

Effect of Fungicides on Nut Quality and Control of Pecan Scab 'Premature Defoliation'

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Abstract. Fungicides, dodine, fentin hydroxide, captafol, and benomyl, gave adequate control of pecan scab caused by *Fusicladium effusum* Wint., using a 3-week spray schedule beginning April 22 and concluding August 5. Massive applications of dodine and captafol at bud break to replace the first 3 scheduled applications failed to give equivalent control of scab.

Leaf scorch symptoms are described. Control was excellent using any of the fungicides tested. Leaves of checks were severely damaged by scorch. It is suggested that 1 or more fungi are associated with the cause(s) of this malady. Fungicides increased quality by increasing percentage of edible kernel, reducing shuck damage, and increasing wt of nuts.

Effective control of pecan scab caused by the fungus, *Fusicladium effusum* Wint. has been achieved by the development of modern fungicides, dodine and fentin hydroxide (2, 3, 9, 16, 17, 18). The search continues, however, for more effective materials and use at lower dosages. Spraying to control insects and diseases is one of the most expensive practices of pecan production. This, therefore, calls for efforts to reduce cost by development of cheaper materials, by reducing amounts of material used, or other means. In addition, a situation known as alternate bearing or failure to achieve adequate annual production is recognized as one of the most serious problems in production of pecans. The problem most often exists when trees are not sprayed to adequately control insects and diseases.

Premature defoliation occurs in many pecan cultivars beginning in August or earlier which may be involved in alternate bearing. This condition often goes unnoticed because growers assume it to be a natural senescence. Prior to leaf drop a condition often occurs known as leaf scorch. Leaf scorch symptoms have not been adequately described, and the term is often used to designate many leaf abnormalities caused by nutritional imbalances, insect injury, or mite damage (5, 13). This condition is reported to be reduced by mulching, shading, or irrigation (7). Leaf scorch has been attributed to drought, excessive soil water, or heavy production of nuts (1). Hammar and Hunter (6) reported that leaf scorch in their studies might have been caused by a nutritional deficiency, but leaves from trees that scorched in 1945 contained more K than leaves from the same trees in 1943 when no scorch was observed. They suggested 3 causes of scorch: 1) excessive rainfall in July (12.31 inches) following a hot, dry June, 2) depletion of mineral elements utilized in the production of a heavy crop of nuts, and 3) a high Ca + Mg/K ratio. Littrell and Worley (10) reported that the malady is associated with at least 7 genera of fungi isolated from leaf scorch specimens. Because improved scab control is desired and premature defoliation is considered one of the most serious problems, we designed this study to determine effectiveness of fungicides for 1) control of scab in a 3-week spray schedule, 2) control of scab with fewer applications by substituting 1 massive application at dormancy for the first 3

regularly scheduled sprays, 3) control of premature defoliation, and 4) effect on nut quality.

Materials and Methods

We used only 'Schley' trees in a grove of mature 'Stuart' and 'Schley' pecans (*Carya illinoensis* Koch.). The trees were 40 + years old in a mixed planting located near the Coastal Plain Station, Tifton, Georgia. This grove has been in fungicide tests since 1962, and recommended grove practices for insect control and fertilizer applications have been used (15, 16, 17). Sprays were applied with a John Bean 453 Speed Sprayer calibrated to deliver 114 liters (30 gal) of liquid per tree. Fungicides employed include: fentin hydroxide (triphenyltin hydroxide) (47.5% a. i.) (Du-ter); dodine (*n*-dodecylguanidine acetate) (65% a. i.) (Cyprex); captafol (cis-N-[(1, 1,2,2-tetrachloroethyl)thio]-4-cyclohexene-1, 2-dicarboximide) (80% a.i. WP or 0.47 kg/liter (4 lb./gal EC) (Difolatan); and benomyl ([methyl 1-(butylcarbamoyl)-2-benzy midazolecarbamate]) (50% a.i.) (Benlate). Dosages are given in tables. Six regularly scheduled sprays were applied at 3-week intervals beginning April 22, 1968 and April 29, 1969. The massive dormant applications were made at bud break on March 26, 1968. Scab was rated in September using a 0 to 9 scale: 0, no lesions; 9, 89-100% of nut surface with lesions. Sample size for scab rating was 50 nuts per tree, and 6 to 40 trees were used per fungicide treatment. Treatments were completely randomized in single tree plots. Insects were controlled by insecticides, and visible insect damage was slight.

Leaf scorch severity was estimated by counting scorched and missing leaflets per 25 adjacent leaves on the north, south, east, and west side of each tree on October 29 through November 5, 1969. As other leaf diseases were minor, missing leaflets were presumed to result from extensive scorching. On November 5, 5 of the most severely damaged leaflets and 5 leaflets showing least amount of external symptoms from terminals of 4 to 6 trees of each treatment were placed in moist chambers at 27°C. The extent of leaf necrosis was estimated after 10 days using a 0 to 10 scale. Fungi sporulating on leaf surfaces were observed with a stereoscopic microscope and predominate forms identified. Nut quality was determined by grading kernels into percent fancy, percent standard, and percent amber. Total percent edible kernel, nut size, and number of nuts per kg were also determined for each tree. Nuts per kg count was determined from a .227 kg (1/2 lb.) sample of nuts from each tree. Data were analyzed by analysis of variance and the means

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compared using Duncan's multiple range test.

Results and Discussion

Scab control. In 1968 and 1969 all fungicide sprays

differences were not statistically significant. The massive dormant applications of captafol gave fewer scab-free nuts and a higher percentage of nuts with light scab infection than applications made at 3-week intervals (Table 1). The mean scab

Table 1. Comparison of fungicides for control of *Fusicladium effusum* on 'Schley' pecan nuts using regular spray schedules and massive applications at bud break (1968).

Fungicide ^z	Dosage of active ingredient g/tree/spray	Mean scab rating ^w 0-9 ^x	Clean nuts ^x no. ^w	Nuts with light infection ^x no. ^w	Nuts with severe infection ^x no. ^w
Dodine	89 (.196 lb.)	0.2a ^v	42.8de ^v	7.1ab ^v	0.1a ^v
Dodine-massive dormant then regular beginning June 24 ^y	531+ (1.170 lb.) then 89 (.196 lb.)	0.8abc	32.5c	14.3c	3.2ab
Fentin hydroxide	26 (.057 lb.)	0.1a	46.8e	3.2a	0.1a
Captafol	109 (.240 lb.)	0.7ab	36.0c	11.2bc	2.8ab
Captafol-massive dormant then regular beginning June 24 ^y	719+ (1.583 lb.) then 109 (.240 lb.)	1.4bc	23.8b	20.0d	6.2b
Benomyl (no surfactant)	25 (.055 lb.)	0.7ab	37.7cd	9.5b	2.8ab
Benomyl + surfactant F (34 g/tree)	25 (.055 lb.)	0.2a	43.2de	6.7ab	0.2a
Control	- - -	3.1d	7.5a	24.0d	18.6c

^zRegularly scheduled sprays were applied April 22, May 13, June 3, June 24, July 15, and August 5.

^yMassive dormant applications were made at bud break on March 26. Volk 70 Supreme spray oil [2 liters/100 liters (2 gal/100 gal)] was used as a spreader for the captafol dormant spray.

^xScab rating September 5 to 10 were on a scale of 0 to 9: 0, clean; 1, up to 11% covered; 2, 12-22%; 9, 89-100% covered. Light infection consisted of ratings of 3 or less; severe infection, ratings greater than 3.

^wSample size was 50 nuts per tree.

^vDuncan's multiple range test, within columns, 5% level.

controlled the scab fungus when compared with the check (Tables 1, 2). The mean scab rating was lower, the number of clean nuts was higher, and the number of nuts with severe infection was lower for trees receiving sprays with any of the fungicides when compared with unsprayed checks.

Dodine and fentin hydroxide are used commercially for scab control, and both gave excellent control in our studies. Benomyl with surfactant F gave control equal to that of dodine and fentin hydroxide in all categories of scab infection (Tables 1, 2). Benomyl with no surfactant produced slightly fewer clean nuts than fentin hydroxide, but gave control equal to dodine and fentin hydroxide for the average scab rating and number of nuts with severe infection (Tables 1, 2).

Mean scab ratings and counts of the number of nuts with severe scab infection showed captafol, when used in the regular 3-week schedule, to be equivalent to dodine or fentin hydroxide at dosages used in both years (Tables 1, 2). In 1968, mean scab rating and mean number of nuts with severe infection were several times higher for captafol than for dodine or fentin hydroxide sprays; but at these low levels of infection,

rating and number of nuts with severe scab infection for trees sprayed with the massive dormant applications of dodine were not statistically different from those sprayed with the regular dodine schedule, but trees on the regular schedule had more clean nuts and fewer nuts with light infection (Table 1). Apparent physiological damage to the nut was negligible at scab ratings of 1 and 2. The results indicate that excellent scab control can be obtained by the use of dodine, fentin hydroxide, captafol, or benomyl when applied at 3-week intervals during the growing season. Captafol and benomyl are not now labeled for use on pecans, but requests for a label for benomyl have been submitted.

Although the commercial control obtained from massive dormant applications of captafol and dodine was favorable, weather conditions in 1968 were not favorable for the spread of scab until July. Control might have been equally as good if no sprays had been applied until June 24. Precipitation for April, May, and June averaged 6.5, 10.4, and 4.4 cm, respectively, compared with the 46-year averages of 10.6, 8.7, and 12.0 cm for this period. In June there was rain in only 4 days with only

Table 2. Effect of fungicides on control of *Fusicladium effusum* and 'Schley' pecan nut quality (1969).

Fungicide	Dosage of active ingredient g/tree/spray	Trees per treatment no.	Mean scab rating 0-9 ^y	Nuts with no scab spots no. ^v	Nuts with light scab infection ^w no. ^v	Nuts with severe scab infection ^w no. ^v	Nuts/lb. no.	Edible kernel %
Dodine	89 (.196 lb.)	17	0.1a ^x	44.8d ^x	5.1a ^x	0.0a ^x	66a ^x	61b ^x
Fentin hydroxide	26 (.057 lb.)	17	0.1a	44.9d	5.0a	0.1a	71a	61b
Captafol, 4-flowable ^z	136 (.300 lb.)	6	0.2a	42.2bcd	7.7a	0.2a	70a	60ab
Captafol, 4-flowable ^z	163 (.359 lb.)	6	0.3a	40.3bc	9.7a	0.0a	75ab	59ab
Benomyl (Benlate)	25 (.055 lb.)	6	0.3a	39.2b	10.7a	0.2a	73ab	60b
Benomyl + Du Pont surfactant F (34 g/tree)	25 (.055 lb.)	6	0.2a	43.0cd	7.0a	0.0a	70a	61b
Control	- - -	33	4.4b	0.8a	21.3b	27.9b	81b	57a

^zApplied with 71 ml/tree Chevron Spray Sticker.

^yScab ratings: 0, no scab; 1, few small spots; 9, 89-100% covered with scab lesions; sample size, 50 nuts.

^xDuncan's multiple range test, within columns, 5% level.

^wScab ratings of 1 to 3 are considered light; above 3, severe.

^vAverage no. in 50-nut sample.

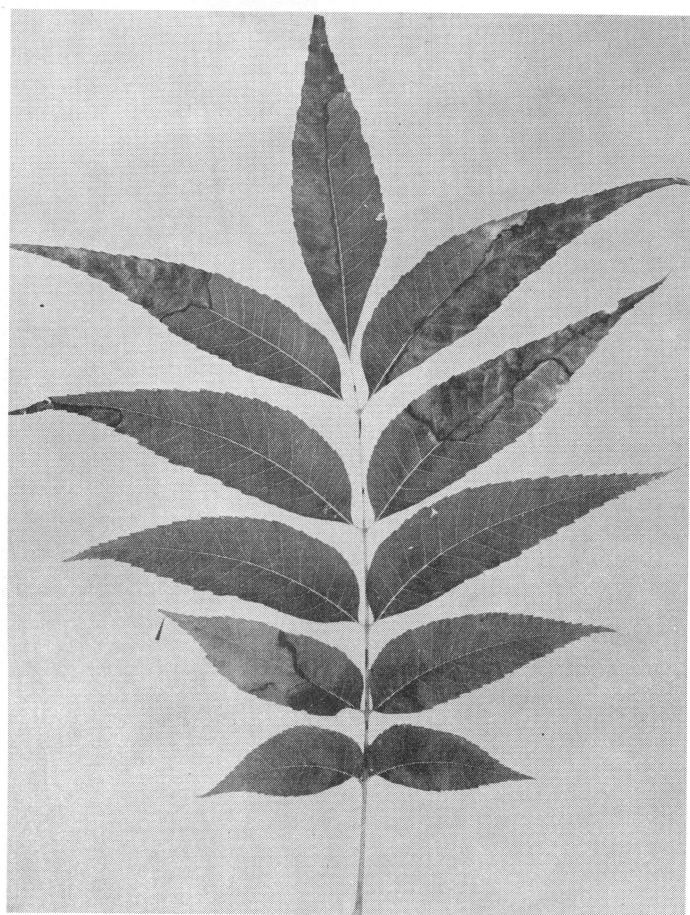


Fig. 1. Pecan leaf showing scorch symptoms with characteristic dark borders at periphery of advancing margins.

1 amounting to more than 1 cm; therefore, the spring was dry. Tests the previous year (19) showed that delaying application until July 6 gave much poorer control than the regularly scheduled sprays, but in that year 18 cm of rain fell in June with rain occurring on 11 days.

Leaf scorch. Symptoms of leaf scorch first appeared as necrotic areas on apex of leaflets or on margins. Necrosis progressed toward midrib and covered a large portion of the leaflet and subsequently resulted in leaflet abscission (Fig. 1). This usually began in August and became progressively more

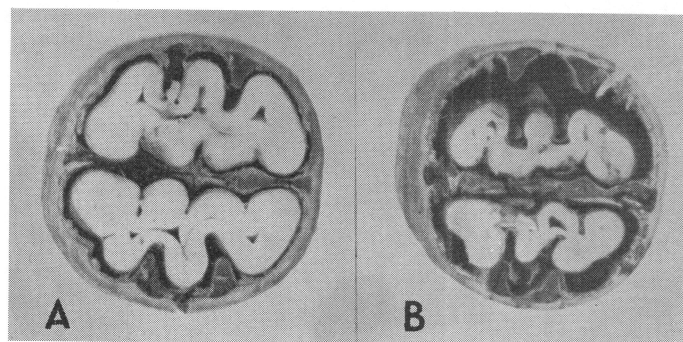


Fig. 2. Comparison of nuts collected (A) from trees sprayed with captafol, and (B) from non-sprayed 'Schley' trees.

severe with time. Margins of necrotic areas were usually black and interior a silver or light tan. Dark spots of fungi-fruited structures often occurred on the surface. The dominant genera of fungi fruiting on leaf surfaces were *Pestalotia* and *Cladosporium*. Symptomatology described here is different from that attributed to spider mites. Mite damage symptoms first appear near the midrib and progress toward the margin (12).

Trees sprayed with any of the 4 fungicides in 1969 retained foliage in excellent condition until a heavy frost killed the leaves on November 15. It is assumed from the work of Lutz and Hardy (11) that these leaves were still actively carrying on the process of photosynthesis. Trees not sprayed with fungicides had severely scorched leaves, and much of the foliage abscised well before frost. We assumed, therefore, that the photosynthetic activity of unsprayed trees was much less. Lutz and Hardy (11) reported that foliage diseases reduced photosynthetic rate of unsprayed leaves below that of sprayed (Bordeaux mixture) leaves by one-third. Leaflet counts in early November in our study revealed over a 7-fold increase in the number of scorched leaflets for unsprayed leaves compared with leaves from any of the fungicide sprayed trees (Table 3). Seventy-nine percent or more of the leaves sprayed with either dosage of captafol or benomyl contained no scorched leaflets compared with only 11% for trees receiving no fungicides. Poor foliage condition of unsprayed trees in the fall is expected to reduce the amount of stored carbohydrates and might account for poor nutlet set for unsprayed trees in some years (19). Removal of leaves prior to October 1 can completely prevent female flower formation the next year (8, 15). Fungicides also influenced the shelf life of detached leaflets in early November. When these leaflets were placed in a moist chamber 27°C for 10 days, leaves sprayed with dodine or not sprayed with fungicides

Table 3. Effectiveness of fungicides in preventing leaf scorch of 'Schley' pecan and residual effects on detached leaflets under high relative humidity conditions.

Fungicide	Dosage of active ingredient g/tree/spray	Leaf scorch index ^Y no.	Necrosis rating ^X		
			A 0-10	B 0-10	C 0-10
Dodine	89 (.196 lb.)	43a ^W	7.5c ^W	5.0b ^W	6.5b ^W
Fentin hydroxide	26 (.057 lb.)	36a	3.2ab	trace a	1.8a
Captafol 4-F ^Z	136 (.300 lb.)	27a	2.6ab	0.2a	1.1a
Captafol 4-F ^Z	163 (.359 lb.)	19a	4.0b	0.0a	1.2a
Benomyl 50%	25 (.055 lb.)	20a	0.9ab	trace a	0.4a
Benomyl 50% + surfactant F (34 g/tree)	25 (.055 lb.)	25a	0.3a	0.0a	0.1a
Control	---	328b	9.2c	4.7b	6.9b

^ZApplied with 71 ml/tree Chevron Spray Sticker.

^YLeaf scorch index = number of scorched or missing leaflets per 100 leaves.

^XNecrosis rating from 0 to 10 where 10 indicates 100% of area is necrotic: A, rating of 5 severely affected leaflets; B, rating of 5 least severely affected leaflets; C, combined rating.

^WDuncan's multiple range test, within columns, at 5% level.

deteriorated more extensively than those receiving fentin hydroxide, captafol, or benomyl sprays (Table 3).

Several investigators have studied leaf scorch and premature leaf abscission and several causes for the disorder have been proposed (1, 4, 5, 6, 7, 12, 13). This suggests there are different leaf scorch disorders based on symptoms expressed and cause. Our research indicates that the type of leaf scorch described may be caused by one or more fungi since fungi occurred on the leaves, and fungicide sprays significantly reduced its occurrence. The causal factor(s) of symptoms awaits reproduction of symptoms by inoculations under experimental conditions. Since broken midribs result in similar symptoms, plugging of xylem and phloem tissues may be involved.

Nut quality. Fungicide sprays increased the nut quality which was more apparent visually (Fig. 2) than the data showed. Shells of unsprayed nuts were incompletely filled and kernels were shriveled and hollow. Nuts of sprayed trees were packed with kernel. Nut/kg count was highest and total percentage edible kernel was lowest for the control trees (Table 2). Fungicide treatments did not affect kernel grade or size significantly. The scab fungus caused early shuck opening, poor filling, and premature drop, which reduced quality and yields. Nuts which have early shuck dehiscence are more susceptible to bird damage than those that dehisce later.

Schaller (14) reports benomyl fungicide reduced occurrence of stem-end blight in pecan. This condition and the similar tulip disease were not noticed, but could have existed in non-sprayed trees and been masked by scab. Stem-end blight is mainly a disorder of 'Success'; therefore, we doubt that it was present on the 'Schley' nuts.

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