Breeding for Scab Resistance in Pecan

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Pecan scab is a serious constraint to pecan culture in the southeastern United States, and as such is the focus of much research. One of the cheapest and most convenient methods of scab control would be the development of resistant cultivars. However, the history of this disease in overcoming resistance, coupled with the inherent variability of the scab fungus, suggests the production of durable resistance will not be easy to achieve. This paper will focus on some of the challenges faced in resistance breeding and some possible methods for overcoming or at least ameliorating them.

It is useful to study the history of pecan scab in order to better understand how to approach the development of scab resistant cultivars. In their 1929 paper, Demaree and Cole provide an interesting review of the history of pecan scab in the Albany, Ga., region. Prior to 1910, scab was considered a relatively minor disease, of spotty incidence, primarily affecting seedlings or a few cultivars. Before 1920, the authors state that 'Georgia' was the only cultivar generally affected by scab. Beginning in 1920, however, 'Delmas' began to be affected, and in three years the fungus had spread to the entire region and became a serious problem on this cultivar. At the same time, 'Alley' also began to be affected. In 1923, 'Schley' began to be affected in Putney and Baconton Ga., located to the south of Albany. From there it spread so rapidly that by 1926 it had become extremely destructive throughout the region. In 'Van Deman' the amount of scab was slowly increased during the 1920's and was causing slight destruction under favorable conditions. 'Pabst' was still free of the disease in Albany at the time the article was written. In contrast, in Ocean Springs, Miss., 'Pabst' was very susceptible but 'Schley' was relatively free of the disease. In a Louisiana orchard, 'Pabst' and 'Moneymaker' were scabbing, while trees of the very susceptible cultivars 'Delmas' and 'Georgia' were unaffected.

Two facts stand out from these early reports on scab incidence: 1) cultivars now considered quite susceptible, such as 'Schley' and 'Alley', were at one time little affected by scab, and 2) cultivars can vary quite a bit in susceptibility depending upon location. Both of these factors are explained by the existence of multiple races of the fungus. Indeed, the presence of multiple races of the scab fungus has been demonstrated experimentally by several authors including Demaree and Cole, 1929; Converse, 1960; and Bracewell, 1996; and in our own research (Conner, 2002).

What are races of the scab fungus?, and how does their presence affect a resistance breeding program? Because the fungus causes similar symptoms across different pecan cultivars, and these are all broadly termed scab, it leads one to think of the fungus as being a single homogenous organism. However, it is more useful to think of the fungus as being similar to pecan itself in terms of variability. For example, someone who is unfamiliar with pecan may think that all pecan trees look alike, and can simply be termed generically as "pecan". However, a grower will know that there are many different pecan cultivars, and these cultivars vary widely in their characteristics. For example, it makes a world of difference whether one has a pecan orchard of 'Desirable' trees as compared to an orchard of 'Moore' or 'Mahan' trees. In the same way that pecan consists of many different cultivars, the scab fungus consists of many different races. How do these races differ from each other? Primarily we distinguish among them based upon the pecan cultivars on which they can grow and reproduce. A fungal race that causes severe disease on the cultivar 'Schley' may be unable to grow on a 'Desirable' tree. An example of this is shown in Table 1. Twelve pecan cultivars were inoculated with two different scab races. One race, Sc-Tif-1, was isolated from a Schley tree, and the other, Cf-Au-2, was isolated from a 'Cape Fear' tree. When race Sc-Tif-1 was inoculated back onto 'Schley', the cultivar from which it was isolated, it produced normal black lesions with abundant sporulation. When it was inoculated onto 'Mahan' it produced smaller, weakly sporulating lesions (an intermediate reaction). When Sc-Tif-1 was inoculated onto the other ten cultivars it did not produce any visible disease symptoms. This is despite the fact that many of the test cultivars like 'Cheyenne' and 'Desirable' are frequently infected by scab in the field. In a similar fashion, race Cf-Au-2 was only able to form normal lesions when inoculated back onto 'Cape Fear'. These two scab races are thus very specific in which cultivars they are able to infect. In our laboratory we have tested scab fungal isolates from eight different cultivars on 19 test cultivars to determine on which cultivars they could grow and reproduce. All 8 isolates reacted differently, and thus represent 8 different races. Most isolates only produced normal sporulating lesions on one or two cultivars, although one isolate was able to infect five different cultivars. This research indicates that there is quite a bit of variability in the scab fungus, and most races are quite specific in which cultivars they can infect.

The variability present in the scab fungus has several important implications for a resistance breeding program. One of the most important is that cultivar resistance has a tendency to break down over time. We have seen this in the past with cultivars such as 'Desirable', 'Stuart', and 'Schley', all of which were at one time considered highly resistant. However, as the cultivars became popular and widely planted, scab fungal races that are able to infect these cultivars have evolved and become prominent. This leads to the second point which is that the more widely a cultivar is planted the more likely it is that resistance will eventually break down. This is because as a cultivar is planted on a wide scale there are more opportunities for a new scab race to appear which infects that cultivar. This race can then spread quite quickly because there are many nearby orchards

planted with the same cultivar. Thus a cultivar essentially becomes a victim of its own success. Another important factor to remember is that often lone seedling trees will appear to be scab resistant. If you have an orchard of 'Desirable' trees, it is safe to assume that most of the scab fungus in that orchard is going to be of the type that infects 'Desirable' trees. A seedling tree within that orchard may be entirely free of disease and appear highly resistant. This is because the seedling tree has different resistance genes than the 'Desirable' trees, and these resistance genes protect it from the 'Desirable' scab races. It may take many years for a scab race to appear which is capable of infecting that seedling, or it may never happen. However, if you propagate that seedling and plant a large block to it, the odds of a race of scab appearing that can infect that cultivar are much larger. If that same seedling is planted throughout the southeast, the chances of it becoming infected are larger still. Thus, as history has shown, the odds are against any cultivar that is planted on a wide scale remaining immune to scab.

Even with the pessimistic situation presented above, there are still many opportunities for a breeding program to assist in the control of this disease. Many new cultivars seem to have a grace period during which they are relatively free of the disease. For some cultivars this period is relatively short, for others it has lasted decades. By testing new selections in several locations breeders can hopefully select cultivars whose resistance will not be overcome quickly. An active breeding program can take advantage of this grace period by producing a continual supply of new cultivars. This will assist growers by giving them an opportunity to plant a new cultivar with new resistance genes when they turn over an orchard. Hopefully, by the time a current cultivar has become extremely susceptible to scab, there will be new cultivars with different resistance genes ready to replace it. Thus the overall level of disease decreases and becomes more manageable. If resistant selections have nut quality equal or superior to the standard susceptible cultivars, then loss of resistance once it happens need not be catastrophic. Growers would begin controlling scab using the methods they use on susceptible varieties, and eventually rotate to newer resistant varieties when replanting.

Perhaps the most important role a breeding program can play in controlling scab, as well as many other orchard pests, is to increase the genetic variability in pecan orchards. We are in a situation in Georgia where two cultivars, Desirable and Stuart, make up over half of our orchard trees, and one cultivar, Desirable, makes up about half of all newly planted trees. In addition, orchard blocks often consist of a single cultivar and perhaps a pollenizer. This uniformity has been useful in developing a high quality product and more standardized production methods. But this same uniformity also makes it very difficult to manage orchard pests. Once a new race of scab develops, it can quickly spread throughout an orchard and from there throughout a region. The same may be true for other diseases and even insects. A computer simulation based on apple scab, a disease very similar to pecan scab, predicted that planting three cultivars, all

scab susceptible but possessing different resistance genes, reduced the number of lesions by 65% after six generations when planted in alternate rows and by 79% in a within-row mixture, as compared to planting an orchard with a single cultivar (Gessler and Blaise, 1994). Utilizing such a mixture in pecan is currently difficult because the few acceptable cultivars available differ widely in their cultural attributes and the marketability of their nuts. However, a breeding program focused on selecting new cultivars for similar attributes, while maintaining variability in resistance genes, may produce cultivars suitable for use in such mixtures.

Other projects our breeding program is researching include developing DNA markers for resistance genes and examining the physiological basis of scab resistance. DNA markers for scab resistance genes will be very useful in a breeding program. They will allow us to quickly identify resistance genes in our seedling progenies without laborious inoculation procedures. They may also allow us to pyramid multiple resistance genes into a single cultivar. Resistance based on several different resistance genes may be more difficult for the scab fungus to overcome and thus be more durable in the field. Currently we understand very little about how pecan protects itself from scab infection. By studying the infection process microscopically we hope to better understand this process and use this knowledge to select trees with higher levels of resistance.

The release of new pecan cultivars selected for scab resistance, coupled with increased genetic variability in pecan orchards and advances in chemical control measures, will allow future pecan growers to manage this disease much more effectively.

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Table 1. Resistance level of pecan cultivars to two races of the pecan scab fungus.

Pecan Cultivar Tested	Scab Race	
	Sc-Tif-1 (Schley scab isolate)	Cf-Au-2 (Cape Fear scab isolate)
Barton	Resistant	Resistant
Cape Fear	Resistant	**Susceptible**
Cheyenne	Resistant	Resistant
Desirable	Resistant	Resistant
Elliot	Resistant	Resistant
Farley	Resistant	Resistant
Kiowa	Resistant	Resistant
Mahan	**Intermediate**	**Intermediate**
Pawnee	Resistant	**Intermediate**
Schley	**Susceptible**	Resistant
Stuart	Resistant	Resistant
Sumner	Resistant	Resistant