Epidemiology and Control of Vein Spot Disease of Pecan Caused by *Gnomonia nerviseda*

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ABSTRACT

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The incitant of vein spot disease of pecan, *Gnomonia nerviseda*, infected vascular tissue of the foliage and generally caused localized lesions. Infection frequently occurred at the junction of the petiolule to the rachis and at the base of the rachis. The disease caused premature loss of leaflets and compound leaves. Infection was initiated by ascospores that had been released after rainfall, primarily in May and June. No significant relationship was found between the height of the foliage above the ground and the number of infections. Of the fungicides labeled for use on pecan, benomyl was the most effective, followed by dodine, for control of vein spot. Fentin hydroxide provided little protection when disease development was severe. Trees treated with benomyl had significantly fewer lesions and less defoliation than untreated trees in a year of high vein spot severity.

Additional key words: *Carya illinoensis*

The foliage of pecan (*Carya illinoensis* K. Koch) is susceptible to vein spot disease cited by *Gnomonia nerviseda* Cole (6). The disease was reported in 1933 in Louisiana, Mississippi, Arkansas, and Texas (5). Even though Cole suggested that vein spot might be an important pecan disease, there have been no reports on it since the initial work (5,6).

The pathogen infects vascular tissue of pecan foliage. This includes leaflet veins, midribs, petiolules, and rachises (5). Tissue between the leaflet veins apparently is not infected. On the leaflets, lesions are centered on veins and seldom spread more than 0.5 cm into the leaf lamina (5). Brown to black lesions usually first appear in May on both sides of leaves (1). Lesion width increases only slightly through the summer but sometimes increases in length on vascular tissue, particularly along the midrib, petiolule, and rachis (5).

In observations made over 3 yr (1978–1980), vein spot was the most frequently encountered foliage disease on several pecan cultivars throughout northern Louisiana. Spore trapping and weather monitoring were used to determine the conditions and patterns of spore release. Seasonal development of the disease was recorded along with severity of the disease within trees. Information was obtained on the degree of defoliation caused by vein spot on one cultivar.

Previously, no fungicides had been tested for control of vein spot and no control practices had been recommended. Therefore, fungicides labeled for use on pecan trees were tested for control of vein spot.

MATERIALS AND METHODS

Disease observations and spore trapping. Disease development and damage was observed from 1978 through 1981 in the experiment station orchard near Shreveport, LA. All observations and tests were conducted on mature trees of the Success cultivar.

Ascospore release was monitored with a Burkard 7-day recording volumetric spore trap (Burkard Manufacturing Co. Ltd., Rickmansworth, Hertfordshire, England). The trap drew 9–10 L of air per minute through an orifice measuring 2 × 14 mm. The trap orifice was 2.3 m above the ground (approximate height of lowest tree limbs). The trap ran from 1 April to 13 October 1980 and from 1 April to 5 October 1981. Each week, the spore-trap tape was cut into seven 48-mm-long sections (representing 24 hr), placed on glass slides, and examined microscopically. Ascospores of the pathogen were identified by size and shape.

Rainfall was recorded with a 7-day-recording rain gauge (Weather Measure Corp., Sacramento, CA 95841). Temperature, relative humidity, and leaf wetness were monitored with a 7-day-recording hygrothermograph (Belford Instruments Co., Baltimore, MD 21204). The hygrothermograph had been modified to record leaf wetness by Small (17). A weather shelter near the spore trap housed the hygrothermograph 1.2 m above the ground. The leaf-wetness probe was placed 3.6 m above the ground in the lower limbs of a tree.

Height distribution, defoliation, and control. Severity of vein spot disease was determined at three heights above the ground: 1.2–1.8, 3.7–4.3, and 7.3–7.9 m. Lesion counts were made on trees that had not received fungicide applications. In 1978, lesions on 40 leaves at each of the three heights on each of four trees (replicates) were counted. Leaves were selected from the perimeter of the tree. The number of leaflets present and missing from each leaf was recorded. Vein spot lesions on leaflets and on rachises were recorded separately. Counts were made from 25 July to 3 August.

In addition to the untreated trees, similar counts were made on trees that had received fungicide treatments. Four trees each were sprayed with 113 and 340 g a.i. benomyl (Benlate 50W) per 378.5 L of water throughout the season with an air-blast orchard sprayer. About 114 L was applied to each tree per application. Four applications of the benomyl were made at intervals of 3–4 wk; application dates were 22 April, 5 May, and 6 and 30 June. Treated and untreated trees were in a completely randomized design.

The test was repeated in 1979 with six replicates each for the untreated and benomyl-treated trees. Five applications of the fungicide were made on 24 April, 7 and 30 May, 27 June, and 3 August. The numbers of leaves, leaflets, and lesions on eight terminals at each height were recorded for the period 15–28 August. Because rachis lesions were numerous and had often coalesced, they could not be counted. All trees used in these tests in both years received standard insecticide applications.

Comparison of foliar fungicides. In 1979, three fungicides labeled for use on pecan were tested for effectiveness in reducing vein spot lesion numbers. A preliminary report has been presented (15). They were applied in the amounts recommended in Louisiana for control of pecan scab (*Cladosporium caryigenum* (Ell. et Lang.) Gottwald) (9). Fungicides used were benomyl 50W, dodine 65W (Cyprex), and fentin hydroxide 47.5W (Du-Ter) at 113, 295, and 86 g a.i./378.5

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L, respectively. Benomyl 50W also was tested at 340 g a.i./378.5 L. A randomized complete block design was used in which two of the lowest individual limbs of each tree served as replicates on each of eight trees. The test was repeated at two locations, the Louisiana State University Pecan Research and Extension Station in northwestern Louisiana (Loc. 1) and a commercial orchard in northeastern Louisiana (Loc. 2).

Treatments were applied with a hand-held compressed-air sprayer and foliage was sprayed to runoff. Three applications were made at each location between 24 April and 8 June.

The numbers of leaflets and leaflet lesions on 10 compound leaves of each replicate were assessed. The number of rachis lesions were usually too numerous to count and could not be used. Lesion counts were made from 6 to 16 July.

The test was conducted again in 1980 at the same two locations. The fungicides and amounts (a.i./378.5 L) were benomyl 50W (113 and 227 g), fentin hydroxide 47.5W (86 and 172 g), and dodine 65W (295 g). A fungicide recently labeled for use on pecan trees, fentin hydroxide 4L (Super Tin), was tested at 68 g a.i./378.5 L. This rate was suggested by the manufacturer for control of pecan scab. Four applications were made at each location and each treatment was replicated 10 times. Applications were made at about 2-wk intervals from 27 April to 16 June. Lesion counts were made from 21 to 29 July. Because of the relatively low lesion numbers, it was possible to record the total number of lesions on each leaf, including the rachis. Lesions were counted on 10 leaves per test limb. Statistical analyses of all tests reported in this paper were conducted by the Experimental Statistics Department, Louisiana State University.

RESULTS

Disease observations and spore trapping. Ascospores of the pathogen were produced each year in leaf debris on

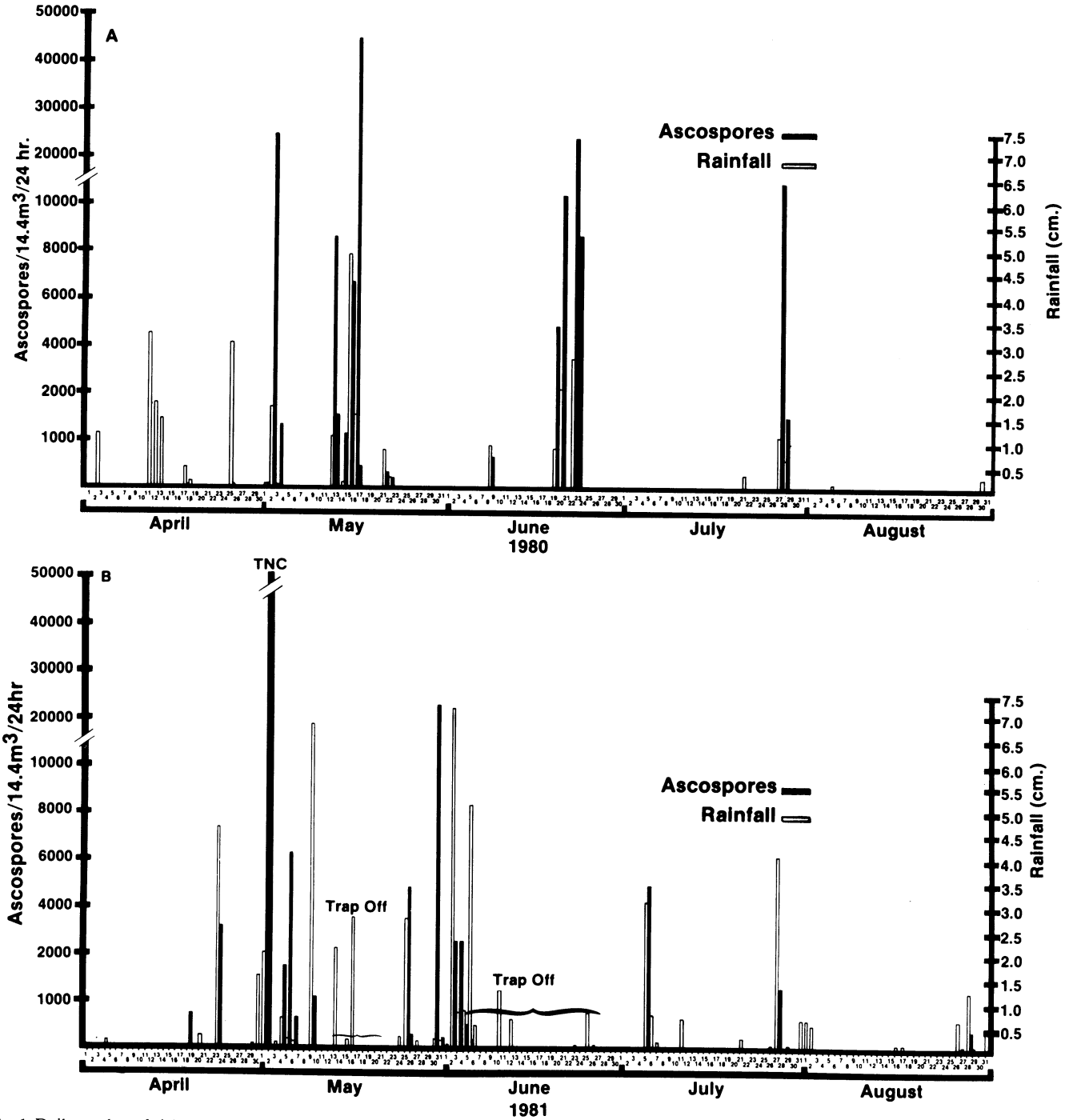

Fig. 1. Daily catches of airborne ascospores of *Gnomonia nerviseda* from the Louisiana State University Pecan Station orchard near Shreveport, LA, in **(A)** 1980 and **(B)** 1981.

the ground. Ascospore measurements were similar to previous reports (2,6). The average size of ascospores from perithecia in leaf debris beneath Success trees was 14–17 × 2–3 μm. Spores were hyaline, ellipsoid to cylindroid, and constricted at a central septum. Each half of the spore contained two refractive globules. Frequently, a gelatinous appendage was visible on each end of the ascospores. The appendages stuck to glass slides; the adhesive appendages may serve as a means of spore attachment to its host. Eight spores were produced in each ascus of the hypophyllous perithecia. A description of the ascospores, asci, and perithecia has been published (2).

Cole found perithecia only in old lesions (6), but we found perithecia of the pathogen over the entire surface of tissue infected the previous year, including the leaf lamina. The fungus may become saprophytic and grow throughout the dead tissue. After exposure of the perithecia to water, the spores appeared to exit through the beak ostiole as the tissue dried.

Of the parameters monitored, ascospore release was obviously associated with rainfall (Fig. 1). Ascospores of the pathogen were caught on the spore trap tape immediately after rainfall. Rainfall amounts of 0.25 cm or less were sometimes enough to induce spore discharge (Fig. 1). However, heavy dew formation, which occurred frequently from April through June, usually did not result in ascospore catches. Once in 1981 (18 April), a few ascospores were caught that were not associated with rainfall (Fig. 1B). This may have been associated with moisture from dew because the spores were caught in the evening. Ascospores of the pathogen were recorded on the trap tape 19 and 18 times in 1980 and 1981, respectively (Fig. 1). However, the trap was off for 21 days in June 1981 due to a power failure (Fig. 1B), and several spore releases were probably not recorded.

The initial spore catches were in April and were relatively low. The most frequent and largest spore releases occurred in May and June each year. Several rainfalls occurred in April of 1980 and 1981 that did not result in spore catch. Practically every rainfall in May and June of both years produced some spore release. Two ascospore releases, one of significant size, were recorded as late as 27 and 28 July 1980 (Fig. 1A). Two catches were recorded in July 1981, and the latest for that year was on 28 August (Fig. 1B).

During heavy spore release periods, it sometimes was not possible to make accurate counts of the masses of ascospores on the tape. Spore release periods extended from 1 to 20 hr, with an average of nearly 7 hr after a rainfall. Even though a spore release period lasted several hours, most (>50%) of the total ascospore catch frequently had occurred by 2 hr after a spore catch began (Fig. 2). Based on trap tape counts, the number of spores caught could change dramatically in less than 1 hr. The number of spores caught was not necessarily correlated with amount of rainfall (Figs. 1 and 2). There was apparently no correlation between leaf wetness, temperature, or humidity to spore catch other than the

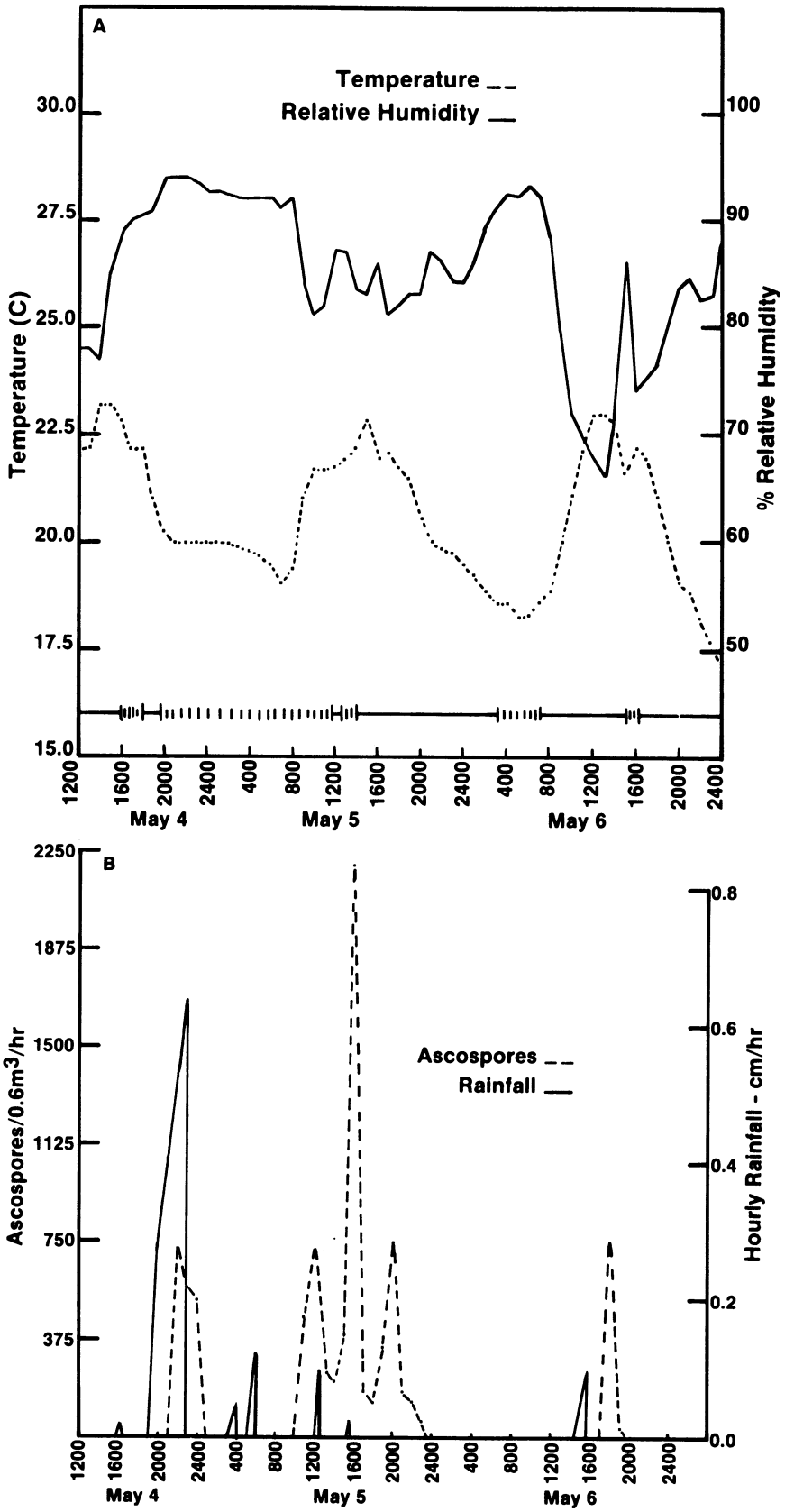

Fig. 2. Relationship of **(A)** temperature, relative humidity, leaf wetness (|||||||), and **(B)** rainfall to hourly catches of airborne ascospores of *Gnomonia nerviseda* from the Louisiana State University Pecan Station orchard near Shreveport, LA, in 1981.

obvious relationships of these parameters with rainfall (Fig. 2).

It is not known how long it takes for infection to occur after spore release or what conditions are required for infection. The first vein spot lesions in the station orchard were observed on 22 May in 1980 and 26 May in 1981. This was 20 and 33 days after the initial large spore release in 1980 and 1981, respectively.

Frequently, infections occurred at the junction of petiolule to rachis. A single lesion in this position caused premature leaflet drop. Also, numerous infections occurred near the bases of rachises and coalesced to form solid necrotic areas. Vein spot on rachises caused defoliation of entire compound leaves, even though there may have been only a few lesions on the individual leaflets. If lesions were numerous, defoliation could begin in June but was usually greatest in late summer and early fall.

The acervuli and conidia appeared to be of the *Gleosporium* type. Conidial size (8–12 × 1.5–3 μm) was similar to previous descriptions (2,5). We observed conidia production as early as June, but conidia were found more abundantly in the fall.

Table 1. Incidence of vein spot disease in Success pecan trees at different heights above the ground[a]

	1978			1979	
Height[b]	Lesions/leaflet	Lesions/rachis	Leaflet loss (%)	Lesions/leaflet	Leaflet loss (%)
1.2–1.8	0.5	7.4	2.9	3.7	13.5
3.7–4.3	0.6	6.8	1.9	4.4	13.4
7.3–7.9	0.3	4.9	2.8	3.2	13.6
	NS[c]	NS	NS	NS	NS

[a] In 1978, lesions were counted on 40 compound leaves per tree, and data are means from four trees. In 1979, lesions were counted on eight terminals per tree, and data are means of six trees. Trees were not sprayed with fungicides.
[b] Meters above the ground.
[c] Linear regression analysis; NS = not significant ($P = 0.05$).

Table 2. Control of vein spot disease with benomyl[a]

	1978			1979	
Rate (g a.i./378.5 L)	Lesions/leaflet	Lesions/rachis	Leaflet loss (%)	Lesions/leaflet	Leaflet loss (%)
340	0.2	1.8	2.0	0.4	6.0
113	0.3	3.7	2.5	0.9	9.6
Untreated	0.5	6.4	2.5	3.8	13.5
	S[b]	S	NS	S	S

[a] In 1978, lesions were counted on 120 compound leaves per tree, and data are means from four trees. In 1979, lesions were counted on 24 terminals per tree, and data are means of six trees.
[b] Linear regression analysis; S = significant and NS = not significant ($P = 0.01$).

Table 3. Comparison of fungicides for control of vein spot disease in 1979[x]

Treatment	Rate (g a.i./378.5 L)	Lesions/leaflet		Leaflet loss (%)	
		Loc. 1	Loc. 2	Loc. 1	Loc. 2
Benomyl	340	0.9 a	0.6 a	4.7 a	2.2 a
Benomyl	113	1.9 ab	1.1 a	5.4 ab	4.6 ab
Dodine	295	2.9 b	2.4 b	7.9 bc	4.9 ab
Fentin hydroxide 47.5W	86	4.9 c	2.5 b	8.8 c	6.3 bc
Untreated	···	5.4 c	2.8 b	12.3 d	8.2 c

[x] Data are means of 16 replicates (10 compound leaves per replicate). Loc. 1 = Louisiana State University Pecan Station orchard near Shreveport. Loc. 2 = Commercial orchard near Monroe, LA. Means not followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 4. Comparison of fungicides for control of vein spot disease in 1980[x]

Treatment	Rate (g a.i./378.5 L)	Lesions/compound leaf[y]	
		Loc. 1	Loc. 2
Benomyl	227	1.2 a	1.1 a
Benomyl	113	7.4 ab	2.6 a
Dodine	295	3.1 ab	4.4 ab
Fentin hydroxide 47.5W	172	9.5 ab	13.8 ab
Fentin hydroxide 47.5W	86	19.5 c	17.3 b
Fentin hydroxide 4L	68	12.8 bc	32.1 c
Untreated	···	111.0 d	53.0 d

[x] Data are means of 10 replicates (10 compound leaves per replicate). Loc. 1 = Louisiana State University Pecan Station Orchard near Shreveport. Loc. 2 = Commercial orchard near Monroe, LA. Means not followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.
[y] Includes leaflet and rachis lesions.

Height distribution, defoliation, and control. Even though leaves sampled 7.3–7.9 m above the ground had the fewest lesions in both years, there was no significant correlation of infections with height from the ground (Table 1). The compound leaves in this test had an average of 10.5 leaflets per leaf. Thus, the untreated trees averaged 12.7, 13.1, and 8.4 lesions per leaf at heights of 1.2–1.8, 3.7–4.3, and 7.3–7.9 m, respectively.

There were no differences among the three sampling heights in percentage of leaflets missing from the untreated trees in either year (Table 1), but the number of infections and amount of defoliation were much higher in 1979 than in 1978 (Table 1).

Trees treated with both rates of benomyl showed a significant reduction in lesion numbers compared with unsprayed foliage in both years (Table 2). The benomyl treatments did not reduce defoliaton in 1978. In 1979, however, there was a significant reduction in defoliation on the benomyl-treated trees (Table 2).

Comparison of foliar fungicides. In 1979, limbs treated with benomyl had the fewest lesions per leaflet at both Loc. 1 and Loc. 2. In both tests, there was no significant difference between the two rates of benomyl (Table 3). At Loc. 1, dodine-treated limbs also had significantly fewer lesions per leaflet than the untreated limbs (Table 3). At Loc. 2, only the benomyl-treated limbs showed a significant reduction in lesion numbers compared with untreated ones (Table 3). The fentin hydroxide treatment did not provide a reduction in leaflet lesions at either test site (Table 3).

Percent leaflet defoliation corresponded directly with the number of leaflet lesions at each location. At Loc. 1 and 2, benomyl-treated limbs had the lowest percent defoliation, followed by dodine and fentin hydroxide (Table 3).

In 1980, the intensity of vein spot was much lower than in the previous year. Perhaps because of lower disease intensity, all fungicide treatments resulted in significantly fewer lesions than on untreated leaves. Because of the relatively low lesion numbers, it was possible to record lesions on both the leaflets and rachises, and data are shown as the mean number of lesions per compound leaf (Table 4). Benomyl at 227 g a.i./378.5 L resulted in the fewest vein spot infections at both locations. The lower rate of the benomyl and dodine treatments provided a similar reduction in lesion numbers. Leaves treated with fentin hydroxide 47.5W at twice the recommended rate (172 g a.i./378.5 L) had higher lesion numbers than the

benomyl or dodine treatments but not significantly greater. No significant differences in percent of leaflet loss were recorded between any of the fungicide treatments and the untreated leaves.

DISCUSSION

Most ascospore release took place immediately after rainfall while tissue was still wet and decreased rapidly as the tissue dried. Sometimes a very small amount of rainfall could cause a large spore release (5 May, Fig. 2B). A small amount of rainfall could trigger spore discharge but heavy dew formation apparently did not. Ascospore release after rainfall occurred throughout most of the summer. It had been generally assumed that most of the vein spot infections occurred in April and early May when leaves were young and growing rapidly. If leaves are susceptible throughout the period of ascospore release, fungicide protection should cover the time from mid-April through June. Information is needed on requirements for infection and influence of time of infection on damage to the host, as well as the overall effect of the disease on nut quality and production. The disease appears to have a long incubation time because more than 20 days elasped in both 1980 and 1981 from the initial large spore release to observations of symptoms.

As with vein spot, ascospores serve as the primary inoculum of several other *Gnomonia*-induced diseases of deciduous hardwoods such as walnut anthracnose (*G. leptoslyla* (Fr.) Ces. & de Not.) (1,3,11). With these diseases, conidia play an important role in secondary infection and spread (1,3,11). The role of conidia in vein spot severity is not known. Some conidia are produced in the summer; however, abundant conidial production appears to be too late to have a large influence on disease severity. Cole (5) reported that *Leptothyrium*-type conidia were produced in the lesions during late summer or fall. In this study, conidia appeared to be in acervuli rather than in pycnidia. Barr (2) also indicated that the fruiting structures were acervuli. Even though Cole (5) reported that some conidia survive the winter, the tremendous amount of ascospore production probably overshadows infections caused by conidia.

Because inoculum each spring was in the form of ascospores produced in leaf debris on the orchard floor, it is possible that a higher severity of vein spot occurred on the lower leaves than on the leaves of the upper part of the trees. Trees used in this work were about 15 m tall, and we had the ability to sample up to about one-half this height. The severity of vein spot decreased slightly as the height of foliage above the ground increased. Because of the reduced number of lesions at 7.3–7.9 m above the ground compared with lower levels, there may have been less vein spot on the upper half of the trees.

Most leaflet defoliation recorded in 1978 and 1979 was apparently induced by vein spot. Leaflets with lesions at the base of the petiolule were easily detached. No other diseases or insects were observed to have caused defoliation on the test trees, and loss caused by physical damage was minimal. Presumably, a disease gradient could cause greater defoliation on the lower limbs of tall trees (higher than 9 m) than from upper limbs. However, no significant differences in defoliation were recorded between the upper and lower heights in either a year of moderate (1978) or high (1979) vein spot incidence.

A similar situation occurred between the untreated and fungicide-treated trees in 1978. Even though treated trees had fewer lesions, there were no differences in leaflet loss. Disease intensity was greater in 1979 and the fungicide-treated trees had significantly less defoliation than the untreated trees. Thus, a fungicide can be useful in reducing damage caused by vein spot.

When lesion counts were made in both 1978 and 1979, defoliation caused by vein spot had not approached its peak. The average leaflet loss of 13.5% on the untreated trees in August 1979 was significantly higher than from the benomyl-treated trees. By early October, the untreated trees were heavily defoliated, whereas the benomyl-treated trees still retained healthy foliage. To obtain a more accurate determination of defoliation induced by vein spot, data should be collected near the end of September or later.

Trees need to maintain foliage through completion of kernel growth (mid-August to late October) for high quality in the current season's crop (7,16,19). It is also important for trees to retain foliage as long as possible after nut maturity for good catkin and pistillate flower production and fruit set the following year (10,13,16,18,19). In fact, shoot growth, which directly affects the yield and quality of nuts in any year (8,16), is influenced by the condition of the foliage over a 3-yr period (13). However, information on the effects of leaf loss on the current season's and the next season's crop is based on results of defoliation at one point in time (16,19). The effect of defoliation (eg, from vein spot) on nut quality and quantity when leaf loss accumulates over a period of months has not been defined.

Benomyl was the most effective fungicide tested for control of vein spot. It was also the most effective of several fungicides tested for walnut anthracnose control (4,14); however, because of problems with fungi developing resistance to benomyl (12), the fungicide should not be overused to control vein spot in pecan orchards. Dodine showed somewhat lower efficacy against *G. nerviseda* but would probably provide adequate control under most circumstances. Fentin hydroxide, which has been used exclusively by many pecan growers in Louisiana, does not provide very good protection against the vein spot pathogen.

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