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Preference of the Green Peach Aphid, *Myzus persicae*, for Plants Grown in Sewage Sludges

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Since passage of the Clean Water Act in the 1970s, disposal of the millions of tonnes of sewage sludge generated annually has become a major concern of municipalities throughout the United States. With the range of other disposal options having narrowed in recent years, application of sludge to land is increasingly viewed as a practical and economical means to recycle this waste material (Jacobs 1981; Bastian et al. 1982). However, sludges from large cities with industries may be contaminated with various toxic chemicals, including polychlorinated biphenyls (PCBs), other organic chemicals, such as pesticides, and heavy metals (Furr et al. 1976; Mumma et al. 1983, 1984). Sludge application to land thus has the potential adversely to affect biota and the functioning of terrestrial ecosystems.

Culliney and Pimentel (1986b) demonstrated marked reductions in fecundity and survival of green peach aphids, *Myzus persicae*, on collard plants, *Brassica oleracea* var. *sabellica*, growing in soil treated with chemically contaminated sludge as compared to aphids on plants growing either in soil treated with uncontaminated sludge of soil conventionally fertilized. Reduced plant growth and increased restlessness in aphids in the contaminated sludge treatment were also observed. The purpose of the present study was to examine more closely the influence of sludge contaminants on aphid settling behavior as indicated by differential preference of *M. persicae* for leaves of its collard host grown under different soil conditions.

MATERIALS AND METHODS

Collards were grown singly in 40 plastic pots in each of the same three experimental treatments detailed in Culliney and Pimentel (1986b): i) a mixture of soil and sludge from Syracuse, NY, a large city with industries (SS); ii) a mixture of soil and sludge from Groton, NY, a small town (GS); and iii) soil treated with a commercial chemical fertilizer, serving as a control (FT). A fourth treatment of unfertilized soil (UN) was added to the present study.

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Soil was obtained from the same source as in the previous study.

Samples of the two sludges were analyzed for the metal, cadmium, and for PCBs, two contaminants routinely measured in setting tolerance limits for sludge application to land (Baker et al. 1985). Measures of collard leaf surface area (Pimentel 1961) were made five weeks after germination on 10 randomly chosen plants from each treatment.

Aphid preference for leaves from collards grown in the four treatments was evaluated in a choice experiment. Leaf discs (20 mm diameter) were cut from fully expanded young leaves from randomly chosen plants of each treatment. One disc from each treatment was placed on filter paper, moistened with distilled water, in each of 10 replicate plastic petri dishes with lids marked in quadrants. Ten adult M. persicae apterae, obtained from a laboratory clone reared on collards grown in the same soil and fertilized at the same rate as FT plants, were placed in the center of each dish, and the lid replaced. Adequate humidity was maintained by placing dishes on wet toweling paper in large plastic boxes with adjustable covers. The boxes were then placed in a controlled environment chamber duplicating conditions in the previous study.

The numbers of aphids settled on treatment discs in each dish were counted at intervals of 24, 48, and 72 h. The experiment was performed a second time, and data pooled. Differences among treatments were assessed by analysis of variance and Duncan's multiple range test.

RESULTS AND DISCUSSION

Sludges from Syracuse and Groton were similar in cadmium content (8.19 and 8.97 ppm, respectively), but Groton sludge had a slightly higher PCB level (0.71 ppm) than Syracuse sludge (0.62 ppm). These results contrasted sharply with those reported in the previous study, in which cadmium and PCB levels in Syracuse sludge were respectively 15 and two times those in Groton sludge.

Differences in mean leaf surface area per collard plant among the treatments were highly significant ($F_{3,36}$=62.49, $P \ll 0.001$) (Fig. 1). Growth was most vigorous in FT plants and poorest in both GS and UN plants. Growth in SS plants was also significantly reduced compared to that in FT.

Differences in aphid settling among treatment discs were significant at 24 h ($F_{3,36}$=4.21, $P < 0.025$) and 72 h ($F_{3,36}$=3.05, $P < 0.05$); at the intermediate 48-h point, differences were barely nonsignificant ($F_{3,36}$=2.23, $0.05 < P < 0.10$) (Fig. 2). Fewest aphids colonized UN discs, whereas discs from FT plants were settled upon by relatively high numbers. Both treatments exhibited fairly stable numbers of settled aphids over the entire 72-h period (Table 1). After 24 h, most aphids had settled on GS discs. Numbers on these discs then declined steadily over the next 48 h (Fig. 2, Table 1). An opposite trend was evident on SS discs, on which most aphids settled

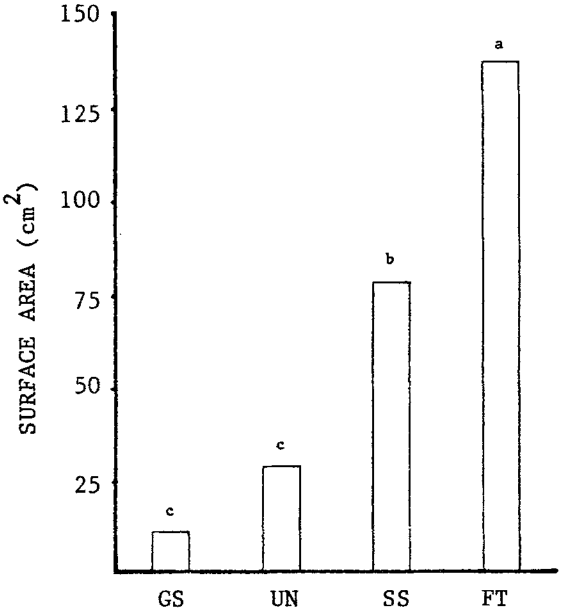

Figure 1. Collard growth, in mean leaf surface area per plant, in GS, UN, SS, and FT at five weeks after seed germination. Means designated by the same letter are not significantly different at the 5% level.

by the culmination of the experiment, although this count was significantly different only from that on UN discs.

Table 1. Distribution of aphids settling on treatment discs at 24, 48, and 72 h.

Time after placement (h)	Proportion of population settled[1] SS	UN	GS	FT
24	0.23	0.17	0.34	0.26
48	0.25	0.17	0.30	0.27
72	0.30	0.15	0.24	0.26

[1]Total proportion at a given time may not equal 1.00 due to one or two aphids found off discs and situated on petri dish surfaces.

The differential settling responses indicated clear differences in aphid preference among treatment discs. These differences, however, were not all consistent over the entire 72-h test period. The persistently low numbers settling on UN discs indicated that these were less attractive to aphids than those of the other three treatments. *Myzus persicae* is known to be highly sensitive to nutrients and other factors in its hosts (van Emden et al. 1969). UN plants were reduced in size, probably resulting from low availability of soil nutrients, and these likely produced leaves of inferior nutritional value for

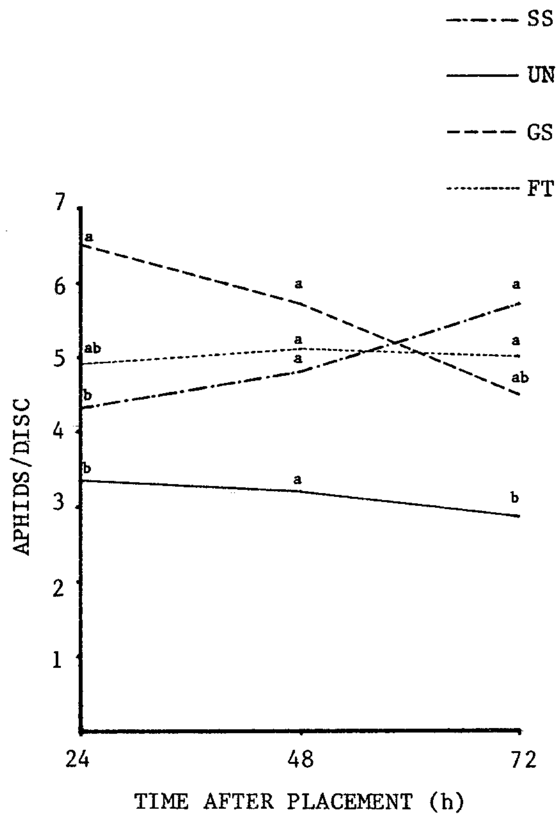

Figure 2. Mean number of aphids settling on treatment discs over the 72-h experimental period (data pooled from two replicate runs). Means designated by the same letter are not significantly different at the 5% level.

the aphids. The higher numbers consistently settling on FT discs indicated the greater suitability of these for aphid feeding. FT discs were cut from plants exhibiting optimal growth rates. Moreover, these plants were grown in identical soil conditions, and were likely closely similar in nutritional quality, to those from which the test population was obtained. Evidence suggests that apterous M. persicae settle more readily on hosts similar to those on which they were reared (Russell 1966; Lowe 1973; San Valentin and Calilung 1980).

While differences in growth and aphid preference between FT and UN plants can be attributed to differences in the soil nutrients supplied to the plants, interpretation of patterns in the two sludge treatments is more complex. Growth in GS plants was less than one-fifth that of SS and FT plants, a finding contrary to results of field studies showing plots treated with Groton sludge supporting significantly greater collard growth than plots treated with Syracuse sludge or with chemical fertilizer (Culliney et al. 1986; Culliney and Pimentel 1986a). Since macronutrient (NPK) content has been found to be similar in both sludges (Mumma et al. 1984; Lee et al. 1980), the severe reduction in growth in GS plants suggests the possible presence of phytotoxic contaminants in the particular sample of Groton sludge used in the present experiment. This sample contained twice the cadmium level of Groton sludge used in the earlier study (Culliney and Pimentel 1986b), and may have been similarly elevated in other toxins. The significantly lower growth rate in SS compared to FT plants may also have indicated exposure of SS plants to growth-inhibiting substances. Sludge from the same source can vary widely over time in the thousands of constituents it typically contains (Mumma et al. 1983; Sommers 1977). The large difference between the cadmium and PCB levels in the two sludges used in the present study and those levels reported previously (Culliney and Pimentel 1986b) provides further evidence of this variability.

The high rate of change in aphid settling response over the 72-h test period in the two sludge treatments, compared to the relative stability of aphid numbers on both UN and FT discs, suggested that the opposing GS and SS trends may largely have resulted from an exchange of aphids between discs of these two treatments. Results from choice experiments on hosts grown under normal conditions have shown that aphids typically settle within 24 h after placement (Bond and Lowe 1975; Weber 1985), a situation approximated on the FT and UN discs. Aphids readily detect a wide range of substances, of varying attractiveness and repellency, in sap (Schoonhoven and Derksen-Koppers 1976; Campbell et al. 1986) and on leaf surfaces (Jördens-Röttger 1979), and have shown increased restlessness when exposed to toxic chemicals taken up from soil and translocated by their hosts (Davidson 1925; Boiteau et al. 1985). GS and SS leaf discs may have contained toxins, contributing to restlessness in aphids exposed to them, and producing the observed flux in aphid numbers between the two treatments.

The opposite trends in settling response between the two sludge treatments indicated a decreasing preference for GS discs and an increasing preference for SS discs in aphids. Why GS discs apparently decreased in suitability for aphids while SS discs increased is unclear. The earlier observations of Culliney and Pimentel (1986b) would predict a consistently low preference in aphids for SS discs and a response to GS discs similar to that to FT discs. While valid comparisons of aphid responses to leaf discs with those to leaves attached to growing plants are problematic (MacKinnon 1961; Schalk et al. 1969; Xia and Tingey 1986), the pattern of response between the two sludge treatments, with reference to the earlier study, indicates not only the variability of sludge composition within and between sources, but also supports the view (Mumma et al. 1983) that even sludges from small towns may at times contain significant quantities of toxins.

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