaf and
6-leaf plants, after alteration, were determined using t-tests (SAS Institute, Cary, North
Carolina, USA).
Tetranychus urticae were obtained from colonies maintained at Kansas State University, Manhattan, Kansas, USA. They were reared on young lima bean plants (*Phaseolus lunatus* L.) in 0.3 x 0.6 m plastic flats under a 16:8 L:D photoperiod, and at 25 ± 2°C and 60 ± 10% R.H. New lima bean plants were provided every other day. For the experiments, spider mites were distributed on either a single basal leaf or on all leaves for each of the two cucumber plant architectures described above. Leaves designated for spider mites were infested by attaching a bean leaf square containing 10 adult female *T. urticae* for 24 h to the lower leaf surface. This resulted in a mixture of adult spider mites, webbing and eggs on infested leaves at the time of predator release. However, in the experiment, only *T. urticae* eggs – which are preferred by *Phytoseiulus persimilis* -- were consumed.

*Phytoseiulus persimilis* were purchased from Koppert, Inc. (Romulus, Michigan, USA), and maintained on lima bean plants infested with *T. urticae*. Predators were fed new spider mites by adding infested lima bean plants every other day. The predator population was maintained under the same environmental conditions as described for *T. urticae*. Voucher specimens of *P. persimilis* and *T. urticae* have been deposited in the Kansas State University Museum of Entomological and Prairie Arthropod Research under Lot Number 200.

The experiment was conducted in a laboratory at Kansas State University. All treatments pertaining to plant architecture and prey distribution were repeated (see below). To begin each test, we placed an adult female predator 24 to 72 h from
emergence, which had been deprived of prey for 2 h, at the base of the stem using a fine-haired paint brush. The test age chosen represents a period of peak vigor and reproductive activity for *P. persimilis*. After release, predators were observed continuously for 20 min. This period was selected because preliminary observations indicated that predators moved onto all plant parts at least once during this period. Predators that were released but failed to move during the first five min were removed and replaced. An individual plant was used to test only one predator. During the observation period, the frequency and duration of resting, moving, and feeding, as well as changes in direction and the specific plant location (stem, petiole and leaf) where behaviors occurred, were recorded. Resting was defined as the time that the predator remained stationary; moving represented the time spent walking, regardless of direction; and feeding was defined as the time spent eating (partially or totally) prey eggs.

Statistical Analyses

Treatments were blocked through time and 2-3 replicates of each treatment were run per day for a total of 11 replicates at the end of the four-day experiment. The experimental design was a 2 x 2 factorial with two plant architectures (2-leafed and 6-leafed) and two prey distributions (basal leaf only or all leaves). Predator behavioral data were organized for analysis into the following categories: 1) time spent moving and resting on the stem before moving onto a petiole, and moving and resting on the petiole before moving onto a leaf; 2) total time spent moving, resting and feeding on either plant stems, petioles or leaves; 3) total time spent moving and resting on the entire plant; 4) percentage of time
spent resting, moving and feeding on either stems, petioles or leaves; 5) percentage of predators that were able to find the first petiole, infested leaf and prey patch; and 6) sequence and probability of predators moving from one plant part to another. To test whether the presence of prey influenced predator behavior, either before or after reaching an infested leaf, we combined behavioral data for leaves within and among plants based on whether or not the leaves were infested with spider mites. The effects of plant architecture, prey distribution, and their interaction were tested using Friedman’s ANOVA (SAS Institute 2002) when comparing predator time allocation among different behavioral variables and different plant parts; and ANOVA PROC GLM (SAS Institute 2002) when comparing the same behavioral variable across treatments. ANCOVA (SAS Institute 2002) was carried out to test whether or not plant architecture (petiole length) and prey presence could affect the transit time of *P. persimilis* from petiole to leaf. The frequency distribution of *P. persimilis* movement from one part of the plant to another, and the success of the predators in finding prey, were analyzed by Fisher’s Chi-square test (SAS Institute 2002). When comparing only two levels of a treatment factor for one dependent response, a t-test was used (SAS Institute 2002).

**Results**

**Plant Characteristics**

The total plant surface areas were approximately the same for 2- and 6-leaved plants, as designed. However, the surface areas of individual plant parts were significantly
different between the two plant architectures (Table 1). For example, 2-leafed plants had longer stems and petioles, and a mean leaf blade surface area that was nearly 3-fold greater than those of 6-leaf plants. Two-leaf plants also had longer internodes, thicker stems and petioles, and were taller than 6-leafed plants. Although 2-leafed plants had fewer internodes, they were taller than 6-leafed plants because the distance from the base to the first internode was longer on 2-leafed plants.

Effects of Plant Architecture and Prey Distribution

Regardless of plant architecture or prey distribution, *P. persimilis* spent significantly more time moving (13.78 ± 0.48 min [mean ± SE]) than resting (3.78 ± 0.41 min) or feeding (2.38 ± 0.46 min) (Friedman’s ANOVA, \( \chi^2 = 80.38, df=2, P<0.0001 \)). In addition, after release onto the stem, all predators walked upward and moved onto a petiole. Fifty percent (22/44; range: 36 – 64%) of the predators turned onto the first (most basal) petiole encountered. Regardless of which petiole was first visited, most (84% [37/44]; range: 73 -100%) moved from the petiole onto the corresponding leaf blade. A much lower percentage (13% [6/44]; range: 0 - 27%) of the predators moved back to a stem, and only one predator stayed on the petiole for the duration of the observation period. Petiole length significantly affected transit time from petiole to leaf blade, with longer petioles on 2-leafed plants associated with longer times predators spent on them (ANCOVA, \( F=9.63, df=1, P=0.035 \)); whereas presence of prey on the attached leaf blades did not affect transit time (ANCOVA, \( F=1.05, df=1, P=0.311 \)). Of those predators that moved onto leaf blades, the percentages that remained there were
significantly affected by prey distribution (Fisher’s, $\chi^2 = 4.65$, $df=1$, $P=0.048$); on plants with all leaves infested with prey eggs, 70% (12 of 17) stayed on the leaf compared with 35% (7 of 20) on plants that had prey on the basal leaf only. Once on an infested leaf, *P. persimilis* were more successful in finding a prey patch on the smaller leaves of 6-leafed plants (14 of 16) than on the larger leaves of 2-leafed plants (8 of 17) (Fisher’s, $\chi^2 = 6.02$, $df=1$, $P=0.025$). There was a trend for predators to find prey patches sooner on 6-leafed (4.67 ± 0.65 min) compared to 2-leafed plants (7.23 ± 1.64 min), but the difference in time was not significant (t test, $F=-1.62$, $df=22$, $P=0.119$).

Predators spent more time (ca. 37% more for each plant part) on stems and petioles of 2-leafed plants than on 6-leafed plants (ANOVA GLM, stems: $F = 7.57$, $df=1$, $P = 0.010$; petioles: $F = 7.93$, $df = 1$, $P = 0.02$) (Figure 1). Most of the difference was attributable to time spent moving (ANOVA GLM, stems: $F=10.85$, $df=1$, $P=0.002$; petioles: $F=4.86$, $df=1$, $P=0.033$) as there were no differences in time spent resting among treatments for any plant part (Table 2). Prey distribution had no effect on time spent moving on stems (ANOVA GLM, $F=0.00$, $df=1$, $P=0.975$) or petioles ($F=1.49$, $df=1$, $P=0.229$), nor were there any significant interactions between plant architecture and prey distribution (ANOVA GLM, stems: $F=0.28$, $df=1$, $P=0.597$; petioles: $F=0.21$, $df=1$, $P=0.653$) (Table 2).

Compared to stems and petioles, *P. persimilis* females spent considerably more time moving on leaf blades, regardless of plant architecture and prey distribution (Friedman’s ANOVA, $\chi^2=44.88$, $df=2$, $P<0.0001$) (Figure 1). Predators appeared to walk more slowly on leaf blades than on stems or petioles, and although stops were less frequent, they were slightly longer (average 30 seconds) than on stem and petioles. For
each prey distribution, predators spent significantly more time moving on leaf blades of 
6-leafed plants (9.75 ± 0.88 min) than on those of 2-leafed plants (6.33± 0.86) (t test, 
\( F=2.763, df=42, P=0.008 \) (Figure 1). Predators that found prey spent about four minutes 
feeding, which represents about 25% (range: 21–37%) of the total time on leaf blades. 
With respect to time spent by \( P. \) persimilis on different parts of the leaf blade, there was a 
marginally significant interaction between plant architecture and prey distribution 
(ANOVA GLM, \( F=3.45, df=1, P=0.07 \) (Table 2). That is, when foraging on uninfested 
leaves (no prey present), predators walked predominantly along the leaf margins; 
whereas, on infested leaves most of the time was spent in the leaf interior.

**Discussion**

The foraging efficiency of natural enemies often decreases in the face of increased plant 
architectural complexity (e.g., Andow and Prokrym 1990; Geitzenauer and Bernays 
1996; Cloyd and Sadof 2000; Hoddle 2003; Legrand and Barbosa 2003). However, our 
results indicate that the effect of plant complexity depends on the specific components of 
that complexity (e.g., leaf size, internode length) as well as on prey distribution. Thus, 
the effects of branching pattern, leaf size, and relative differences in surface areas among 
plant parts need to be carefully evaluated (Gardner and Dixon 1985; Stadler and Völkl 
1991). Furthermore, different components associated with structural complexity may 
have different, perhaps opposite, effects on predator foraging. On 6-leafed plants, which 
have shorter internodes and petioles and smaller leaves than 2-leafed plants, time spent
moving was relatively shorter on stems and petioles, but longer on leaves than on 2-leaved plants.

Two-leafed plants had thicker stems and petioles, as well as longer internodes and petioles, than 6-leaved plants. Therefore, randomly-searching *P. persimilis* females released at the base of a 2-leaved plant had a larger potential surface area to traverse before reaching a leaf blade than they would on 6-leaved plants. The shorter time predators spent on stems of 6-leaved plants may also be related to the greater frequency of petioles along the stem, which would increase the rate at which petioles are encountered compared to 2-leaved plants. Thus, the effects of plant architecture on predator foraging were cumulative, and in general may result from multiple plant structures, ranging from surface area and microstructural influences to those pertaining to large structural differences such as numbers, kinds and proportions of plant parts.

Other studies indicate there may be an inverse relationship between total plant surface area and foraging efficiency for very small natural enemies (Burbutis and Koepke 1981; Treacy et al. 1986; Maini et al. 1991; Geitzenauer and Bernays 1996; Wang et al. 1997; Cloyd and Sadof 2000). Our study demonstrates that variation in foraging efficiency is not necessarily related to variation in total surface area. That is, although the total surface area of our plants was the same, we still found differences in foraging behavior and efficiency because of the way the area was partitioned. For example, the surface area of individual leaf blades on 2-leaved plants was about 3 times greater than those of 6-leaved plants; and yet predators spent more time moving on leaf blades of 6-leaved plants. This apparent contradiction may be explained by our observation that *P. persimilis* spends relatively more time searching leaf edges compared to areas away from
the perimeter of the leaf; the tendency for this predator to search leaf edges also was
documented previously (Sabelis and Dicke 1985). Because 6-leafed plants had smaller
leaf blades, predators may have encountered leaf edges more frequently and, hence, spent
more time moving on leaves of 6-leafed plants than on the larger leaves of 2-leafed
cucumbers. Increased foraging activity on 6-leafed plants, combined with their smaller
leaf areas (which resulted in smaller distances between leaf edges and prey patches), may
explain why predators were more successful in finding prey patches on 6-leafed plants
compared to 2-leafed plants.

*Phytoseiulus persimilis* spent significantly more time moving on the leaf blades of
6-leafed plants where prey were located on just the basal leaf compared to plants in
which all six leaves contained prey. This difference may be due related to the likelihood
that predators would turn onto an infested leaf; on plants with only one infested leaf the
chance would be one in six, while on plants on which all leaves were infested any turn
would lead to prey. Because predators stop moving and spend more time feeding when
they encounter prey patches, when *P. persimilis* find prey patches more quickly (e.g., on
plants on which all leaves were infested with prey), they will allocate more time to
feeding. Similarly, Yasuda and Ishikawa (1999) found that the ladybird beetle,
*Harmonia axyridis* Pallis, spent more time feeding when aphids were distributed evenly
than when they were in patches; that is, more time feeding when prey were more easily
found. Thus, both plant architecture and prey distribution (number and leaf size) can
indirectly affect feeding time and, thus, prey consumption efficiency of *P. persimilis*.

The foraging behaviors of predaceous arthropods are important in the acquisition
of food and impact on prey populations. As such, understanding the factors that affect
foraging behavior may improve the effectiveness and efficiency of biological control programs. For very small natural enemies like predatory mites and many parasitoids, differences in plant architecture and prey distribution may have a profound effect on foraging efficiency and, hence, their effectiveness as biological control agents (Andow and Prokrym 1990; Ryoo 1996; Krips et al. 1999; Skirvin and Fenlon 2001; Stavrinides and Skirvin 2003). Knowing the effects of plant architecture and prey/host distribution on natural enemy behavior will allow better estimates of how many predators or parasitoids to release, and where on the plant to release them, to achieve more efficient and consistent biological control. However, because natural enemies perceive and use plant chemicals during searches for prey/hosts (Turlings et al. 1990; Cortesero et al. 2000), examining how plant structure and prey distribution interact with phytochemical cues will provide an opportunity for understanding natural enemy foraging in a broader context. For example, with respect to *P. persimilis*, herbivore-induced plant volatiles are known to modify search behavior both in and out of prey patches (Dicke and Sabelis 1994; Maeda and Takabayashi 2001) and in response to prey density (Nachappa et al. 2006). This information, when combined with our work on structural effects of cucumber and *T. urticae* distribution on *P. persimilis* behavior (here and see also Gontijo et al. 2010), will allow better predictions of prey-finding and local and regional population dynamics in this predator-prey system.
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**Table 1** Means (± SEM) of plant part dimensions on manipulated cucumber plants, *Cucumis sativus*. Mean differences between 6- and 2-leafed plants were significant at $P < 0.01$ (t-test) except for total plant surface area ($P > 0.05$).

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>N</th>
<th>Petiole diam (cm)</th>
<th>Petiole length (cm)</th>
<th>Stem diam (cm)</th>
<th>Base to first internode (cm)</th>
<th>Internode length (cm)</th>
<th>Plant height (cm)</th>
<th>Leaf surface area (cm$^2$)</th>
<th>Total plant surface area (cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-leafed</td>
<td>18</td>
<td>0.32 ± 0.005</td>
<td>3.61 ± 0.06</td>
<td>0.86 ± 0.02</td>
<td>6.89 ± 0.14</td>
<td>0.93 ± 0.02</td>
<td>12.61 ± 0.14</td>
<td>82.98 ± 1.87</td>
<td>554.80 ± 10.05</td>
</tr>
<tr>
<td>2-leafed</td>
<td>20</td>
<td>0.45 ± 0.008</td>
<td>7.40 ± 0.09</td>
<td>1.04 ± 0.02</td>
<td>10.50 ± 0.24</td>
<td>2.66 ± 0.05</td>
<td>15.34 ± 0.37</td>
<td>240.60 ± 4.11</td>
<td>551.91 ± 9.90</td>
</tr>
</tbody>
</table>

**Table 2** Treatment effects and interactions on *Phytoseiulus persimilis* moving, resting and feeding on stems, petioles and leaves.

<table>
<thead>
<tr>
<th>architecture</th>
<th>prey distribution</th>
<th>architecture*prey distribution</th>
<th>behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$-value</td>
<td>$P$-value</td>
<td>$F$-value</td>
<td>$P$-value</td>
</tr>
<tr>
<td>10.85</td>
<td>0.002*</td>
<td>0.00</td>
<td>0.97</td>
</tr>
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<td>1.78</td>
<td>0.18</td>
<td>0.00</td>
<td>0.99</td>
</tr>
<tr>
<td>4.86</td>
<td>0.03*</td>
<td>1.49</td>
<td>0.22</td>
</tr>
<tr>
<td>0.22</td>
<td>0.64</td>
<td>0.27</td>
<td>0.60</td>
</tr>
<tr>
<td>8.14</td>
<td>0.006*</td>
<td>1.23</td>
<td>0.27</td>
</tr>
<tr>
<td>0.00</td>
<td>0.97</td>
<td>1.87</td>
<td>0.17</td>
</tr>
<tr>
<td>3.91</td>
<td>0.05*</td>
<td>11.52</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

*Significant treatment effect or interaction at $p<0.05$ (ANOVA, PROC GLM)
Figure 1. Time spent moving, resting and feeding by *Phytoseiulus persimilis* on stems, petioles and leaves of 6-leafed and 2-leafed plants with either prey on single basal leaf or on all leaves.