

Resistance and Susceptibility to Insect Pests in Glossy Genetic Lines of *Brassica oleracea* in Connecticut, USA

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Abstract

The glossy cauliflower PI 234599 has been used in breeding programs as a source of resistance to diamondback moth, *Plutella xylostella* (L.), and other lepidopterous larvae, but the relationship between insect resistance and glossiness has not been clear. One way to clarify this relationship is to find glossy lines carrying different genes for glossiness and test their resistance to insects. In the process, additional sources of resistance may be identified. Ten glossy lines of broccoli, cauliflower, kale, and collards with at least four different genes for glossiness (three recessive nonallelic genes and at least one dominant gene) were tested in the field under natural infestation for resistance. The insect species studied were imported cabbageworm (*Pieris rapae* (L.)), diamondback moth (*Plutella xylostella* (L.)), cabbage aphid (*Brevicoryne brassicae* (L.)), and flea beetles (mainly *Phyllotreta cruciferae* (Goeze), but also *Phyllotreta striolata* (F.)). All glossy lines were resistant to cabbage aphid and all except one was consistently resistant to imported cabbageworm. They were susceptible to flea beetles, although less susceptible in the fall than in spring. Their resistance to diamondback moth varied greatly among plantings, probably because of the low insect population in Connecticut. In order for these additional glossy lines to become useful sources of resistance to diamondback moth, they need to be tested and bred where this insect is a serious problem, instead of under low natural populations or artificial infestations in the northeastern USA.

Introduction

The first International Workshop on Diamondback Moth Management included two papers on resistance to diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), and to two other lepidopterous pests, the imported cabbageworm (ICW), *Pieris rapae* (L.), (Lepidoptera: Pieridae) and the cabbage looper (CL), *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), in the glossy cauliflower PI 234599 (Eckenrode et al. 1986, Dickson et al. 1986). It was clear from the breeding work of Dickson et al. (1986) that strong vertical resistance to these Lepidoptera could not be easily separated from the glossy character, but it was unclear whether resistance and glossiness were due to closely linked genes or whether glossiness itself was a factor in resistance.

In other studies, glossiness has been associated with lower populations of the cabbage aphid *Brevicoryne brassicae* (L.) (Thompson 1963; Way and Murdie 1965), and higher than normal populations of flea beetles, although no systematic measurements were made (Anstey and Moore 1954; Way and Murdie 1965; Dickson and Eckenrode 1980). In these papers it was also not clear whether the effects on insect populations were associated with glossiness in general or with other genes in a specific glossy genetic line.

Glossy plants appear dark green and shiny, compared to the bluish-white haze on the surface of plants with normal leaf wax. The glossy appearance is due to a change in the microscopic structure of wax on the leaf surface, with flat plates or sparsely distributed short rods or globules of wax, rather than the dense mat of vertical tubes characteristic of normal wax. These changes in wax structure are usually associated with a decrease in the quantity of wax per unit area, a change in chemical composition of the wax, or both (Baker 1974; Jeffree et al. 1976). At least eight different genes for glossiness have been found in *Brassica oleracea*, and substantial differences in the chemistry and wax morphology among these glossy lines have been described (Anstey and Moore 1954; North and Priestley 1962; Macey and Barber 1969, 1970; Denna 1970; Netting et al. 1972; Baker 1974; Jeffree et al. 1976).

The first step toward establishing the relationship between glossiness and resistance was to collect plants with several different genes for glossiness and test them for resistance. I tested them in the field under natural infestations of several insect pests. There would be three possible outcomes of this test with respect to any of the pest species to which PI 234599 was resistant: (1) only PI 234599 (called here Caul1) would be resistant and none of the other lines with other genes for glossiness would be; (2) all glossy lines would be resistant; or (3) some but not all of the lines with different genes for glossiness would be resistant. Any of these outcomes would help to narrow the search for the mechanism of resistance, and either of the last two would suggest additional glossy lines that could be used in breeding as sources of resistance.

Materials and Methods

Seed from the specific genetic lines described from 15 to 35 years ago was not available in most cases, but I did find seed of glossy lines from several sources in different crop morphotypes within *B. oleracea* (Table 1). I have at least four nonallelic genes for glossiness (three recessive and one dominant), and possibly more, since I have not yet determined allelism for the dominant

Table 1. Glossy lines tested for resistance to insects in 1988 and 1989.

	No. of plantings	Genetics of glossiness		Source ¹
		Dominance	Allelism	
<i>Broccoli</i>				
Broc3	7	dominant	?	Borchers
Broc4	6	dominant	?	Borchers
Broc5	4	recessive	not allelic	Sampson
<i>Cauliflower</i>				
Caul1	7	recessive	to KCR4, Gl. Vates	NERPIS (PI 234599)
Glossy Andes	4	recessive	not allelic	discovered in cv. Andes
<i>Collards</i>				
Green Glaze	7	partial dominant	?	Christianson
S.C. Glaze	7	partial dominant	?	Borchers
White's Gr. Glaze	7	partial dominant	?	Borchers
<i>Kale</i>				
KCR4	7	recessive	to Caul1,	Borchers
Gl. Vates	7	recessive	to Caul1 KCR4	Christianson

¹Sources: Borchers = E. A. Borchers of the Hampton Roads Agricultural Experiment Station, Virginia Beach, VA, USA; Sampson = D. R. Sampson, Plant Research Centre, Ottawa, Ontario, Canada; NERPIS = Northeast Regional Plant Introduction Station, USDA-ARS Germplasm Resources Unit, NYSAES, Geneva, NY, USA; Christianson = Alf. Christianson Seed Company, Mount Vernon, WA, USA.

genes. As noted in Table 1, I have observed the insect populations under natural infestations on these genetic lines in 4-7 plantings for each line in 1988 and 1989. These observations were made at Lockwood Farm in Hamden, CT, or the Valley Laboratory in Windsor, CT. The glossy lines and normal standards were transplanted in early May for harvest in July-early August (spring planting), and in late July for harvest in late September-October (fall planting). All plantings were made in a nested randomized block design with three blocks and one row of each genetic line within each block. Observations were made on two plants from the interior of each row.

Figures 1-4 have been produced from selected data sets from 1988. The data from that year have been published in full (Stoner 1990). Reference will also be made to data from 1989. The glossy lines Broc5 and Glossy Andes were first tested in the field that year. These data have been analyzed, but are not yet published.

Results

ICW

The resistance of glossy lines to ICW is shown in Fig. 1. In the seven plantings in 1988 and 1989, all glossy lines of broccoli, cauliflower and collards and the glossy kale Glazed Vates consistently had lower numbers of ICW larvae than the lines with normal wax. The only exception to this pattern was one line with highly variable resistance, the glossy kale KCR4, which had numbers of ICW equal to those on some normal lines, including normal kales, in three out of seven plantings.

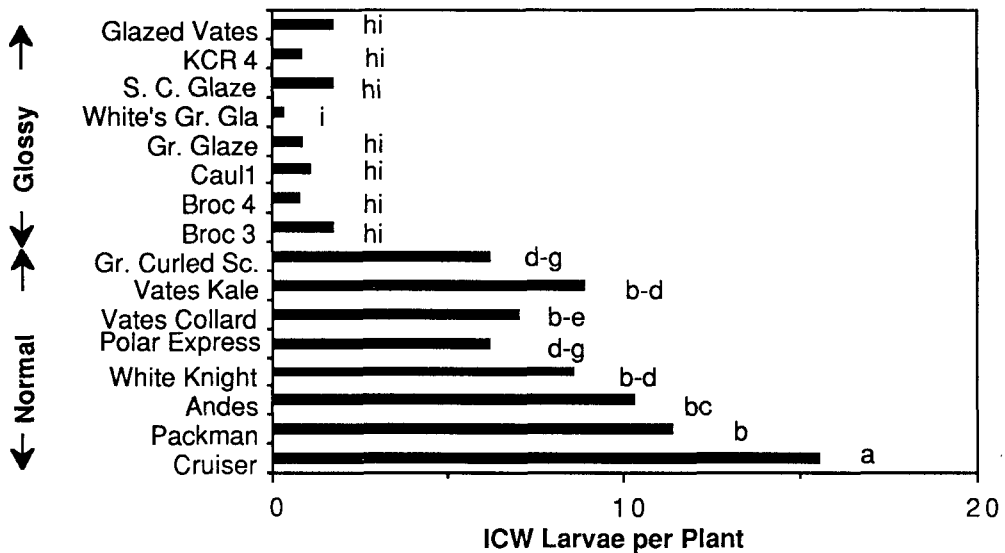


Fig. 1. ICW per plant in repeated sampling over the growing period. Bars followed by the same letter are not significantly different ($P = 0.05$; protected LSD test). Crop morphotypes of glossy lines are listed in Table 1. Crop morphotypes of normal lines are: Gr. Curled Sc. and Vates Kale--kale; Vates Collard--collard; Polar Express, White Knight and Andes--cauliflower; Packman and Cruiser--broccoli. Lockwood, fall 1988.

DBM

DBM, unlike ICW, occurred in substantial numbers only sporadically in my plots, and, in fact, did not occur in numbers large enough for comparison of different lines in any planting in 1989. As illustrated in Fig. 2, glossy lines as a group appear slightly more resistant than normal lines, but DBM numbers varied widely within both groups. The relative resistance of glossy lines also varied between plantings (Stoner 1990). Thus, the natural population level of DBM in Connecticut, as in New York (Eckenrode et al. 1986), is insufficient either in numbers or in uniformity of infestation for accurate screening for resistance.

Sanford Eigenbrode (University of California Riverside, pers. comm.) has tested many of the same glossy lines in the field in New York State using artificial infestation with DBM eggs and found that all the glossy genotypes studied except KCR4 had lower larval mining and survival than normal varieties of the same crop morphotype. He also found that levels of resistance were correlated with a low quantity of wax per unit leaf area and low density of crystalline structures per unit area under scanning electron microscopy.

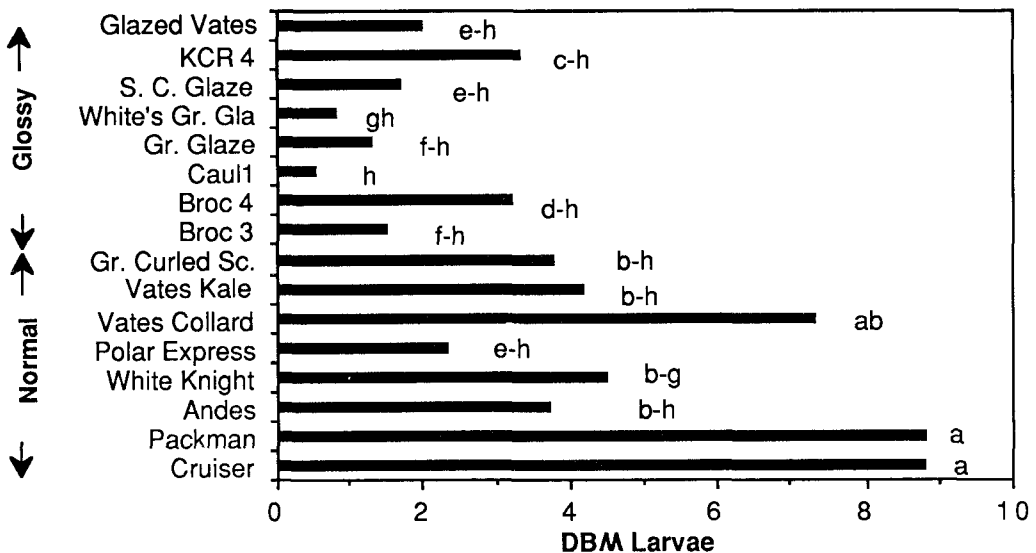


Fig. 2. DBM larvae per plant in repeated sampling over the growing period. Bars followed by the same letter are not significantly different ($P = 0.05$; protected LSD test). For identification of the lines, see Table 1 and caption of Fig. 1. Lockwood, fall 1988.

Brevicoryne brassicae

The data for *B. brassicae* are limited to three plantings, because these aphids occurred in substantial numbers in only one of the two locations, and not in all plantings at that location. But the pattern of low numbers of apterous *B. brassicae* on all glossy lines is consistent both within plantings (as illustrated in Fig. 3) and between plantings. When transformed back into antilogarithms, the mean numbers of aphids per plant were 100-313 for the more susceptible normal lines in this planting (Green Curled Scotch, Vates Kale, Packman and Cruiser), as compared to a maximum of 5.4 aphids/plant for the most susceptible glossy line KCR4.

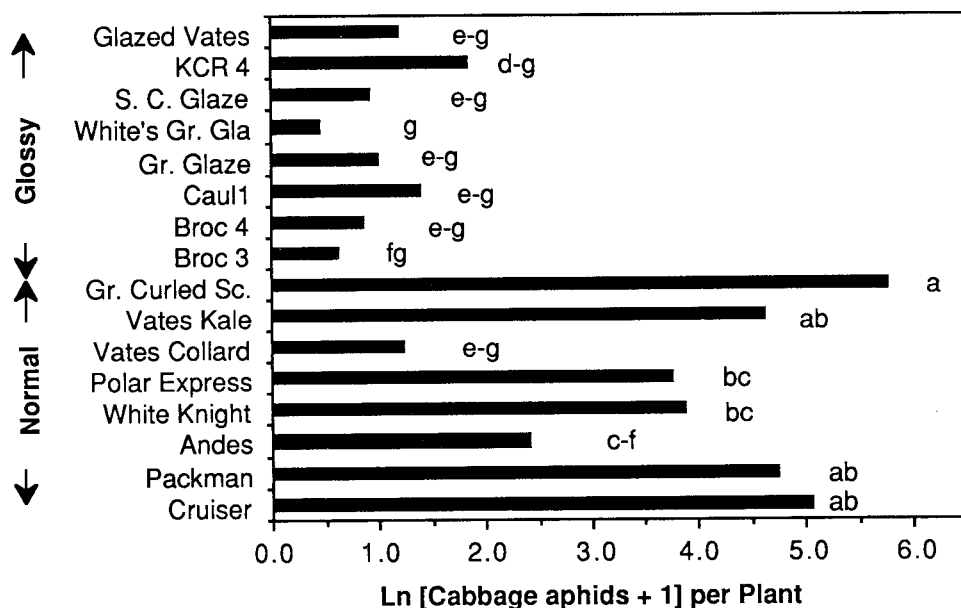


Fig. 3. Apterous cabbage aphids *Brevicoryne brassicae* per plant in repeated sampling over the growing period. Bars followed by the same letter are not significantly different ($P = 0.05$; protected LSD test). For identification of the lines, see Table 1 and caption of Fig. 1. Lookwood, fall 1988.

Phyllotreta cruciferae

As shown in Fig. 4, glossy plants had higher numbers of the flea beetle *P. cruciferae* than normal plants in some plantings. These data are from a spring planting in 1988; in the fall planting in 1988 at the same location, the trend of the data was reversed, and most normal lines had higher numbers than glossy lines, although the differences were not statistically significant. In 1989, glossy lines tended to have more *P. cruciferae* in both spring and fall, but the differences were not always statistically significant, particularly in the fall. Another species of flea beetle *Phyllotreta striolata* has a pattern similar to that of *P. cruciferae*.

Discussion

Most glossy lines were more resistant to ICW, *B. brassicae*, and DBM, and more susceptible to the flea beetles *P. cruciferae* and *P. striolata* than lines with normal leaf wax. However, the kale KCR4 was more variable in its resistance to ICW than the other glossy lines and has not shown any resistance to DBM. It was surprising that the level of resistance of KCR4 was so different from that of Caul1 because genetic tests indicated that these two lines (and also the kale Glazed Vates) have allelic genes for glossiness. This means that there are either modifying genes elsewhere in the genome that interact with glossiness genes (and possibly environmental factors) to affect resistance, or the genes for glossiness in these lines, although allelic, are not identical in their action, and these differences in action affect resistance. The difference in resistance between KCR4 and Caul1 and how it relates to differences in wax structure and chemistry in crosses and segregating populations between these two lines is currently under investigation.

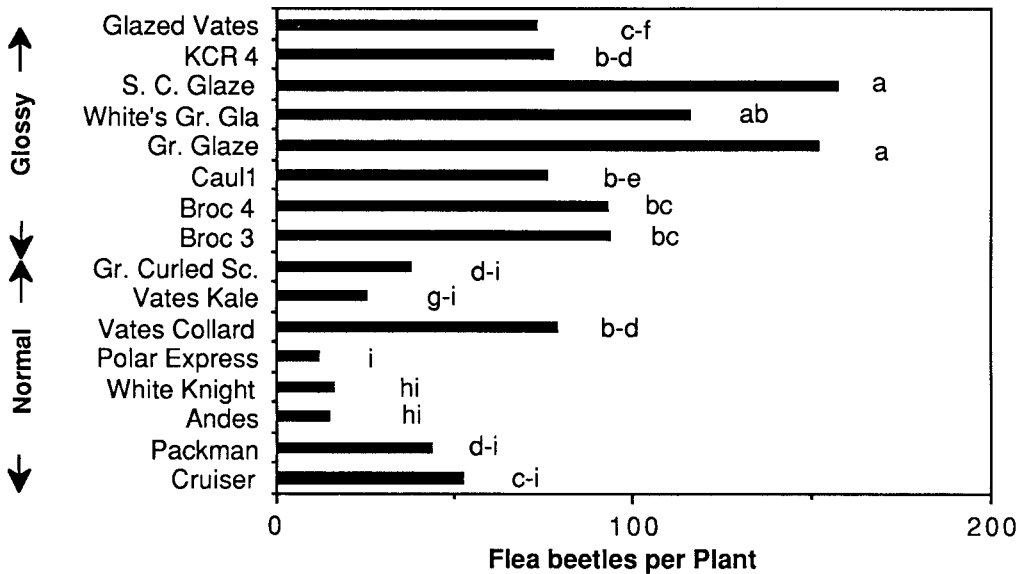


Fig. 4. Adult crucifer flea beetles *Phyllotreta cruciferae* per plant in repeated sampling over the growing period. Bars followed by the same letter are not significantly different ($P = 0.05$; protected LSD test). For identification of the lines, see Table 1 and caption of Fig. 1. Lookwood, spring 1988.

Aside from KCR4, the other glossy lines can be used as sources of resistance to ICW, *B. brassicae*, and DBM, and may present advantages to plant breeders, such as dominance, availability in other crop morphotypes, or avoidance of a single narrow genetic base, over the breeding material produced by Dickson derived from PI 234599 (or Caul1). In order for these lines to become useful sources of resistance to DBM, however, they need to be tested and bred under realistic conditions in regions of the world where DBM is a serious problem, instead of under low natural populations or artificial infestations in the northeastern USA.

Glossiness changes much more than just resistance to a few species of lepidopterous larvae. It increases resistance to the aphid *B. brassicae* (but there was no observed effect on the other common aphid species *Myzus persicae* (Sulzer)). As shown here, it may increase susceptibility to flea beetles. If, as Stork (1980) has proposed, glossiness affects the ability of all insects using adhesive setae to walk on the plant, glossiness may affect the movement of many predators and parasites (as observed by Way and Murdie (1965) for coccinellid and anthocorid predators) as well as pests. Water sticks to the surface of glossy leaves, instead of rolling off as it does on a normal waxy surface, a factor that could change the dynamics of plant and insect pathogens, the effectiveness of pesticides, and the effect of rain on many small insects. In my experience, glossy broccoli and cauliflower plants often produce heads later than normal plants, although this could relate to inbreeding or lack of local adaptation rather than the glossy trait itself.

In short, glossiness alters the entire ecology of the plant. In order to know if glossiness would fit into an integrated pest management system as a way of controlling DBM, all these changes in plant ecology must be observed under the conditions where the plant will ultimately be used.

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