Effect of Grapevine Training Systems and Pruning Practices on Occurrence of Phomopsis Cane and Leaf Spot

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ABSTRACT

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Vitis labrusca 'Concord' vineyards with hand-pruned umbrella Kniffin trained vines, hand-pruned top-wire cordon trained vines, or hedged top-wire cordon trained vines were examined for incidence and severity of Phomopsis cane and leaf spot, caused by *Phomopsis viticola*. These vineyards were also evaluated for the development of pycnidia of *P. viticola* before budbreak. Vines that were hedged for 2 yr or more had significantly more disease than hand-pruned vines. No consistent difference in the duration of cane wetness or temperature during the wetting period could be detected between pruning systems from budbreak through bloom. Shoots at the 12.7-cm growth stage and clusters in bloom were spray-inoculated with 1×10^7 alpha spores of *P. viticola*. Inoculated internodes from shoots of hand-pruned vines were more susceptible to symptom development than internodes from shoots of hedged vines. Leaves and clusters from both pruning types were of similar susceptibility, however. Bundles of 1-yr-old canes from severely infected vines in 1986 were tied above hand-pruned umbrella Kniffin trained vines before budbreak in 1987. The incidence of Phomopsis cane and leaf spot on leaves and internodes two to five from the base of the shoot and on summer lateral shoots increased significantly as the size of the bundles increased. In addition, the number of berries with symptoms of Phomopsis fruit rot was significantly higher on vines with 907-g bundles than on vines without bundles. Hedged vineyards were at a higher risk of disease development because of higher inoculum levels but not because of environmental differences or increased susceptibility. Growers who use mechanical cutter bars for pruning are encouraged to remove dead and infected canes or adopt a more comprehensive disease control program utilizing chemical eradication or protection.

Additional keywords: latent infection

Phomopsis cane and leaf spot, caused by *Phomopsis viticola* (Sacc.) Sacc., has become an increasing problem during the past 10 yr in the Lake Erie grape region of western New York. The principal grape cultivar grown in this area is *Vitis labrusca* L. 'Concord.' Many changes in viticultural practices have occurred in Concord production during this time period. A major cause for these changes has been declining prices paid to Concord growers (1). Growers responded by reducing production costs, which included applying fewer fungicides, changing training systems, and changing pruning practices.

Many growers have discontinued the use of early-season fungicides to control Phomopsis cane and leaf spot. The percentage of growers using captan for such control declined from 44% in 1974 to 23% in 1981 (7). This was due, in part, to the discovery in 1978 that the dieback disease of grapes, formerly known as "dead arm," was actually caused by *Eutypa lata* (Pers.:Fr.) Tul. & C. Tul. (syn. *E. armeniacae* Hansf. & Carter), not *P. viticola* (8,9). The decline in the use of protectant fungicides for control of Phomopsis cane and leaf spot may account in part for the disease increase.

During the same period, many vineyards had been converted from the traditional umbrella Kniffin training (6) to a less costly top-wire cordon training system (6) coupled with either hand or mechanical pruning (Fig. 1). The top-wire cordon raises the renewal zone—and thus potential inoculum of *P. viticola*—above susceptible shoots. Hedging retains two or three times the number of live nodes per vine that traditional hand pruning does (10). Hedging is accomplished with tractor-mounted cutting bars that, after several years of pruning, train the vine in the shape of a hedge. Hedged vines retain a substantial amount of debris containing potential inoculum in the canopy. The objective of this research was to determine the effect of training and pruning systems on disease development.

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MATERIALS AND METHODS

Vineyard survey. Five Concord vineyards with mechanically pruned (hedged) top-wire cordon trained vines and either hand-pruned umbrella Kniffin trained vines or hand-pruned top-wire cordon trained vines were examined for disease incidence and severity during 1986 and 1987. These vineyards did not receive any fungicide applications before bloom.

Vineyard 1. A small experimental block of 48 Concord vines was planted in 1959 at Cornell's Vineyard Laboratory, Fredonia, New York. This block contained 24 hand-pruned umbrella Kniffin trained vines and 24 hedged top-wire cordon trained vines. Vines and rows were spaced 3.05 m apart and had been maintained in their respective training systems for the previous 14 yr.

Vineyard 2. A 12 row × 24 vine block of Concord vines was planted in 1963 with a standard 2.75 × 2.44 m spacing at Cornell's Vineyard Laboratory. All of these vines had been hand-pruned and trained to the umbrella Kniffin system before 1985. Four rows totaling 96 vines were converted to a top-wire cordon training system in 1985 and hedged. Crop year 1986 represented the first year of hedging.

Vineyard 3. A 40-ha commercial Concord vineyard of top-wire cordon trained vines planted on a standard 2.75 × 2.44 m spacing located near Westfield, New York, contained both hand-pruned and hedged blocks. An 8-ha hand-pruned block and similar-sized blocks hedged for one and two consecutive years were examined in 1986. In 1987, six randomly selected blocks of three vines each were hand-pruned in an 8-ha block that had been hedged for three consecutive years. Most of the dead and infected canes were removed from the hand-pruned vines.

Vineyard 4. A 1.2-ha commercial Concord vineyard on a standard 2.75 × 2.44 m spacing located near Sheridan, New York, was in the process of conversion from a hedged top-wire cordon training system to a hand-pruned umbrella Kniffin training system. These vines had previously been hedged for more than 7 yr. Comparisons of disease in a block of 350 hand-pruned vines adjacent to a similar-sized block of hedged vines were made in 1986. In 1987, six randomly selected blocks of three vines each were hand-pruned within a 350-vine hedged block.

Vineyard 5. A 30 vine × 4 row block of a commercial Concord vineyard of hedged top-wire cordon trained vines on a standard 2.75 × 2.44 m spacing located near Forestville, New York, was surveyed for disease. Vines had been hedged for more than 7 yr. In 1987, eight randomly selected blocks of three vines each were hand-pruned within this area.

These vineyards and their locations represent a range of environmental conditions and management styles found in the Lake Erie grape region. Therefore, comparisons of disease can be made only within, and not among, the five vineyards.

In November 1986, 120–240 canes that originated below the top wire were examined on 20–40 vines from each pruning system in each vineyard. A similar number of shoots was examined in July 1987. Each internode was examined for disease incidence and severity in 1986 and for disease incidence alone in 1987. Disease severity was estimated using the rating system of Barratt and Horsfall (14).

Production of pycnidia. Each of the vineyards surveyed in 1987 was sampled before budbreak for the potential number of pycnidia that could be produced under optimal environmental conditions. An average of 200 cane segments were selected from each pruning and training system in each vineyard. Cane segments were randomly collected from among the second through tenth node position from the base of the cane. Each cane segment was 3 cm long and cut in half longitudinally. Each half node segment containing a leaf scar was placed in a moist chamber for 60 hr at 22 C, after which the number of pycnidia with white, cream, or yellow cirri was recorded.

Environmental monitoring. Temperature, stem wetness duration, and amount of rainfall were recorded with a CR-21 micrologger (Campbell Scientific, Inc., Logan, UT) from budbreak through bloom in 1986 and 1987. Temperature was monitored with a thermistor sensor, and stem wetness was monitored with a modified resistance grid (5) in the cylindrical shape of a stem. Both sensor types were placed within the middle of the canopy of hand-pruned umbrella Kniffin trained vines and hedged top-wire cordon trained vines. The amount of rainfall was measured using a tipping bucket rain gauge.

Shoot and cluster inoculation. Shoots and clusters on hand-pruned umbrella Kniffin and hedged top-wire cordon trained Concord grape vines were inoculated at Cornell's Vineyard Laboratory during 1987. A 6 × 30.5 m sheet of heavy-duty clear polyethylene film was stretched over PVC pipe arches to make tents that covered eight vines of each training system from budbreak to harvest. This plastic sheet protected vines from rainfall and thus reduced contamination from natural inoculum. A greenhouse whitewash solution was sprayed onto the plastic tents to reduce heat buildup during hot, sunny weather.

Dormant infected Concord canes were collected in April 1986 and placed in a moist chamber for 48 hr at room temperature. Cirri from canes with sporulating pycnidia of *P. viticola* were placed on potato-dextrose agar (PDA) and incubated for 1 wk at room temperature. Cultures were maintained on PDA slants and stored at 4 C. Several isolates were transferred from slants to petri dishes of PDA and incubated for 1 wk at room temperature before inoculation. Dishes were flooded with sterile distilled water to release and suspend pycnidiospores. The suspension was adjusted to a concentration of 1×10^7 alpha spores per milliliter. This suspension was sprayed to runoff onto 2.5-cm shoots (30 April 1987), 12.7-cm shoots (19 May 1987), and clusters at 90% calyptra fall (2 June 1987). Each shoot or cluster was enclosed within a plastic bag containing a small piece of moist paper towel. A white paper bag was stapled over the plastic bag to reduce heat buildup from sunlight. All bags were removed 24 hr after inoculation.

Leaves and internodes of inoculated shoots were rated for disease on 16 July. Only the leaves and internodes above, at, and below the most recently unfolded leaf or expanded internode at the time of inoculation (for a total of three leaves and three internodes) were rated. A 0–3 rating scale was used, where 0 = no lesions, 1 = a few lesions covering no more than 25% of the leaf or internodal area, 2 = many lesions covering 25–50% of the leaf or internodal area, and 3 = over 50% of the leaf or internodal area severely scarred or necrotic.

Inoculated clusters were collected on 1 October 1987, stored at 1 C, and examined within 2 wk. The number of infected and missing berries per cluster was recorded.

Shoots inoculated at the 2.5-cm growth stage were collected on 1 October to determine if latent infections had occurred. The first three basal internodes were dipped into 95% ethanol for 5–10 sec, 0.5% sodium hypochlorite for 2 min, sterile distilled water for 1–2 min, and a 1:40 dilution of 29.1% paraquat dichloride for 1 min (3). Shoots were placed into a moist chamber and incubated at room temperature for 2 wk. The number of internodes with sporulating pycnidia of *P. viticola* was recorded.

Simulated pruning severity. One-year-old cane prunings were obtained from a Concord vineyard at Cornell's Vineyard Laboratory that had a high level of Phomopsis cane and leaf spot in 1986. These canes were bundled and suspended above hand-pruned umbrella Kniffin trained Concord vines before budbreak in 1987. Ten bundles 61 cm long were tied end to end above three vines. Each bundle weighed 227, 454, or 907 g and was equivalent to an average of 71, 138, or 251 extra nodes per vine, respectively. Vines without bundles served as controls. The experimental design was a randomized complete block, and each block was replicated six times.

The development of pycnidia was evaluated on 1 May 1987 by collecting 20 cane segments from each set of three vines and each set of 10 bundles. Cane segments were incubated and evaluated as described above.

An average of 50 summer lateral shoots were evaluated under each set of bundles on 24 July 1987. Ten main shoots per set of bundles were examined on 30 July for the number of infected leaves and internodes; each shoot selected had grown directly under the bundles at all times. Fifty clusters each were collected from vines without bundles and from vines with 907-g bundles on 1 October and examined for symptoms of Phomopsis fruit rot.

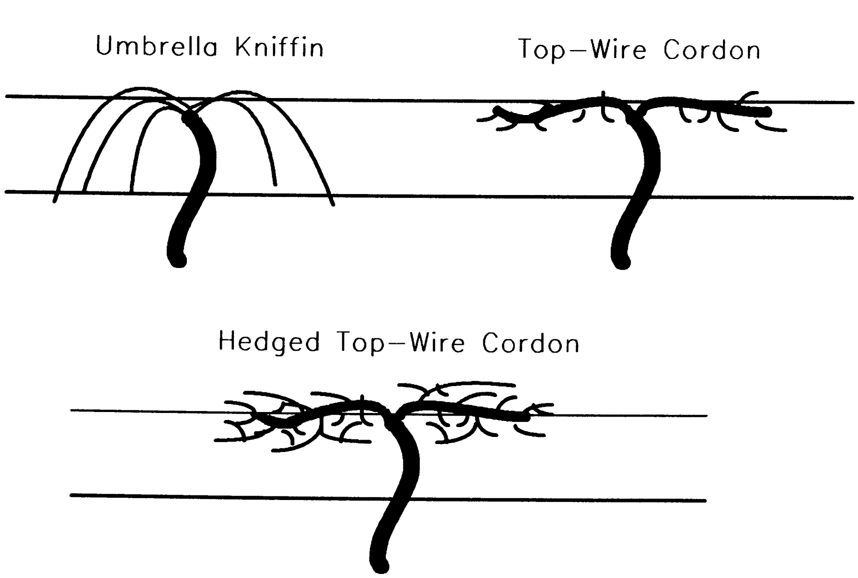

Fig. 1. Generic shape of grapevine training systems after pruning in early spring.

RESULTS

Vineyard survey. Disease development was high in 1986 because of heavy rains during the 12.7-cm shoot growth stage and bloom. Rainfall occurred on 17 days from budbreak through bloom, for a total of 238.5 mm. Disease incidence on internodes was uniformly high (60%) in all vineyards surveyed in 1986. Disease severity, however, differed within the various vineyards (Table 1). Disease severity was significantly higher on vines hedged for more than 2 yr than on vines pruned by hand for 1 yr or more (vineyards 1 and 4). Vines hedged for only 1 yr did not have significantly more disease than vines pruned by hand (vineyards 2 and 3).

Dry conditions before bloom in 1987 resulted in low disease development. Rainfall occurred on 8 days from budbreak through bloom, for a total of 39.9 mm. Disease severity on the internodes was uniformly low within all vineyards surveyed. Disease incidence, however, differed within each of the various vineyards (Table 2). Disease incidence in each vineyard was significantly higher on hedged vines than on hand-pruned vines.

Production of pycnidia. The number of mature pycnidia per cane segment followed a Poisson-like distribution. The analysis was based on a square root transformation of the raw data. Although hedged vines tended to have more mature pycnidia per cane segment than hand-pruned vines, this was not significant at the 5% level for any vineyard surveyed (Table 3).

Environmental monitoring. Potential periods of spore dissemination and infection, determined according to the criteria of Bugaret (2), from budbreak through bloom for 1986 and 1987 are shown in Table 4. One potential infection period on 18–20 May 1986 was not recorded because of equipment malfunction. Vines were estimated to have been wet for 36–48 hr during an 88-mm rain event.

No consistent difference in the canopy environment could be detected between the training systems. Hedged vines were wet longer than hand-pruned vines for half of the rain events. Average temperatures during the time canes were wet were similar between the two pruning systems. A potential infection period that occurred on one pruning system also occurred on the other pruning system.

Shoot and cluster inoculation. Inoculations of 12.7-cm shoots resulted in typical symptom development. Elongate lesions on the internodes and necrotic, crinkled leaf spots first appeared on 2 June 1987, 2 wk after inoculation. Symptoms generally developed on the internode or leaf below, at, and above the youngest unfolded leaf at the time of inoculation. For example, if the shoot inoculated had four unfolded leaves, the third, fourth, and fifth leaves from the base generally showed disease symptoms. Based on a *t* test at the 5% level, shoots from hand-pruned vines had a significantly higher internode disease rating (1.0) on the 0–3 scale than did hedged vines (0.2). Disease ratings of leaves did not differ significantly between shoots from hand-pruned (0.6) and hedged vines (0.5). Typical symptoms of Phomopsis fruit rot developed on all clusters inoculated at bloom. The percentage of berries with fruit rot was not significantly different between hand-pruned (26.5%) and hedged vines (33.7%).

Inoculations of 2.5-cm shoots did not result in the development of cane and leaf symptoms. However, 1 wk after treatment with paraquat, 70 and 78% of these shoots from hedged and hand-pruned vines, respectively, developed sporulating pycnidia of *P. viticola*.

Simulated pruning severity. Disease incidence on leaves two to five from the base of the shoot, on internodes two to five from the base, or on summer lateral shoots was significantly higher as the size of the bundle increased (Fig. 2). Regression analysis determined that a significant, positive slope was associated between disease incidence and bundle weight.

Bundle weight can be expressed in terms of inoculum potential: inoculum potential/vine = (mature pycnidia/vine node) (nodes/vine) + (mature pycnidia/bundle node) (nodes/bundle). Cane

Table 1. Survey for Phomopsis cane and leaf spot lesions on canes of hand-pruned and hedged Concord grapevines in the Lake Erie grape region in 1986

	Disease severity (%)[a]				
	Years hand-pruned		Years hedged		
Vineyard	1	>1	1	2	>2
1	···	2.7	···	···	4.2*[b]
2	···	6.9	8.0	···	···
3	···	4.6	4.2	5.4	···
4	4.6	···	···	···	7.4*

[a]Estimated on each internode of 120–240 canes using the rating system of Barratt and Horsfall.
[b]Treatment means within these vineyards are significantly different according to Fisher's protected LSD procedure at the 5% level.

Table 2. Survey for Phomopsis cane and leaf spot lesions on canes of hand-pruned and hedged Concord grapevines in the Lake Erie grape region in 1987

	Disease incidence (%)[a]			
	Years hand-pruned		Years hedged	
Vineyard	1	>1	2	>2
1	···	0.6	···	6.4*[b]
2	···	1.0	3.3*	···
3	4.4	···	···	10.4*
4	2.9	···	···	7.9*
5	2.5	···	···	5.9*

[a]Percentage of internodes with symptoms.
[b]Treatment means within these vineyards are significantly different according to Fisher's protected LSD procedure at the 5% level.

Table 3. Production of pycnidia of *Phomopsis viticola* on cane segments of hand-pruned and hedged Concord grapevines in the Lake Erie grape region in 1987

	Pycnidia per cane segment[a]			
	Years hand-pruned		Years hedged	
Vineyard	1	>1	2	>2
1	···	22	···	34
2	···	21	27	···
3	23	···	···	25
4	18	···	···	22
5	21	···	···	24

[a]Analysis was based on square root transformation of raw data. The training systems did not differ significantly according to a *t* test at the 5% level.

Table 4. Potential periods of dissemination and infection by *Phomopsis viticola* in hand-pruned and hedged Concord grapevines from budbreak to bloom

			Hours of cane wetness		Temperature during cane wetness (C)	
Date	Growth stage	Rain (mm)	Hand-pruned	Hedged	Hand-pruned	Hedged
1986						
28 April	Budbreak	···	···	···	···	···
30 April	2.5-cm shoots	···	···	···	···	···
12 May	12.7-cm shoots	···	···	···	···	···
18–20 May	···	88.0	36–48[a]		13.5[a]	···
1 June	···	9.9	12.6	12.1	10.4	10.9
5 June	···	30.5	28.5	26.2	15.1	14.9
7 June	···	29.7	36.5	37.7	18.9	18.7
9 June	90% bloom	···	···	···	···	···
11 June	···	8.6	9.0	12.7	19.9	19.9
12 June	···	54.6	23.6	24.4	20.1	20.2
1987						
24 April	Budbreak	···	···	···	···	···
30 April	2.5-cm shoots	···	···	···	···	···
14 May	12.7-cm shoots	13.7	7.7	11.4	15.2	13.9
18 May	22.9-cm shoots	6.1	14.0	13.0	12.5	12.1
25 May	···	2.5	9.1	6.9	13.1	12.7
1 June	···	0.0	8.2	9.8	15.6	17.7
4 June	90% bloom	···	···	···	···	···

[a]Estimated using National Weather Service records collected at Fredonia, New York.

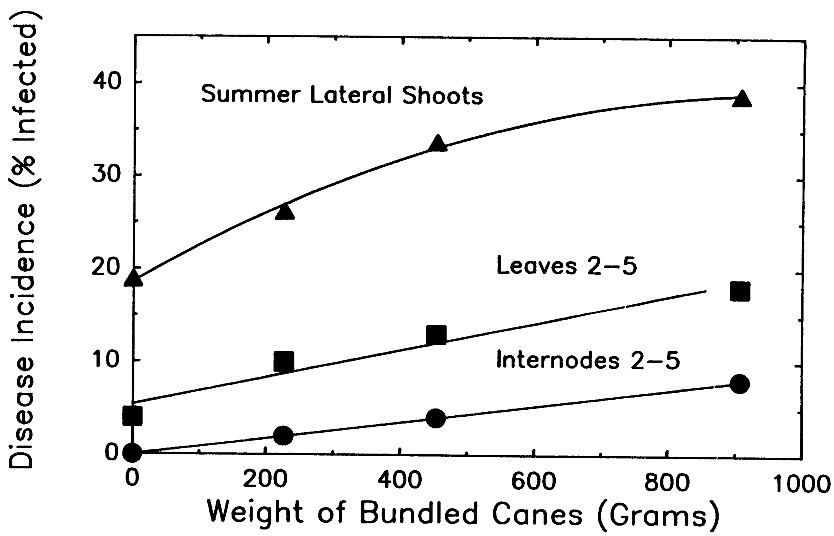

Fig. 2. Incidence of Phomopsis cane and leaf spot as influenced by weight of bundled canes, i.e., weight of 1-yr-old grape cane prunings suspended above hand-pruned vines.

segments from hand-pruned umbrella Kniffin trained vines produced an average of 22.8 mature pycnidia and those from the bundles produced an average of 11.4; inoculum potential = (22.8 pycnidia/node) (40 nodes/vine) + (11.4 pycnidia/bundle node) (71, 138, or 251 nodes/bundle). Therefore, each vine with 227-, 454-, or 907-g bundles had the equivalent potential of 1,721, 2,485, or 3,773 mature pycnidia per vine, respectively.

Based on a *t* test at the 5% level, the number of berries with symptoms of fruit rot on vines with 907-g (4.7%) bundles was significantly higher than on vines without bundles (0.5%).

DISCUSSION

Vineyard surveys revealed that vines that had been hedged for 2 yr or more had significantly more disease than hand-pruned vines. This was consistent in years with both high (1986) and low (1987) disease pressure. Hand pruning vines that have been hedged for several years resulted in a significant reduction of disease even during the first year, which indicates that cultural practices such as pruning impact on disease development.

Higher levels of disease could have been due to a combination of such factors as longer wetting periods, increased susceptibility, and increased inoculum levels. Environmental monitoring of the canopy has shown no consistent increase in the length of wetting or in temperature during a wet period in hedged vines. Environmental differences may occur later in the year when the canopy becomes more dense (15). However, early in the growing season when shoots and clusters are most susceptible to infection by *P. viticola*, no modification of the environment could be detected.

The internodes of 12.7-cm shoots from hand-pruned vines had greater symptom development of Phomopsis cane and leaf spot than internodes from hedged vines. This may have been due to shoot development and not to increased infection, as hand-pruned shoots expand considerably in length and girth when compared with hedged shoots. Leaves and clusters from both pruning systems had similar symptom development. In addition, the number of latent infections on 2.5-cm shoots was similar between the two pruning systems, as indicated by use of a paraquat dip technique. This would indicate that increased susceptibility of hedged vines is not responsible for the disease differences recorded between pruning systems.

Although the number of mature pycnidia produced on cane segments was similar for both pruning systems, hedged vines contained more nodes and dead canes capable of producing inoculum. Thus, hedged vines have a higher inoculum potential than hand-pruned vines. Simulating the inoculum effect of hedged vines showed that a higher dose of inoculum resulted in a higher disease response on hand-pruned vines.

Hedged vines also may be at a higher risk of developing other diseases, such as black rot. The percentage of berries with black rot was increased on hand-pruned vines with old grape cane prunings attached to the top-wire (*unpublished*). These vines may also be at a higher risk of developing powdery mildew, since cleistothecia are known to overwinter on exfoliating bark (12).

Growers who prune their vineyards with mechanical cutter bars can control this disease in several ways. A follow-up pruning that removes the dead and infected canes would help reduce the inoculum and thus the threat of disease development. Dormant chemical treatment of vines with dinoseb (4,11), sodium arsenite (4), or lime sulfur (*unpublished*) will reduce inoculum levels; these methods may not be available in all viticultural areas, however. The chemical protection of young shoots and clusters during the growing season will also reduce disease development (11,13).

Growers have obtained a monetary savings by pruning their vineyards with mechanical cutter bars (16). One grower in western New York estimated his savings at $40.50/ha. Growers who prune their vineyards with machines should reinvest a small portion of those savings in a more comprehensive disease control program that includes the application of fungicides before and during bloom.

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