Grape Phylloxera (Homoptera: Phylloxeridae): Comparison of Leaf Damage to Grape Cultivars Grown in Arkansas[1]

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ABSTRACT Grape cultivars (*Vitis*) grown in northwestern Arkansas varied significantly in gall counts per leaf produced by the foliar grape phylloxera *Daktulosphaira vitifoliae* (Fitch). 'Saturn', 'Fredonia', 'Campbells Early', 'Verdelet', 'Concord', 'Venus', 'Mars', and 'Cimarron' had significantly fewer galls per leaf than did 'Villard Noir', 'Himrod', 'Reliance', and 'Lakemont'. Gall counts significantly increased linearly as leaf width and hair density on the lower leaf surface decreased. Only grape cultivars with significantly larger gall counts per leaf had significant reductions in leaf widths relative to leaf widths on gall-free leaves. The relationship between leaf width and leaf hair density to grape cultivar susceptibility to foliar grape phylloxera is yet to be explained. A review of the mechanisms and suggested studies of leaf gall formation and prevention are presented.

KEY WORDS *Vitis*, grape, *Daktulosphaira vitifoliae*, phylloxera, host plant resistance, gall.

Foliar grape phylloxera, *Daktulosphaira vitifoliae* (Fitch), induction of leaf galls can cause economic reductions in yield and soluble solids (McLeod and Williams 1991) for certain grape cultivars grown in humid climates (Stevenson 1970b, Williams and Shambaugh 1988). The species belonging to the section Euvitis of the genus *Vitis* are all affected to some extent by root and leaf galling of the grape phylloxera (Wapshere and Helm 1987).

Comparisons have been made of the differences in susceptibility of certain grape cultivars and species to foliar grape phylloxera (Stevenson 1970ab, Jubb 1976, Townsend 1990, Williams and Shambaugh 1988, McLeod and Williams 1991). The objective of this study was to rank 12 additional grape cultivars for resistance to attack by the foliar grape phylloxera. Four of these cultivars were recently released by the Arkansas Agricultural Experiment station including 'Venus' (Moore and Brown 1977), 'Reliance' (Moore 1983), 'Mars' (Moore 1985), and 'Saturn' (Moore et al. 1989). A determination was made of the association of cultivar leaf widths and hair density on the lower leaf surface to leaf gall formation.

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Materials and Methods

The cultivars compared included 'Villard Noir', 'Mars', 'Himrod', 'Campbells Early', 'Lakemont', 'Verdelet', Cimarron', 'Reliance', 'Fredonia', 'Venus', 'Concord', and 'Saturn'. In 1985, 20 hardwood grape cuttings of these 12 cultivars were dipped in Rootone® (Security brand supplied by Forestry Suppliers, Inc., Jackson, MS), calloused, rooted in a mist bed, transferred to pots, and conditioned in a lath house for two to three weeks before being transplanted in the vineyard in April 1986. Transplants of the 12 cultivars were each placed in five-vine plots in each of four rows oriented north-south in Fayetteville, AR. The distances between rows, plots, and vines were 3 m, 2 m, and 0.6 m, respectively. Adjacent vines were tied to the opposite top wire of a Geneva double-curtain system to provide more space between vines.

Each vine in rows one and two was individually infested with foliar grape phylloxera. Phylloxera-infested 'Vidal' grape leaves were collected from a vineyard near Tontitown, AR on 10 June 1986. A 2-cm diam. leaf disk containing several crawler-producing galls was rolled up in the 5th and 6th youngest leaves of each vine on 11 June 1986. These disks were held in place by a twist-tie (modified from Stevenson 1970b, Williams and Shambaugh 1988). Leaf galls were observed on most of the artificially infested vines in the field by 19 June 1986. Vines varied from 0.7 to 2 m long at the time of infestation.

The cultivar effect on induction of leaf galls by grape phylloxera was determined by recording leaf position above the point of infestation, gall counts per leaf, and leaf widths. Measurements were made from 20 August to 15 October 1986. Twenty fully expanded leaves were used in the analysis. These occurred from the 6th to the 25th node above the point of infestation. Typically, these leaves had the larger leaf widths and gall counts of the 27 or more leaves sampled per vine.

The data were treated as a randomized complete block design with two five-vine plot replicates for each cultivar. Mean gall counts per leaf and leaf widths were separated using the GLM procedure and LSD option (SAS Institute 1988).

Leaf hair density was a characteristic used in the taxonomic keys for grape cultivars and species and was assumed to remain fixed over time (Hedrick 1908, Barrett 1956, O. I. V. 1983). Leaf hair density on the lower leaf surface was ranked for each cultivar. Leaves from each cultivar were collected from > 6-yr-old vines in the vineyard at the Fruit Substation in Clarksville, AR, on 8 September 1992. The hair density ranking of each leaf varied from 1 to 9 where 1 = none to very sparse; 3 = sparse, 5 = medium, 7 = dense; and 9 = very dense (O. I. V. 1983).

Relationships were determined for all combinations of variables, e.g., mean leaf widths from phylloxera-infested rows 1 and 2 and phylloxera-free rows 3 and 4, mean gall counts per leaf collected in 1986 and the 1992 values for leaf hair density. The correlation coefficients and *P*-values were determined using the CORR procedure with the SPEARMAN option (SAS Institute 1988).

Results

The rankings of counts of grape phylloxera galls per leaf ($F = 14.91$; df = 11, 11; $P = 0.001$) and leaf widths ($F = 3.91$; df = 11, 11; $P = 0.016$) differed among cultivars. 'Villard Noir', 'Himrod', 'Reliance', and 'Lakemont' had similar gall

Table 1. Mean gall counts per leaf per plot, leaf widths and leaf hair densities on lower surface compared among grape cultivars.*

Cultivars	Galls/ leaf	Leaf widths (cm) of vines		Hair density†
		with galls	gall-free	
Villard Noir	83.8 a	10.8 c	11.9 h	1
Himrod	80.2 a	11.0 c	13.0 ef	3
Reliance	70.5 a	13.4 a-c	14.6 bc	5
Lakemont	68.5 a	11.2 bc	13.6 de	3
Saturn	26.9 b	13.5 a-c	12.8 fg	3
Verdelet	13.6 b	13.4 a-c	12.1 gh	1
Fredonia	12.2 b	14.5 a	16.5 a	7
Campbells Early	8.6 b	14.0 ab	15.2 b	3
Concord	8.5 b	16.2 a	16.1 a	9
Venus	8.0 b	14.6 a	14.0 cd	7
Mars	3.6 b	15.4 a	14.3 cd	7
Cimarron	3.5 b	16.1 a	13.8 d	5

* $LSD_{0.05}$ = 26.7, 2.98, and 0.73, for mean gall counts, leaf widths of galled, and gall-free vines, from Fayetteville, AR, 1986.

† 1 = none to sparse; 3 = sparse; 5 = medium; 7 = dense; and 9 = very dense (O.I.V. 1983) in Clarksville, AR, 1992.

counts that were significantly greater than those for 'Saturn', 'Verdelet', 'Fredonia', 'Campbells Early', 'Concord', 'Venus', 'Mars', and 'Cimarron'. In comparison, 'Villard Noir' and 'Himrod' had significantly smaller leaf widths than 'Fredonia', 'Campbells Early', 'Concord', 'Venus', 'Mars', and 'Cimarron' but similar to 'Reliance', 'Lakemont', 'Saturn', and 'Verdelet' (Table 1).

There were significant correlation coefficients between several measured variables among the 12 cultivars (Table 2). Gall counts per leaf declined linearly as leaf width and leaf hair density increased. As leaf hair density increased across cultivars, so did the corresponding leaf widths in the galled vines and in the gall-free vines. Leaf widths from the phylloxera-free rows were found to be correlated to those from the phylloxera-infested rows but not to the gall counts per leaf in the infested vines.

Discussion

Wapshere and Helm (1987) said, "resistance to (foliar) phylloxera is a hereditable character which appears to be polygenic as crosses between resistant and tolerant American varieties and between resistant American species and the

Table 2. Spearman correlation coefficients and *P*-values (in parentheses) calculated for leaf variables measured among 12 table grape cultivars.

	Leaf width		Leaf hair density†
	(galled)*	(gall-free)*	
Galls/ leaf	-0.94 (0.0001)	-0.48 (0.11)	-0.64 (0.02)
Leaf width (galled)		0.62 (0.03)	0.79 (0.002)
Leaf width (gall-free)			0.80 (0.002)

* Measurements recorded from 1-yr-old vines in Fayetteville, AR, 1986.
† Measurements recorded from > 6-yr-old vines in Clarksville, AR, 1992 (see Table 1).

susceptible *V. vinifera* varieties show intermediate levels of resistance" (credited to Boubals 1966, Galet 1982). Hybrid cultivars from crosses of *V. vinifera* and various American *Vitis* species were reported as highly susceptible to leaf galling including 'Seyval', 'Aurora', 'Rayon D'Or', 'Cascade', 'Villard Blanc', 'Chancellor', 'Chelois', 'DeChaunac', 'Vidal', and 'Seibel' (Stevenson 1970ab, Jubb 1976, Townsend 1990, McLeod and Williams 1991). In our study, four additional grape cultivars were found to be highly susceptible to leaf galling including 'Villard Noir', 'Himrod', 'Reliance', and 'Lakemont'.

Several grape species were resistant to foliar grape phylloxera. Phylloxera crawlers in Ohio were unable to induce galls in the following: *V. candicans* Engelmann, *V. cinerea* Engelmann, *V. doaniana* Munson, and *V. rotundifolia* (Michx.) (Williams and Shambaugh 1988). Williams and Shambaugh (1988) also found no galls on *V. rupestris* Scheele whereas galls did form on *V. coignetiae* and *V. labrusca* which did not concur with Galet's (1979) observations in France. Numerous foliar galls were formed on *V. vinifera* when sprinkle-irrigated in a lath house in California and in the humid confines of a greenhouse in Ohio (Williams and Shambaugh 1988). Light infestations were detected on the *V. vinifera* cultivars of 'Cabernet', 'Sauvignon', 'Chardonnay', and 'Johannisberg Riesling' (Jubb 1976) that Galet (1971) considered to be resistant to the leaf form of grape phylloxera. These attacked regions formed open and dished-shaped lesions that rarely matured into galls and never contained adults (Jubb 1976). The cultivars of 'catawba', 'Niagara', and 'Concord' also were reported to resist foliar grape phylloxera attack (Stevenson 1970ab, Jubb 1976, Townsend 1990, McLeod and Williams 1991). In our study, eight additional cultivars including 'Concord' were found to have low susceptibility to galling, e.g., 'Saturn', 'Verdelet', 'Fredonia', 'Campbells Early', 'Venus', 'Mars', and 'Cimarron'. In our field study in Arkansas and a greenhouse study by Williams and Shambaugh (1988), grape vines were artificially infested by the crawler stage. Thus, gall for-

mation and counts may be slightly higher than those expected from natural infestations by fundatrix females which are more host selective than are crawlers (Börner and Heinze 1957).

Gall-forming insects alter leaf growth (Fay and Hartnett 1991) and gall induction has been correlated to leaf size at maturity (Zucker 1982). In our study, only the grape cultivars with high gall counts per leaf had reductions in leaf widths when compared with leaves on gall-free vines (Table 1). Grape phylloxera gall induction also was shown to increase linearly with a decrease in leaf width and a decrease in hair density on the lower leaf surface (Tables 1 and 2). Taxonomic keys and descriptions of cultivars indicated that leaves from all these more susceptible cultivars lacked pubescence on the lower surface, and leaf widths ranged from small to medium (Hedrick 1908, Barrett 1956, O. I. V. 1983). We have not been able to explain any cause-and-effect relationship between leaf hair density, leaf width, and gall counts. In contrast, the European red mite, *Panonychus ulmi* (Koch), reproduces better on grape leaves with a high hair density on the lower leaf surface (Rilling 1989). Thus, if low leaf hair density is a useful character, then future breeding programs may select for cultivars with intermediate leaf hair densities for climatic regions where the *P. ulmi* and foliar grape phylloxera are of economic importance.

The mechanisms forming leaf galls and root tuberosities on *Vitis* is still not understood and may involve several factors. Wapshere and Helm (1987) stated that the resistance mechanism for grape roots and leaves were probably similar and involved isolating the attacked region by a cork layer or repelling insects. Granett (1990) indicated that the mechanism of root tuberosity formation and prevention must involve factors other than or in addition to indoleacetic acid. Boubals (1966) hypothesized an antibiosis factor that reduces survivorship. Song and Granett (1990) documented reduced survivorship of some colonies of grape phylloxera from France when reared on cultivars from which the colonies were not originally obtained. In contrast, biotypes A and B from California differed in fecundity and developmental rates on different cultivars and indicated a nonlethal mechanism such as reduced nutrition (Granett et al. 1985).

We suggest complimentary studies to those proposed by Song and Granett (1990) of studying host-based races for assisting in predicting usefulness of cultivars. We need to determine what chemicals occur in *Vitis* leaves and roots that prevent galling by grape phylloxera. Phenolics may be shown to play such role as is the case for another leaf gall aphid, *Pemphigus betae* (Zucker 1982). Once identified, then chemical bioassays of grape leaf or root material could quickly identify grape material with resistance to attack from either form of grape phylloxera.

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