Sugarbeet Resistance to Minnesota Populations of Sugarbeet Root Aphid (Homoptera : Aphididae)

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ABSTRACT

The response of sugarbeet root aphid, *Pemphigus betae* Doane, to selected sugarbeet varieties was examined under greenhouse and field conditions. Nine sugarbeet varieties and a known susceptible host, common lambsquarter, *Chenopodium album* L., were grown in the greenhouse and infested with reproductive apterae (wingless adults) 6 weeks after planting. Mean adult density was significantly ($P \leq 0.05$) lower in four varieties (HM 9155, HM A16, HM TX-18, and ACH 184), compared with *C. album,* with no adults surviving on HM 9155. In the field test, 8 varieties were infested with laboratory-reared *P. betae* 6 weeks after planting (14 July), and at 2 week intervals for a total of four infestations. Nine to 12 reproductive apterae were placed directly on the root mass of one plant per variety on each infestation date. Infestations at harvest were generally low, with a known susceptible, KW 3580, having the highest infestation (52.2%). HM A16, HM TX-18, and ACH 184 showed similar responses to those found in the greenhouse study. No aphids survived on Seedex Monohikari. HM LSR-88 was generally uninfested in the field, but supported large colonies in the greenhouse, suggesting that resistance was apparently limited to antixenosis. Varieties that gave similar results in both tests indicate the possibility of multiple resistance factors, particularly antibiosis.

Additional Key Words: *Beta vulgaris* L., integrated pest management, resistance mechanisms

Sugarbeet root aphids, *Pemphigus betae* Doane or closely related *Pemphigus* spp.[†], are sporadic pests of sugarbeets, *Beta vulgaris* L., throughout North America. Economic infestations have been documented from Alberta to Quebec and in all western states in the U.S. (Harper 1963). Recently, *P. betae* infestations have become more common in southern Minnesota. Approximately 10% of the 33,000 ha-crop was infested in 1984 and 1989; the 1989 loss was estimated to exceed $3,000,000 (Hutchison and Campbell 1991). During a two-year study under dryland production in Minnesota, recoverable sugar was reduced by 54% in *P. betae* infested areas (Hutchison and Campbell 1994a). These results are similar to those of Summers and Newton (1989), in which aphid-induced losses in recoverable sugar averaged 50% under irrigated conditions in California.

Between 1990-1993, isolated *P. betae* populations persisted in the southern Minnesota growing area, infesting about 12% of the fields surveyed (Hutchison and Campbell 1994b) despite generally cool temperatures (daily maximum $<30°C$) and high precipitation. Several management tactics, including insecticide treatments and use of resistant cultivars, have been evaluated since 1990. Although the use of terbufos (Counter 15G) showed some potential for control (Campbell and Hutchison 1991, 1994), results were inconsistent from year to year. In some tests, insecticide applications (e.g., chlorpyrifos, Lorsban 4E, 15G) resulted in increased aphid infestations (Campbell and Hutchison 1991, 1994). Given the sporadic occurrence, cryptic nature of the aphid (Hutchison and Campbell 1994a) and inconsistencies with chemical control, use of resistant varieties appears to be the most promising long term management strategy.

Varietal resistance to *P. betae* has been reported in field (Wallis and Gaskill 1963, Wallis and Turner 1968) and greenhouse studies (Harper 1964). Although specific mechanisms of resistance are not known, both antibiosis and antixenosis (cf., non-preference; Kogan and Ortman 1978) appear to contribute to sugarbeet resistance to the aphid (Wallis and Gaskill 1963, Wallis and Turner 1968, Harper 1964). The purpose of present study was to examine the response of Minnesota populations of *P. betae* to selected sugarbeet varieties in greenhouse and field tests, and based on these results, formulate hypotheses for mechanisms of resistance.

[†] There is considerable doubt as to the synonymy of *Pemphigus betae* Doane and *P. populivenae* Fitch. *P. populivenae,* studied exclusively in California, forms galls on *Populus trichocarpa,* whereas *P. betae* prefers *Populus angustifolia* James and *P. balsamifera.* Our alate specimens from sugarbeets were determined by D. Voegtlin (Illinois Natural History Survey) as *Pemphigus betae* Doane. We prefer to use this name until appropriate research resolves the taxonomic problem.

MATERIALS AND METHODS

Greenhouse Study. Nine commercially available sugarbeet varieties were evaluated: HM 9155, HM A16, HM TX-18, and HM LSR-88 (Hilleshög Mono-Hy Inc., Longmont, CO 80501); ACH 139, ACH 184, and ACH 206 (American Crystal Sugar Inc., Moorhead, MN 56560); and KW 3580 and KW 2249 (Betaseed, Inc., Shakopee, MN 55379). Common lambsquarter, *Chenopodium album* L., a known susceptible host (Hutchison and Campbell 1993, 1994b) was included for comparison. Sugarbeet seed was planted in flats 11 March 1992, and grown until 21 April (4 true leaf stage for sugarbeets). Sugarbeet plants, and *C. album* seedlings taken from a nearby field (Shakopee, MN), were then transplanted into a peat/vermiculite mix in 10.2-cm square pots. Before transplanting, all *C. album* were examined closely to ensure that *P. betae* infestations were not present.

Each plant was infested at transplanting by introduction of overwintering, apterous aphids, field-collected in southern Minnesota (15 April) and held at 4°C. Three reproductive aphids were placed into the root mass before placement into a new pot. Plants were arranged nine to a flat with each variety placed in groups of three each, at random, with a row of empty pots separating each group. For each variety, five replications of three plants each were used. The greenhouse was set at 20°C and plants were watered daily at the base of each flat to prevent aphids from drowning before colonies could establish. On 28 May, root masses were bagged and frozen for evaluation. Populations were evaluated by floating aphids out of the root mass in 12-cm diameter bowls. Aphids were classified as adults or nymphs based on the presence of the sub-genital plate as an indicator of maturity.

Data collected included the number of adults and nymphs per plant, as well as the percentage of plants infested with adults and nymphs. Variances for aphid count data were highly correlated with their respective means. Therefore, all count data were transformed by $\log_{10}(x+1)$ before analysis. Percentage data were transformed by arcsine $(\sqrt{(x+1)})$. Data were analyzed by one-way analysis of variance (ANOVA), and comparisons among means were tested with the Ryan-Einot-Gabriel-Welsch multiple F test (SAS Institute 1988).

Field Study. Eight commercially available sugarbeet varieties were evaluated, including 6 of 9 tested in the greenhouse study (HM A16, HM LSR-88, HM TX-18, ACH 184, KW 3580 and ACH 206). All varieties were planted 2 June 1993 at the University of Minnesota Agricultural Experiment Station at Rosemount, Minn. Each variety was planted in single 7.6-m rows on 76-cm centers. Each variety was replicated 4 times and arranged in a randomized complete block design.

Laboratory-reared aphids, maintained in hydroponic growth pouches (Campbell and Hutchison 1995), were used to infest the variety plots. Nine to 12 reproductive apterae (plus excess nymphs from the colony) were placed in the soil directly adjacent to the taproot of the center plant in each row. The same plant was infested four times biweekly beginning 14 July. A 3-m row sample was harvested from the center of each row on 23 Sept.

Hybrids were evaluated with a root rating system (0-5) (Hutchison and Campbell 1994a) and by recording the percentage of beets infested. Two 9-oz soil samples (by volume) also were collected within each row where aphids were released. Aphids in soil samples were counted and classified as adults or nymphs, based on the presence of the sub-genital plate on adults; only late-instar nymphs (3-4) were recorded. As in the greenhouse study, all aphid density and percent data were transformed by $\log_{10}(x+1)$ and arcsine $(\sqrt{(x+1)})$, respectively. Data were then analyzed by one-way ANOVA and the Ryan-Einot-Gabriel-Welsch multiple F test (SAS Institute 1988).

RESULTS & DISCUSSION

Greenhouse Study. Plants infested with adults ranged from 0-66.7%, with higher infestations generally occurring in those varieties that also supported large individual colonies (e.g., > 100 aphids/plant) (Table 1). Plants infested with adults and nymphs (total percent infested) did not differ significantly among varieties. One variety did not support any adults (HM 9155), whereas several (HM A16, HM TX-18, ACH 184, and ACH 139) harbored a limited number of adults ($\leq$ 35 adults/plant) on at least one plant. Four of these 5 varieties (excluding ACH 139) had significantly ($P \leq 0.05$) fewer adults than common lambsquarter, *C. album,* the most susceptible host. The remaining varieties, including *C. album,* supported at least one colony with over 100 adults (range 185-733). Only HM 9155 and HM A16 had significantly fewer nymphs, total aphids and significantly fewer plants infested with adults than *C. album.* Aphids were present on all varieties, but colony size was variable both within and among varieties.

The greenhouse study could be considered a closed test because aphids were placed within the root mass at transplanting, minimizing expression of antixenosis. However, some dispersal was possible from vigorous colonies; first-instars may have migrated to other pots by way of drainage holes, or across the soil surface. Because of the propensity for first-instar nymphs to disperse (unpublished), we used the absence of adults as the best criterion for antixenosis resistance.

Table 1. Response of *P. betae* to selected sugarbeet varieties and *Chenopodium album* L. in a greenhouse test, Shakopee, MN, 1992.[†]

	Mean no. of Aphids/plant (range)			% Infested[‡]	
Variety	Adults	Nymphs[§]	Total	Total	Adults
HM 9155	0.0d	6.3bc	6.3c	46.7	0c
	(0)	(0-47)	(0-47)		
HM A16	0.1cd	17.1c	17.3c	26.7	6.7bc
	(0-2)	(0-184)	(0-186)		
HM TX-18	2.3bcd	31.9abc	34.1abc	40.0	13.3abc
	(0-25)	(0-211)	(0-168)		
ACH 184	3.2bcd	41.1abc	44.3abc	73.3	13.3abc
	(0-35)	(0-437)	(0-484)		
ACH 139	7.5abc	167.0abc	174.5abc	60.0	33.3abc
	(0-35)	(0-799)	(0-824)		
ACH 206	20.0abc	180.4abc	200.4abc	80.0	60.0ab
	(0-185)	(0-1628)	(0-1813)		
KW 3580	36.5ab	275.3abc	311.9abc	73.3	46.7abc
	(0-289)	(0-2456)	(0-2544)		
KW 2249	42.1abc	323.2abc	365.3abc	40.0	33.3abc
	(0-488)	(0-3046)	(0-3534)		
HM LSR-88	76.13abc	618.7ab	694.9ab	66.7	40.0abc
	(0-733)	(0-4593)	(0-5326)		
C. album	87.60a	394.9a	482.5a	86.7	66.7a
	(0-472)	(0-2380)	(0-2852)		
				NS	

[†] Means followed by the same letter are not significantly different (P = 0.05); Ryan-Einot-Gabriel-Welsch multiple F test. NS = not significantly different. Aphid density data were transformed by $\log_{10}(x+1)$ before analysis; pre-transformed means are presented.
Percentage data were transformed by arcsine ($\sqrt{(x+1)}$) before analysis; pre-transformed means are presented.

[‡] Infested plants included those having one or more aphids.

[§] Nymph stage includes all four instars.

For example with HM 9155, because of the absence of adults on any plant, all immature aphids present were assumed to be migrants. In addition to HM 9155, adult infestations were significantly reduced in HM A16, HM TX-18 and ACH 184. These results suggest the possibility of antixenosis.

Antibiosis includes all adverse effects of the host plant on the insect's life history, such as death of early instars, delayed immature development, and reduced adult longevity and fecundity (Smith et al. 1994). Although there were fewer significant differences in nymphal and total aphid density, the range in mean density and maximum total no. of aphids per plant (47-5326) suggests that antibiosis may also contribute to the resistance levels shown. Our results for total aphid density are similar to those of a previous greenhouse test (Harper 1964), where a broad range of root aphid infestations developed on 11 sugarbeet varieties.

Field Study. Infestation levels were generally low throughout this test (Table 2). Although aphids were placed directly into the soil on the roots, the opening was not sealed allowing aphids to disperse to adjacent varieties prior to root colonization. Of the four varieties that showed evidence of resistance in the greenhouse study (HM 9155, HM A16, HM TX-18, ACH 184), three were included in the field test (HM 9155 seed was unavailable). As in the greenhouse study, all had lower infestation levels, compared to the known susceptible varieties (KW 3580 and ACH 206).

Only one variety (Seedex Monohikari) was completely uninfested (Table 2). Although no aphids were present on HM A16, some wax, known to be secreted by *P. betae,* was present on 2.8% of the beets, indicating the presence of only trace infestations (Hutchison and Campbell 1994a). Significant differences were observed for nymphs, total aphids, and percent beets infested, but adult densities did not differ significantly among varieties. Percent infested plants was significantly less in 6 varieties, when compared to the susceptible KW 3580. Although KW 3580 had the highest percent infestation (52.1) and root rating (1.06), these infestation ratings were below economic injury levels (Hutchison and Campbell 1994a). Recent field studies in Minnesota with laboratory-reared *P. betae,* have shown that damage at harvest can be increased by infesting variety plots earlier (e.g., early June; unpublished).

In addition to Seedex Monohikari and Seedex Ranger, most varieties included from the greenhouse test (HM A16, HM TX-18, and ACH 184) all had low infestations in the field study, with $< 10\%$ of the plants infested. With these varieties, either antixenosis or antibiosis may

be responsible for the resistance shown. Although HM LSR-88 appeared resistant in the field (significantly different from KW 3580), it was among the most susceptible in the greenhouse study, infested with the largest colony (733 adults, 5326 total aphids). This finding suggests that the field resistance was limited to antixenosis.

With the exception of Seedex Monohikari, developed in Japan, all other varieties showing resistance to *P. betae* in this study (HM 9155, HM A16, HM TX-18, ACH 184 and Seedex Ranger) are the result of long-term breeding programs in the U.S. Our results are similar to those of earlier studies where germplasm from the western U.S. (e.g., Great Western Sugar Co.) was most resistant to root aphids (Harper 1964; Wallis and Turner 1968). Because breeding stock in the western U.S. is routinely exposed to naturally occurring sugarbeet root aphid infestations, and only the most promising lines are conserved for further development (i.e., lines with high sugar content in the presence of multiple pest pressure), germplasm developed in the U.S. is more likely to have *P. betae* resistance than European germplasm (J. Widner, personal communication). However, not all U.S. varieties with root aphid resistance are agronomically suitable for every North American growing region and susceptible varieties are planted in several locations, including Minnesota (Hutchison and Campbell 1994a).

In summary, resistance levels of most varieties to *P. betae* were similar in both greenhouse and field tests, suggesting that both antixenosis and antibiosis may be responsible for the resistance shown. However, the differential response of HM LSR-88 indicates that resistance in this variety is apparently limited to antixenosis. Although field trials are necessary for evaluating overall variety performance, our results illustrate a limitation of side-by-side variety trials for *P. betae*. Because of the close proximity of sugarbeet varieties in field trials (often single row plots), the absence of aphids on a given entry may indicate that the resistance response is limited to antixenosis. As noted by Wallis and Gaskill (1963), varieties that have only antixenosis resistance may not perform well in commercial monocultures, where preferred varieties are not available. One useful method for elucidating resistance mechanisms, would be the use of age-specific life table analyses (e.g., Campbell and Hutchison 1995) of data from a closed no-choice rearing system. Specifically, results from aphid fecundity, survivorship, and behavioral studies on varieties that were not preferred in side-by-side field tests, would allow for confirmation of antixenosis or antibiosis resistance (Smith et al. 1994). Knowledge of resistance mechanisms would permit more efficient integration of *P. betae* resistance into useful breeding lines, new varieties and integrated pest management programs.

Table 2. Response of *P. betae* to selected sugarbeet varieties in a field test, Rosemount, MN, 1993.[†]

	Mean no. of Aphids/9 oz. sample (range)				
Variety	Adults	Nymphs[‡]	Total	% Infested[§]	Root Rating[¶]
Seedex Monohikari	0.0 (0)	0.0a (0)	0.0a (0)	0.00a	0.0a
HM A16	0.0 (0)	0.0a (0)	0.0a (0)	2.80a	0.04a
Seedex Ranger	0.5 (0-1)	0.5ab (0-2)	3.0ab (0-2)	4.15a	0.04a
HM LSR-88	0.7 (0-3)	1.5ab (0-9)	3.0ab (0-12)	15.52a	0.25a
HM TX-18	1.2 (0-4)	2.2ab (0-15)	5.0ab (0-19)	7.83a	0.13a
ACH 18	2.2 (0-8)	3.7ab (0-5)	3.7ab (0-13)	5.40a	0.12a
KW 3580	9.9 (0-29)	55.6b (0-186)	65.5b (0-215)	52.15b	1.06b
ACH 206	10.2 (0-41) NS	74.7b (0-287)	85.0b (0-328)	33.58ab	0.78ab

[†] Means followed by the same letter are not significantly different ($P = 0.05$); Ryan-Einot- Gabriel-Welsch multiple F test. NS = not significantly different. Aphid density data were transformed by $\log_{10}(x+1)$ before analysis; pre-transformed means are presented. Percentage data were transformed by arcsine ($\sqrt{(x+1)}$) before analysis; pre-transformed means are presented.

[‡] Nymph stage includes instars 3 - 4 only.

[§] Infested plants included those with wax, and/or aphids, on the taproot at harvest.

[¶] Beet root rating index developed for *P. betae* in Minnesota, defined as follows: 0 = no aphid colonies or wax present; 1 = one colony, wax (or both), $\leq$ 2.5 cm diameter each; 2 = two or more colonies, wax (or both), $\leq$ 2.5 cm diameter each, covering $<$ 50% of root surface; 3 = one or more colonies, wax (or both), $>$ 2.5 cm diameter each, covering $<$ 50% of root surface; 4 = multiple colonies, wax (or both), covering 50 to 95% of root surface; 5 = multiple colonies, wax (or both), covering $>$ 95% of root surface.

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