

# BEHAVIOR OF CLADOSPORIUM EFFUSUM (WINT.) DEMAREE ON SOME VARIETIES OF PECAN<sup>1</sup>

By J. B. DEMAREE, Associate Pathologist, and J. R. COLE, Assistant Pathologist,  
Office of Horticultural Crops and Diseases, Bureau of Plant Industry, United  
States Department of Agriculture

## INTRODUCTION

Although named varieties of the pecan (*Hicoria pecan* Brit.) were first planted in orchards in Louisiana and Mississippi about 1880, the tree was not generally introduced commercially east of the Mississippi River until after 1890. By 1900 several large orchards had been planted in Georgia and Florida. Now the industry is extensive in the southeastern United States.

Prior to 1900 diseases attacking the trees or nuts had not attracted much attention. The pecan-scab fungus, *Cladosporium effusum* (Wint.) Demaree, was recorded (2)<sup>2</sup> on the pecan in 1888 from specimens collected by J. B. Ellis and A. B. Langlois near St. Martinville, La. Pecan scab was mentioned by Orton (5) in 1905, when he reported the disease as being of considerable economic importance in the Southern States. Hume (3) in 1910 said: "Thus far, the disease [scab] has been observed mostly on seedling pecans, though a few budded and grafted varieties have been noted which are subject to it." Georgia and San Saba varieties were mentioned by him as being susceptible, whereas Frotscher, Curtis, and Schley appeared then to be immune. Reed (7), in 1912 reported that Alley was somewhat susceptible to scab, Delmas very susceptible under certain conditions, Georgia extremely susceptible, Schley sometimes quite subject to the disease, and Van Deman very susceptible in some sections.

All early reports showed that the disease was not uniformly distributed and that the causative organism did not attack the same varieties to an equal extent in all localities. During an early period in the pecan industry the fungus usually attacked such varieties as San Saba, Georgia, and Delmas, when planted in the southeastern United States, but other varieties, such as Schley, Van Deman, Pabst, or Alley, now known to be susceptible, might be found growing in the same locality or even in contiguous rows in the same orchard and remain free of the disease for a number of years, or in some instances to the present time. Formerly apparent inconsistencies in varietal susceptibility were attributed to weather conditions. The disease is always more severe and a greater number of varieties are attacked in orchards growing near the Gulf of Mexico, a region of frequent rains, than elsewhere in the southern pecan belt.

The very destructive nature of the disease was first demonstrated by its behavior on the Georgia and San Saba varieties. These varieties showed evidence of being extremely susceptible over a wide area of the southern pecan belt 20 or more years ago. The pioneer

<sup>1</sup> Received for publication Oct. 26, 1928; issued April, 1929.

<sup>2</sup> Reference is made by number (italic) to "Literature cited," p. 370.

work on pecan-scab control was conducted by Waite (9) on Georgia and San Saba varieties at Orangeburg, S. C., in 1909, and at Baconton, Ga., in 1911. These two varieties were about the only ones attacked by the fungus in those localities at that time, although other varieties such as Schley, Van Deman, Alley, and Delmas were then grown at Baconton.

The progress of the pecan-scab disease seems to have been northward from the more humid region of the southern pecan belt. This migration has not been general or simultaneous on all varieties, and the spread on one variety has been independent of that on others. The most striking example of the distribution of the disease is that on Pabst. In 1919 this variety was first reported (6) to be severely attacked by the pecan-scab pathogene at Ocean Springs, Miss., its place of origin. Judging from the severity of the attack, scab had evidently become established there several years previously. By 1923 the Pabst variety was known to be affected as far east as Mobile, Ala., and west to New Orleans, La., and by 1926 as far north as Selma and Eufaula, Ala. In 1927 the fungus was found to be attacking this variety in the western part of Florida, the southwestern corner of Georgia, and the southeastern corner of Louisiana. However, the Pabst variety is still free of the disease in the extensively planted pecan area in the vicinity of Albany, Ga., where other varieties such as Schley, Delmas, Alley, and Georgia are affected. It is quite obvious that the disease is increasing its range of distribution on Pabst as well as on other varieties. There is, however, no evidence that it is spreading to Pabst by annual reinfection from other named varieties or from planted seedlings. It seems rather that infection of this variety, having begun in the vicinity of Ocean Springs, Miss., has gradually spread east, north, and west, just as a new disease may spread from some focal center.

The fungus has undoubtedly been distributed often by infected nursery stock, but it seldom, if ever, becomes established in a young orchard from such a source of infection. Ordinarily pecan trees under first-year orchard conditions develop only short and slow-growing twigs with scant production of leaves. This new growth soon becomes immune to infection. Even if the early formed leaves and twigs should become infected, there is no susceptible growth during the summer or early autumn to permit reinfections, and therefore the fungus distributed by nursery trees apparently dies before the beginning of the following season.

Prior to 1920 Georgia was the only variety generally affected in the extensive pecan region around Albany, Ga. In 1920 scab appeared on the Delmas variety and during the three following years spread rapidly through Delmas orchards in the vicinity of Albany, where it has now become a serious disease of that variety. At about the same time the Alley variety began to show the disease. In 1923 scab began to attack the Schley variety at Putney and Baconton, Ga., a few miles south of Albany. It spread so rapidly on Schley during the next three years that in 1926 it attained an epiphytotic stage. As previously stated, the Pabst variety, although regarded as very susceptible in some localities, is still free from the disease in the vicinity of Albany. On the susceptible Van Deman variety the amount of scab has been increasing slowly for the last five or six years

in the Albany, Ga., pecan district, and is now causing a slight loss of nuts there in some orchards where conditions are especially favorable for infection.

The reverse condition with reference to the relative susceptibility of the Pabst and Schley varieties has been observed in an orchard near Ocean Springs, Miss. There Pabst scabs very severely, but Schley is comparatively free from the disease. Another unusual situation has been observed in an old orchard near Jeanerette, La. There such varieties as Schley, Van Deman, Pabst, and Moneymaker are susceptible, but a few trees of Delmas and Georgia, varieties generally regarded as the most susceptible of all, are growing among the scab-infected trees and yet are free of the disease.

Near Thomasville, Ga., for several years there were two pecan trees so near to each other that their branches interlocked. One tree was a Delmas and the other a Schley. Both varieties are known to be generally very susceptible to the pecan-scab disease. In 1918, when the senior writer first saw these trees, the Delmas tree was affected but the Schley was not. This condition was not considered unusual at that time, for in the vicinity of Thomasville the Schley variety was usually free from the disease. The grower called the senior writer's attention to these trees as proof of the resistance of the Schley variety. A few years later, when scab of the Schley variety became general in the vicinity of Thomasville, this particular Schley tree showed no more resistance than others of that variety. It is evident, therefore, that the susceptibility of a given variety of pecan in one district and the resistance of the same variety in another district can not always be attributed to differences between the climatic conditions of the two districts.

The senior writer (*1*) suggested in a previous publication the probability of the existence of distinct or specific physiologic forms of the pecan-scab fungus. This hypothesis was advanced as a result of observations of its erratic or irregular behavior in different localities. A study of the fungus to determine whether or not physiologic specialization exists was undertaken by the writers, because proof of the existence of such strains would offer a plausible explanation of the selective parasitism exhibited by it. Studies of the varietal specialization of some of the Uredinales and Ustilaginales have been made by several investigators. Less work, however, has been done on physiologic specialization in other orders of fungi.

#### METHODS AND MATERIALS

The observation that the fungus attacking one variety of pecan might not readily attack other susceptible varieties when growing in contiguous rows, or even when branches of the trees interlocked, suggested to the writers the idea of cross-inoculating varieties known to be susceptible. Closely planted young trees of four susceptible varieties—Delmas, Van Deman, Schley, and Pabst—were used in the preliminary work. The pecan-scab fungus does not attack mature leaves, and all inoculations therefore necessarily had to be made on young and growing leaves. Normally, adult pecan trees produce a vigorous growth of twigs and leaves during the first six weeks to two months of the growing season. New leaf and twig growth then either is retarded or ceases to develop except that some second growth may appear during the rainy season of July. Some difficulty was

encountered in forcing the trees to produce new leaves for inoculation work throughout the season, but this was partly overcome by frequent irrigations and heavy applications of nitrogenous fertilizers.

The original inocula used in this experiment were taken from naturally infected leaves or nuts found in orchards or nurseries. Conidia were taken from infected leaves or nuts of one variety and placed in a small quantity of sterile water. With a sterile camel's-hair brush the conidial suspension was placed upon at least 25 young leaflets of each of the four varieties. The inoculated leaflets were then inclosed in either double glassine bags or closed celluloid cylinders. The transpired moisture from the inclosed leaves was retained within the bags or cylinders, and sufficient collected on the leaves to favor germination of the conidia.

The bags or chambers were removed 24 hours after inoculation, and final records were taken on the fourteenth day. To eliminate as far as possible the danger of contamination in later work, all leaves bearing infection originating from the artificial inoculations were promptly removed from the experimental plot as soon as the records were completed.

### RESULTS

Since all varieties used in the experiment were regarded as unusually susceptible to pecan scab, any considerable variation shown in the percentage of infection as the result of using a common inoculum on all varieties was considered as evidence of existing physiologic forms. Since infections produce the same type of lesion on all varieties regardless of the source of the inoculum, a scheme similar to the one Stakman and Levine (8) used in describing the various types of infections and degrees of susceptibility or resistance to *Puccinia graminis* Pers. could not be used. The results of the inoculation experiments made on the pecans were recorded by determining the percentage of leaflets infected.

The preliminary work done in 1926 proved that when the inoculum was taken from one variety and inoculated on the original host and on three other varieties, the percentage of infection was always high on the original host, but either nil or low on the other varieties used. Furthermore, it indicated the probable existence of physiologic specialization and a mixture or a variation in the adaptability of forms of the pathogene to some varieties.

In Table 1 are given the results of the first series of inoculations made in 1927. The work performed that year was more extensive than that of 1926, the inoculum was taken from more varied sources, and most of the inoculations were made either in duplicate or in triplicate. From each inoculation a high percentage of infection resulted on the trees of the same variety from which the inoculum was taken, and either none or a low percentage of the leaflets of other varieties became infected. The results of these inoculations not only gave further evidence of the existence of distinct physiologic forms of the fungus, but also indicated that the varieties of the pecan used in the experiment may be separated into two groups—(1) Schley and Van Deman, and (2) Delmas and Pabst—each composed of members showing a similar degree of susceptibility or resistance to the same strain of the fungus. When conidia taken from either nuts or leaves of the Schley variety were applied to all four varieties,

a high percentage of the Schley leaves, a low percentage of the Van Deman leaves, and none of the Delmas and Pabst leaves were infected, with one exception when 1 per cent infection was found on inoculated Delmas leaves. When conidia were taken from Van Deman leaves and placed on all four varieties, a high percentage of infection took place on that variety, a moderate percentage on the Schley, a low percentage on Delmas, while Pabst remained uninfected. When the inoculum was taken from Pabst, there resulted no infection on either the Schley or Van Deman varieties, a low percentage of infection on the Delmas, and a high percentage on the Pabst. With conidia taken from the Delmas variety there was little or no infection on Schley and Van Deman, a moderate infection on Pabst, and a very high percentage on Delmas.

TABLE 1.—Results of inoculating four varieties of pecans with conidia of *Cladosporium effusum* from leaves or nut shucks of several pecan varieties in 1927

No.	Date of inoculation	Source of inoculum	Percentage of infected leaflets of variety named			
			Schley	Van Deman	Delmas	Pabst
1	Mar. 4	Stromata on old shucks of Schley nuts, Thomasville, Ga.	53	5	0	0
2	Mar. 24	do.	71	10	0	0
3	May 7	Schley leaves, Thomasville, Ga.	76	3	0	0
4	May 10	do.	87	6	1	0
5	Apr. 14	Van Deman leaves, Monticello, Fla.	22	83	6	0
6	Apr. 19	do.	15	89	1	0
7	Apr. 14	Delmas leaves, Monticello, Fla.	3	0	81	10
8	Apr. 20	do.	0	0	89	2
9	June 11	Pabst leaves, Ocean Springs, Miss.	0	0	4	100
10	June 25	do.	0	0	8	92
11	May 16	Pabst × Delmas cross leaves, Philema, Ga.	0	7	68	14
12	May 21	do.	0	3	72	13
13	Mar. 14	Seedling leaves, Thomasville, Ga.	0	0	41	7
14	Mar. 24	do.	0	0	59	4
15	Mar. 30	do.	0	0	53	0
16	Apr. 8	Jacocks leaves, Orlando, Fla.	0	0	0	0

During March and April, 1927, a search was made for scab conidia of the current season on named varieties of pecans. At Orlando, Fla., scab was found on young leaves of an obscure variety known as Jacocks. Infected leaves from these trees, wrapped in paraffin paper and packed in a box containing ice, were sent to the writers' laboratory at Thomasville, Ga. Conidia taken from the Orlando material were placed on leaves of the usual four varieties the following day. The results (Table 1, No. 16) indicated that the Orlando form was different from all others tried in either 1926 or 1927. The difference was shown by the fact that all four varieties of pecan planted in the experimental plot were immune to it. Inoculations with conidia from a scab-infected tree originating from a cross of the Pabst and Delmas varieties (Table 1, Nos. 11 and 12) resulted in a relatively high percentage of infected Delmas leaves, a moderate degree of infection on Pabst, a low percentage of infection on Van Deman, and none on Schley.

Early in March the scab fungus was found attacking young leaves of a seedling of unknown parentage. Conidia from these leaves

were used in inoculating all four of the named varieties. Both Schley and Van Deman appeared to be immune to this form, but Delmas and Pabst were susceptible. At first, however, the seedling form did not exhibit a high degree of virulence on Delmas and Pabst, but two or three series of reinoculations caused the virulence to increase rapidly, especially on Delmas, as shown in Table 2. Apparently the form found on the seedling is identical with that commonly found on the Delmas variety or has similar pathogenic tendencies.

TABLE 2.—Percentages of infected leaflets resulting from successive inoculations of four varieties of pecans with conidia

Pecan-scab conidia taken from a pecan seedling of unknown parentage, Thomasville, Ga. (Mar. 14, 1927).....	Delmas, 41.....	Delmas, 89.....	Delmas, 91.
		Pabst, 12.....	Pabst, 4.
	Pabst, 7.....	Van Deman, 0.	Van Deman, 0.
		Schley, 0.	Schley, 0.
Van Deman, 0.	Schley, 0.	Delmas, 12.	
		Van Deman, 0.	Pabst, 13.
		Delmas, 7.....	Van Deman, 0.
		Pabst, 19.	Schley, 0.
		Van Deman, 0.	Delmas, 73.
		Schley, 0.	Pabst, 19.
			Van Deman, 0.
			Schley, 4.

In Table 2 it will be noted that both Pabst and Delmas were infected by conidia taken from a seedling. The pathogenicity of the fungus increased rapidly on Delmas at each reinoculation, which was to be expected, but the Pabst variety was also infected in the third transfer even when the inoculum had been passed through the Delmas twice. There are two other features shown in Table 2 that are not easily explained. The inoculum resulting from the first inoculation infected Pabst, this in turn infected Delmas, on which its pathogenicity to Delmas was increased 10 times, as shown in the third inoculation. The other confusing feature is the infection on Schley in the third inoculation, when that variety appeared immune to the first two inoculations. Before one can arrive at even a fair degree of understanding, the work must be carried through several seasons, and inoculum must in some cases be carried over from season to season.

During the course of these experiments it was noted that the incubation period varied with the source of the inoculum and the variety inoculated. That is, when conidia from one variety were inoculated on young leaves of the same variety, the incubation period was shorter than when the same inoculum was placed on leaves of the same age of other and less congenial varieties. For example, when conidia from Delmas leaves were applied to both Delmas and Pabst, 90 per cent of the inoculated Delmas leaves showed definite scab lesions on the sixth day, while none appeared on the Pabst leaves until the eleventh day after inoculation. Ordinarily a period of 10 days elapsed between the date of inoculation of natural or congenial hosts and the date of the appearance of the maximum number of infections, but the delayed incubation period on the less congenial hosts made it necessary to postpone the final record until the fourteenth day after inoculation.

It should be understood that in these experiments monosporous cultures were not used. The inoculum was always a composite collection of conidia from several scab lesions on the same host. It is suspected that closely related host varieties may harbor two or more strains or physiologic forms of the fungus, and if this proves to be true the results with monosporous cultures would be expected to be more definite and uniform than those given here.

During the season of 1927 the forms were carried through two and three series of reinoculations on the same hosts, but the results are considered merely suggestive. Unless the original source of the inoculum is from a single conidium or a single lesion, thus eliminating all danger of a mixture of forms, successive transfers are of little scientific or practical value. In future work it is proposed to use as inoculum conidia from monosporous cultures.

#### DISCUSSION

The results of the writers' preliminary work on the behavior of *Cladosporium effusum* when a common inoculum was applied to several varieties of the pecan tend to explain some features of the disease not well understood heretofore.

The experiments showed that when the inoculum was taken from one variety and inoculated on young leaves of the same variety and on leaves of the same age of another variety, there resulted a heavy infection on the original host and a light infection or none on the other. This tends to explain why two extremely susceptible pecan varieties may grow in the same orchard, even with their branches interlocked, and one variety may be attacked by the parasite while the other is not. The writers interpret such occurrences to mean that only one physiologic form of the fungus had been introduced in that orchard. This also explains why Pabst, a variety extremely susceptible to the disease in southern Alabama and southern Mississippi, is free from the disease near Albany, Ga., where the Georgia, Delmas, Schley, and Alley varieties are badly scabbed.

#### SUMMARY AND CONCLUSIONS

The pecan-scab fungus, *Cladosporium effusum* (Wint.) Demaree, formerly caused a disease of minor importance attacking a limited number of pecan varieties and was confined to restricted areas. All early reports showed that the disease was not uniformly distributed and that the causative organism did not attack the same varieties to an equal extent in all localities.

A variety known to be susceptible is often free from the disease when grown in the same locality with other varieties that are severely attacked. Trees of a susceptible variety may also be growing in the same orchard in contiguous rows, or even with their branches interlocking those of scab-diseased trees of another variety, and not be affected with the disease. Varieties are sometimes very susceptible in one locality and apparently immune in others.

During the last 10 years the senior writer has observed several instances of the apparent plasticity and increased virulence of *Cladosporium effusum*. The most striking of these has been the ability of the fungus to adapt itself to the Stuart, Frotscher, and Money-maker

varieties. In 1920 these three varieties were listed (4) as immune, but now it is not unusual to find nuts of these varieties severely attacked by the fungus.

Orchard observations suggested the probable existence of physiologic strains as an explanation of the erratic or irregular behavior of *Cladosporium effusum*. Experiments were conducted by applying conidia to four known-susceptible varieties. A heavy infection resulted in all cases when the inoculation was made on the variety from which the conidia were taken, and either a light infection or none when conidia from the same source were applied to other varieties.

The results of these preliminary experiments indicate not only some physiologic specialization of the fungus, but also that there is either a mixture of forms of the pathogene on similar host varieties or a plasticity in the adaptability of forms.

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