Spectral reflectance from a broccoli crop with vegetation or soil as background: influence on immigration by *Brevicoryne brassicae* and *Myzus persicae*

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**Key words:** crop background, reflectance, light, aphids, *Myzus persicae*, *Brevicoryne brassicae*, living mulches, intercropping

**Abstract**

Light reflectance in five wavebands of the spectrum was measured from broccoli (*Brassicae oleracea* var. *botrytis* [L.]) interplanted with leguminous cover crops (cover crop background) or broccoli grown as monoculture (bare soil background), and fertilized with compost or synthetic fertilizer. Alate *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) (Homoptera: Aphididae) were monitored in yellow pan water traps and on broccoli leaves. Reflectance intensity was higher with a background of bare soil at all wavebands except blue (400–455 nm) in the early-season. Intensity decreased as broccoli canopy cover increased at all wavebands except blue and green (515–550 nm), declining-most dramatically in the yellow (550–590 nm). Highest late-season intensities were in plots with bare soil background and fertilized with compost (those stressed for nitrogen). Few differences in spectral composition, expressed for each waveband as a percentage of total intensity, were recorded. Numbers of alatae were lowest in cover crop background plots in the early season, reached equivalency with bare soil background by mid-season, and showed highest positive correlations with intensity in the yellow (550–590 nm). Results correspond to laboratory findings that aphids are attracted to higher intensity light, especially in the yellow waveband, and support a phototactic explanation for aphid orientation in the field.

**Introduction**

Interplanting annual crops with alternate crops (intercropping) or non-crop vegetation (living mulches) often reduces numbers of immigrating alate aphids compared to annual crops grown as monocultures (Horn 1981; Tukahirwa & Coaker, 1982; Andow et al., 1986; Cartwright et al., 1990; Bottenberg & Irwin, 1992a). Moreover, for most aphid species, fewer alatae are trapped on monocultures with open canopies (i.e., having a high ratio of exposed soil to crop foliage) than closed canopies (A’Brook, 1964, 1968; Gonzalez & Rawlins, 1968; Ogenga-Latigo, 1992; but see A’Brook, 1968; Halbert & Irwin, 1981). Such patterns in aphid abundance are often attributed to the greater visual contrast between a crop and a background of soil versus a background of vegetation (Smith, 1976; McKinlay, 1985; Ogenga-Latigo, 1992; Bottenberg & Irwin, 1992b), which affect aphid optomotor response (Kennedy et al., 1961) or phototaxis (Moericke, 1955).

Evidence that spectral light quality influences orientation and host plant finding by Homoptera is abundant. Peak attraction to yellow (560–590 nm in the light spectrum) has been found for whiteflies (Vaishampayan et al., 1975; Coombe, 1981), leafhoppers (Todd et al., 1990), psyllids (Mensah & Madden, 1992) and aphids (Kring, 1972; Kieckhefer, 1976; Burrows et al., 1983; Campbell, et al., 1991), although some aphid species are attracted most strongly to green (500–560 nm) (Kieckhefer 1976; Nottingham et al., 1991). Repellence by aluminized and other surfaces reflecting a high proportion of UV light has been shown for leafhoppers (Zalom, 1981) and aphids (Burton
& Krenzer, 1985; Schalk & Robbins, 1987; Kring & Schuster, 1992). Aphids in the initial phase of migration respond positively to shortwave skylight (<500 nm), but become more attracted to longwave light (<500 nm) reflected from plants and soils when in the alighting phase (Kennedy et al., 1961).

Despite these findings, I have found no studies on aphids in interplanting systems which measured the degree of crop canopy-to-background contrast in terms of light reflectance. Presented here are results of a study which attempts to draw an association between patterns of spectral light reflectance from broccoli with bare soil or vegetation as background and immigration by *M. persicae* and *B. brassicae*.

**Materials and methods**

The study site was located in the Salinas Valley, California USA; Soil type was a Hanford series sandy clay loam. The experiment took place between 18 May and 8 July 1991 and was designed as a 4 x 2 factorial in a randomized complete block, split plot design with blocks replicated four times and plot size 10 x 10 m. The main plot (background) factor consisted of four levels: three levels of cover crop and one level of a no cover (bare soil) control. The purpose for including different cover crops in this study was to compare their competitiveness and compatibility with broccoli as a living mulch, the results of which are presented in a separate paper (Costello, 1994). Cover crops used were white clover (*Trifolium repens* L.), strawberry clover (*Trifolium fragiferum* L. cv. O’Conners) and a mixture of trefoil (*Lotus corniculatus* L. cv. Kalo) and red clover (*Trifolium pratense* L.). The sub-plot (fertilizer) factor consisted of two levels: synthetic fertilizer (high available nitrogen) or compost (low available nitrogen). Fertilization with compost lowered mid- to late-season broccoli leaf area, leaf water content and leaf nitrogen (Costello, 1994), and therefore enabled comparison of late-season reflectances from plants with less than full canopy cover and low nitrogen/water levels. On 18 May 1991 broccoli (cv. ‘Arcata’) was transplanted into cover crop plots and bare soil plots in 10 cm-wide rows at a row spacing of 0.6 m and an intra-row spacing of 22 cm. These spacings provided 83% cover at planting time in cover crop plots. Other methodology has been described earlier (Costello, 1994).

Light measurements were taken using a light meter (LI-185, LICOR, Lincoln, Nebraska, USA) with a sensor having a range of 400–700 nanometers (nm) and equally sensitive to all wavelengths of light. The light meter was modified to a spectral radiometer using a series of glass interference filters (Long Pass Filters, Oriel Co., Stratford, Connecticut, USA), each of which limited transmittance of light to that greater than a specified wavelength. The filters were placed sequentially over the sensor, which was ensheathed in a 5 cm-long tube of black polyurethane to prevent angled light from entering. Spectral reflectance curves were generated by taking readings with each filter from three randomly selected broccoli plants per subplot, excluding the outer 2 meters to eliminate interference from the edges. The sensor was held 30 cm above the canopy, which recorded reflectance from an area of 784 cm² (a circle with diameter of 31.6 cm). Readings were taken from the same plants with each filter, and were taken on 22, 32 and 52 days after transplanting (DAP) the broccoli. To minimize changes in light quality, readings were taken under cloudless skies and when the soil surface was uniformly dry, generally between 11 A.M. and 3 P.M.. The period most favorable for aphid activity in the Salinas Valley was from dawn until mid- or late-afternoon, at which point wind speeds increased to greater than 2m/sec. Five filters were used, which transmitted incoming light greater than 400 nm, 455 nm, 515 nm, 590 nm, and 645 nm, respectively. Light transmittance for each filter was recorded with a spectrophotometer (Shimadzu Co., Kyoto, Japan; Fig. 1). This created wavelength bands (hereafter referred to as wavebands) of 400–455 nm (blue), 455–515 nm (blue-green), 515–550 nm (green), 550–590 nm (yellow), and 590–640 nm (orange). UV light was not measured in this study; however, UV light is not a major component of spectral reflectance from plants or soils (Kennedy et al., 1961).

Alatae were trapped with 12 x 8 x 8 cm water-filled aluminum pans painted yellow on the inside and black on the outside. The pans were filled with water and a small amount of non-sudsing detergent was mixed in to break the surface tension. Two pans were used per subplot, maintained at broccoli canopy height. Samples were taken on 12, 22, 32, 42 and 52 DAP. Alatae from broccoli leaves were collected by heat-extraction using a combination of the methods described by Hughes (1963) and Pielou (1961). Samples were taken on 22, 32, 42, 52 and 62 DAP.
Fig. 1. Spectral distribution curves for light transmitted by Oriel long pass filters.

Statistical analyses
Reflectance measurements were analyzed by ANOVA (SAS Institute, 1988) and are presented for each waveband as intensity in microEinstein/m²/s (absolute readings) and spectral composition (percentage of total light intensity), adjusting for variation in wavebands widths.

Aphid data were log₁₀ transformed to stabilize the variance (Sokal & Rohlf, 1981). Densities of alatae were analyzed by ANOVA (SAS Institute, 1988). Because of differences among treatments in broccoli growth parameters (Costello, 1994), numbers of alatae from leaf samples were analyzed using estimated leaf area per plant as a covariate, which partitioned variation due to the effects of the treatments on plant size. To avoid confusing numbers of immigrating alatae with resident alatae, fourth instar alatae from leaf samples were recorded.

Numbers of alatae from water traps were regressed on reflectance intensity and proportion of reflectance at each waveband (with zero counts removed), fitting data to the equation

\[ y = a/1 + b(c^e), \]

which generates a sigmoidal curve and produced the best fit to the data. Aphid catches were combined into categories of early season (12–22 DAP), midseason (22–32 DAP) and late-season (42–52 DAP) and regressed on reflectance from 22, 32 and 52 DAP, respectively. Parameter estimation was undertaken using the Marquardt-Levenberg algorithm (Jandel Scientific, 1990).

Results
No differences were found among white clover, strawberry clover and trefoil/red clover cover crops with respect to spectral reflectance (\(F<2.03, \text{ d.f.} = 1.9, P>0.18\)) or alate abundance (\(F<3.31, \text{ d.f.} = 1.9, P>0.10\)). Therefore, these three background factor levels are combined and results are presented as though the experiment were a 2 × 2 factorial, with two levels of cover crop (cover vs. bare soil) and two levels of fertilizer (synthetic vs. compost).

Intensity and spectral composition (proportion of total reflectance). Treatments differed less in the shorter wavebands (i.e., blue and blue-green) than the longer wavebands (Figs. 2 & 3). Reflectance of blue light was the least intense of all the wavebands and proportionately the lowest, and did not differ among treatments (Figs. 2a and 3a; \(P>0.05\)). Intensity of blue-green light was significantly higher from plots with bare soil background compared to cover crop (Fig. 2b; \(F=164.20, \text{ d.f.} = 1, 3, P=0.001\)), and the difference was higher on 22 DAP (67% higher) and 32 DAP (71% higher) than 52 DAP (19% higher) (date by background interaction, \(F=18.60, \text{ d.f.} = 2, 44, P=0.0001\)). No differences among treatments existed in the percentage of blue-green light reflected (Fig. 3b; \(P>0.05\)).

Intensity of green light was greater from plots with bare soil background than cover crop on 22 and 32 DAP (Fig. 2c; \(F=68.70 \ & 30.81, \text{ respectively, d.f.} = 1, 3, P=0.003 \ & 0.01, \text{ respectively} \)), but not on 52 DAP (\(P>0.05\)) (date by background interaction \(F=30.01, \text{ d.f.} = 2, 44\)). Compared to synthetic fertilizer plots, compost plots reflected higher intensity green light on 52 DAP (Fig. 2c; \(F=43.80, \text{ d.f.} = 1, 22, P=0.001\)) but not on 22 or 32 DAP (\(P>0.05\)) (date by fertilizer interaction, \(F=10.83, \text{ d.f.} = 2, 44, P=0.0001\)). Green light was more intense from plots with bare soil background given synthetic fertilizer versus compost on 22 DAP, and was more intense from compost plots with bare soil background versus those with cover crop background on 52 DAP (Fig. 2c; date by cover by fertilizer interaction, \(F=22.20, \text{ d.f.} = 2, 44, P=0.0001\)). Green light was reflected in the highest percentage compared to all other wavebands for all treatments on 32 DAP (Fig. 3c), and on 52 DAP the bare soil/compost and the cover crop/synthetic fertilizer treatments reflected a greater percentage of green light than bare soil/synthetic fertilizer or cover crop/compost (Fig. 3c; date by fertilizer interaction, \(F=8.01, \text{ d.f.} = 2, 44, P=0.001\)).
Fig. 2. Mean intensity of light (microEinsteins/m²/s) reflected from broccoli plants and backgrounds of soil or cover crop, adjusted for variation in waveband width. Colors correspond to waveband widths as follows blue - 400-455 nm, blue-green - 455-515 nm, green - 515-550 nm, yellow - 550-590 nm, orange - 590-645 nm. Error bars (s.e.m.) are shown when the ANOVA was significant at P<0.01 (indicated by *).---o--- Bare Soil/Synthetic Fertilizer — Bare Soil/Compost — — Cover Crop/Synthetic Fertilizer — — Cover Crop/Compost

Yellow light was reflected at a higher intensity from plots with bare soil background than those with cover crop background on 22 (71% higher) and 32 DAP (16% higher) (Fig. 2d, F = 121.40 & 12.34, respectively, d.f. = 1, 3, P = 0.001 & 0.039, respectively) but not on 52 DAP (P>0.05) (date by cover interaction, F = 108.20, d.f. = 2, 4, P = 0.001). Intensity was higher from plots given synthetic fertilizer compared to compost on 22 DAP (F = 17.72, d.f. = 1, 22, P = 0.0004), but was just the opposite on 32 and 52 DAP (F = 5.22 & 15.68, d.f. = 1, 22, P = 0.032 & 0.0007, respectively) (date by fertilizer interaction, F = 16.54, d.f. = 2, 44, P = 0.0001). A greater percentage of yellow light was reflected compared to all other wavebands on 22 DAP (Fig. 3d), but no differences among treatments were detected (P>0.05).
Fig. 3. Spectral composition of light reflected from broccoli plants and their backgrounds, expressed for each waveband as the mean percent of total light intensity. Means are adjusted for variation in waveband width. Legend otherwise as in Figure 2.

Reflectance of orange light was higher from plots with bare soil background than those with cover crop background (Fig. 2e; $F = 260.87$, d.f. = 1, 3, $P = 0.0005$), although the difference was greater on 22 DAP (125% higher) than 52 DAP (23% higher) (date by cover interaction, $F = 238.88$, d.f. = 2, 44, $P = 0.0001$). Plots fertilized with compost reflected lower intensity 'orange light' than those given synthetic fertilizer on 52 DAP (Fig. 2e; $F = 5.09$, d.f. = 1, 3; $P = 0.034$) but not other dates (fertilizer by date interaction, $F = 7.94$, d.f. = 2, 44, $P = 0.001$), and intensity was higher from bare soil background given synthetic fertilizer versus those given compost on 22 DAP (Fig. 2e; date by cover by fertilizer interaction, $F = 13.33$, d.f. = 2, 44, $P = 0.0001$). Bare soil background plots reflected a higher percentage of orange light compared to cover crop background on 22 DAP (Fig. 3e; $F = 47.70$, d.f. = 1, 3, $P = 0.006$), but not on 32 or 52 DAP (date by cover interaction, $F = 8.01$, d.f. = 2, 44, $P = 0.008$).

Alate abundance. The most dramatic effect on alate abundance was due to crop background, but this was limited to the early-season. Water pans in plots...
with bare soil backgrounds trapped higher numbers of *B. brassicae* on 12 and 22 DAP than those in plots with cover crop background (Table 1; \( F = 82.42 \) & 60.79, respectively, \( d.f. = 1, 3, P = 0.002 \) & 0.004, respectively) (date by background interaction \( F = 28.81, \ d.f. = 4, 88, P = 0.0001 \)) and higher numbers of *M. persicae* on 12 and 32 DAP (Table 1; \( F = 46.95 \) & 19.82, respectively, \( d.f. = 1, 3, P = 0.006 \) & 0.021, respectively) (date by background interaction \( F = 9.82, \ d.f. = 4, 88, P = 0.0001 \)). Mid- to late-season effects were due to fertilizer or interaction between crop background and fertilizer, indicating the influence of broccoli canopy cover and leaf nitrogen and water content. Numbers of *B. brassicae* (22 and 42 DAP) and *M. persicae* (32 and 42 DAP) were higher in the bare soil background plots given compost (this treatment had low leaf area, leaf nitrogen and leaf water content, see Costello, 1994) versus those given synthetic fertilizer (Table 1; date by background by fertilizer interaction \( F = 6.07, \ d.f. = 4, 88, P = 0.0002 \)).

Numbers of *B. brassicae* alatae on broccoli leaves were significantly greater in plots with bare soil background compared to those with cover crop background on 22 DAP (Table 1; \( F = 20.27; \ d.f. = 1, 3; P = 0.02 \)), as was the case with *M. persicae* (Table 1; \( F = 219.48; \ d.f. = 1, 3; P = 0.0007 \)), with no fertilizer effect nor interaction. By 32 DAP no significant difference remained for *M. persicae*, although numbers of *B. brassicae* remained significantly higher on leaves with bare soil background compared to cover crop background (Table 1; \( F = 12.48; \ d.f. = 1, 3; P = 0.04 \)), but no significant differences were found by 42 DAP. Fourth instar alatae first appeared on 42 DAP for *M. persicae*, and on 62 DAP for *B. brassicae*.

### Relationship between mean trap catch and spectral reflectance

A significant positive relationship was found between both *M. persicae* and *B. brassicae* numbers caught in water traps and intensity of blue-green, yellow and orange light from the bare soil background plots, the best fit line being with yellow (Table 2). In cover crop plots numbers of both aphid species had a significant positive relationship with light intensity in the yellow waveband, although the relationships were much weaker than with bare soil background. In addition, *M. persicae* had a negative relationship with the intensity of green light in cover crop plots. With both bare soil and cover crop backgrounds the relationship between *M. persicae* and proportion of reflected light was negative with the green waveband and positive with the yellow, although \( r^2 \) values were higher in clean cultivation (Table 2). *B. brassicae* showed a negative relationship with the proportion of green light from cover crop and with the proportion of blue light from bare soil background, and showed a positive relationship with the proportion of yellow light from bare soil background.

### Discussion

Light reflectance from an annual agroecosystem, under given solar conditions, depends not only on the species or cultivars of plants present, but also on the proportion of the soil surface covered by plant material. In annual single crop plantings the proportion of exposed soil is quite high in the early stages of growth, and decreases as crop canopy increases. Reflectance hues from leaves are very similar over a wide range of plant species (Moericke, 1969; Prokopy & Owens, 1983). However, in annual cropping systems it is the combination of light reflected from the main crop and its background (usually soil in temperate systems) which determines spectral composition and intensity. Kennedy *et al.* (1961), in studying aphid alightment, measured spectral reflectance from several plant species and soil types, but independently of one another. The present study is the first to measure simultaneous spectral reflectance from crop plants and their backgrounds in an interplanting system and draw inferences regarding effects on immigrating aphids.

Results support the hypothesis that crop background affects light reflectance patterns and, subsequently, aphid immigration (Smith, 1976). Given that Kennedy *et al.* (1961) found a relationship between the percentage of long-wave light reflected and alightment by *B. brassicae* and *M. persicae*, one might infer that vegetation as crop background affects aphid immigration by altering the proportion of long-wave light reflected. However, the view of Prokopy & Owens (1983) was that background affects intensity to a greater degree than spectral composition. The present study confirms this, as the major effect of the cover crop background was not in altering spectral composition, but rather in lowering reflectance intensity. Moreover, although alate abundance in the monoculture was positively correlated with intensity of blue-green, yellow and orange light, the highest \( r^2 \) was with light in the yellow waveband. Whereas some researchers have found aphid attraction to be independent of intensity (Kring, 1969; Kieckhefer *et al.*, 1976; Burrows *et al.*, 1983), Moericke (1969) showed that landings
Table 1. Mean number of alate aphids (+S.E.M.) caught in yellow water traps or shaken from broccoli leaves with cover crop or bare soil as background

<table>
<thead>
<tr>
<th>Aphid sp.</th>
<th>Water traps</th>
<th>Broccoli leaves</th>
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<tbody>
<tr>
<td></td>
<td>DAP&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Cover crop</td>
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<tr>
<td><strong>B. brassicae</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>12</td>
<td>0.79 ± (0.23)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.33 ± (0.12)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>32</td>
<td>0.04 ± (0.04)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>42</td>
<td>0.08 ± (0.06)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td>0.46 ± (0.16)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td><strong>M. persicae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>1.50 ± (0.34)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>22</td>
<td>0.71 ± (0.18)&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td>32</td>
<td>0.17 ± (0.08)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>42</td>
<td>0.08 ± (0.06)&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>52</td>
<td>0.25 ± (0.11)&lt;sup&gt;a&lt;/sup&gt;</td>
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<sup>1</sup> Sampling date in days after planting.
<sup>2</sup> Fourth instar alates present.

* On each sampling date, for each aphid sp. and type of sampling method, means not sharing the same letter are different at \( P < 0.05 \) (ANOVA).

of alate *Hyalopterus pruni* and *Aphis fabae* on yellow cards declined when presented with shades of yellow and black admixtures (degrees of lower intensity yellow), Hodgson & Elbakhi (1985) found that *M. persicae* apterae most frequently approached turnip leaves which reflected the highest intensity light and Hardie (1989) found that summer migrants of *Aphis fabae* had peak sensitivities to wavelengths of 573 nm (yellow) and 598 nm (yellow-orange) at higher intensities than to light at 535–556 nm (green-yellow). Both *B. brassicae* and *M. persicae* are known to be 'yellow sensitive' (Kring, 1967), and attraction by other aphids to yellowish foliage in the field has been shown (Ajayi & Dewar, 1983; Campbell, 1991). However, a high correlation between alate immigration and reflectance intensity of yellow light in an agroecosystem has previously not been shown. I suggest that in this study immigrant *B. brassicae* and *M. persicae* were attracted to the newly planted broccoli monoculture because of higher intensity reflected light, especially that in the yellow waveband. Covering the soil behind and between crop rows with vegetation (cover crop) dampened this intensity.

Results of the present study also indicate that aphid immigration is also reduced as main crop canopy increases. Ogenga-Latigo *et al.* (1992) trapped more *Aphis* spp. over beans interplanted into an established stand of maize versus a simultaneous planting, and Gonzalez & Rawlins (1968) trapped fewer *M. persicae* and *B. brassicae* over lettuce fields as the plants grew and the foliage covered the soil. Reflectance intensity, too, was reduced with increasing broccoli canopy cover; convergence in yellow light reflectance between bare soil and cover crop backgrounds (synthetic fertilizer) occurred between 22 and 32 DAP (before complete broccoli canopy closure), which indicates that a lesser degree of soil coverage to that provided by the cover crop in this study (83%) may be sufficient to deter aphid immigration. Higher late-season intensities were reflected from the bare soil/compost treatment, which could have been a result of the lower average leaf area and more open broccoli canopy in this treatment (Costello, 1994) or may have been due to leaf nutrient- or water-stress, which is also known to influence spectral reflectance (Prokopy & Owens, 1983). However, given the severe nutrient- and water-stress in this treatment by the end of the season (Costello, 1994), one would expect even greater differences to have occurred, suggesting that leaf condition does not contribute as much to reflectance as does background. These late-season differences were either in wavebands unattractive to aphids or at intensities not great enough to attract aphids, and therefore did not lead to increased alate abundance.

It cannot be ruled out that other variables in these cropping systems might also correlate with alate immigration. Non-host vegetation can produce odors which are disruptive or repellent to specialized herbivores,
and this is considered the mechanism explaining lower numbers of flea beetles (Phyllotreta cruciferae Goeze) in Brassica interplanting systems (Garcia & Altieri, 1992). However, host plant odor has been thought to have little effect on aphid host plant finding (Kennedy, 1965; Hodgson & Elbakhiel, 1985), although some evidence of positive attraction has been found in laboratory olfactometer studies (Pettersson, 1973; Chapman et al., 1981; Nottingham & Hardie, 1993). In addition, vegetation as crop background may alter aphid perception of shape, affecting the optomotor response (Kennedy et al., 1961). Shape has been shown to be an important mechanism for host plant finding (Åhman et al., 1985; Hodgson & Elbakhiel, 1985).

The present study shows that light reflectance intensity is lower with vegetation as crop background and decreases with increasing main crop canopy cover. Aphid immigration followed a similar pattern, especially with intensity in the yellow waveband, which supports a phototactic explanation for aphid host plant orientation in the field. Further studies are needed to determine consistency of these patterns over a range of crop cultivars, aphids, cover crops, spacings and soil types. In addition, olfactory and optomotor responses of aphids should be analyzed in the field.

Acknowledgments

Thanks are expressed to Dr. Miguel Altieri for his support of this study, to Dr. Lewis Feldman, who gave critical advice on the light measurement and provided the use of the light meter. Thanks also to Dr. Kent Daane for his many helpful comments and suggestions to the manuscript.
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