Pecan Breeding Overview – Part 1

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Over the last couple of years I have gotten a lot of questions about our breeding program and what we are doing. I have also begun to realize that there are a lot of misconceptions about what exactly is involved in breeding pecans. I have been asked to submit a write up to the Pecan Grower describing our pecan breeding efforts which have been funded by the Pecan Commodity Commission for the last several years. So, to kill two birds with one stone, I am going to write a short series of articles describing my breeding program. The first part of this series will focus on deciding which crosses to make and the methods of accomplishing these crosses. The second article will focus on growing out the progenies and making initial selections. The final article will describe testing of advanced selections and cultivar release.

Let me provide a quick overview of pecan genetics to get us started. There are two things you need to know about pecan genetics. The first is that pecan trees are very heterozygous. What this means is that for many genes in pecan tree the tree will have two different alleles, one inherited from each parent. Thus when this tree produces a pollen or egg cell, one of those two different alleles will go to that cell, based on chance. When you add up the thousands of different genes, each with different alleles segregating randomly, the result is that each pollen or egg cell is pretty much unique in the specific combination of alleles inherited from the parent. Thus each seedling produced from that tree will inherit different traits from the parent, based on which of the different alleles got combined together in the egg or pollen cell.

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This is why pecans do not breed true to type and must be grafted. The easiest way to think of pecan genetics is to compare them to people. You have two parents, each of which provide different traits to their progeny. Just like children will resemble their parents in some ways but not in others, pecan seedlings will resemble their parents but not be identical to them. Also just like each child is different from the others of the same parent, each pecan seedling will be different from every other pecan seedling in that progeny.

The other thing you need to know about pecan genetics is that most traits are inherited quantitatively. What this means is that rather than the traits being yes/no , they are more gradations in terms of less/more. For example, if you cross a red and white flower and flower color is inherited in a qualitative (yes/no) fashion, the progeny will have either red or white flowers. If you make the same cross and the flower color is inherited in a quantitative fashion, the progeny will have a range of flower colors including: red, dark pink, pink, light pink, and white. Most traits in pecan have this type of inheritance. For example if you cross a tree with a large nut like 'Pawnee' to a tree with a small nut like 'Elliott' you get a range of nut sizes in the seedlings (Figure 1). Notice two things about this chart. Firstly you get a smooth bell shaped curve with the majority seedlings falling in the middle and fewer and fewer as you get to the edges with very large or very small nuts. Secondly note that the majority of seedlings produced nuts somewhere around

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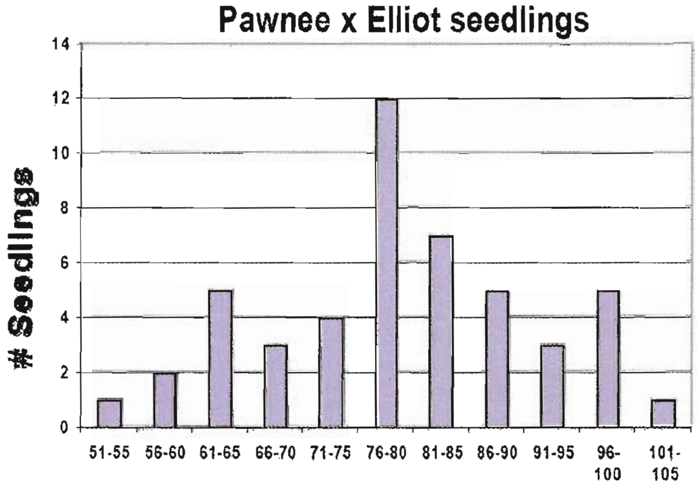

Figure 1. Nut size of 48 seedlings produced from the cross 'Pawnee' x 'Elliott'. The 'Pawnee' parent produced nuts sized 52 nuts/lb and the 'Elliott' parent produced nuts sized 77 nuts/lb.

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70 to 90 nuts/lb, which is similar to the size of the smaller parent. This is why you need large progeny sizes, only with large progenies do you have a reasonable chance of finding trees that are as good as the best parent. An old saying in fruit breeding is "Quantity makes Quality", the meaning of which is that only if you select from large progenies do you have chance of selecting a truly superior selection. To counteract this, breeders often use a parent with a very large nut size so that the progeny average is pulled up to the larger sizes. This is why parents like 'Mahan' and 'Mohawk', which have very large nuts, have been used frequently in pecan breeding.

The first step in any breeding program is deciding which cultivars are going to be your parents. In general, you have two choices. You can make a controlled cross where you know the identity of each parent, or you can use an open pollinated seed lot in which you are only certain of the identity of the female parent, the pollen having been supplied by natural pollination in the orchard. There are advantages to each method. With controlled crossing you know each of the parents and can be more sure of the traits that are likely to be inherited in the offspring. This allows you to more easily cover a deficiency of the female parent. For example, if you use a cultivar with a small nut like 'Elliott' as one parent, you will probably want to use a cultivar with a larger nut like 'Oconee' as the other parent so that the progeny have a chance of having an acceptable nut size. The other major advantage of controlled crosses the ability to parental combinations that are unlikely to happen by chance, either because the parental trees are not located in the same orchard, or they don't flower at the same times.

The primary advantage of open pollinated progenies is the ease of producing a large amount of seed, all you have to do is pick it up in the fall. This can be useful in off-years where you weren't able to make many of the desired crosses or where several crosses failed for some reason. One other advantage of open pollinated progenies is they sample a wider amount of germplasm, especially if the female tree is located in something like a cultivar trial orchard where there are a large number of different cultivars. Random chance may make a cross that you would have never thought of making, and you will certainly see more variation in these progenies. Despite this, my breeding program has focused heavily on controlled crosses. Many of our trial orchards have a large percentage of poor cultivars, and open pollinated seed

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lots from these have reflected this in the low quality of seedlings produced.

Once you have decided to make a controlled cross, you will need to decide what your parents are going to be. This decision is determined primarily by your goals is for the new cultivar and what parents have the desired traits. Your basic assumption is that the progeny produced from your cross will tend to average the traits of each parent together. For example, when I first began this project, and still today, a major goal is to produce superior scab resistant varieties. When looking over the possibilities for a parent with scab resistance the most obvious choice to come to mind was 'Elliott'. When you think about 'Elliott', what are its basic traits? Yes, it has high levels of scab resistance, but it also has small nuts, round nuts, susceptibility to yellow aphids, medium early harvest, and a tendency to bear alternately. Once you have picked the first parent you now have a second choice, do you pick a second parent that makes up for the deficiencies of the first, or do you double down on the trait you are most interested in achieving? For example, 'Curtis' is also very scab resistant, and if you use that as your second parent you may have high levels of scab resistance in the progeny. However, 'Curtis' also has a small nut, and the chances of producing a seedling with even medium sized nuts would be low, and so the cross might not be very useful. Generally I wind up choosing a second parent that makes up for the most severe deficiencies of the first parent. If possible, however, I try to double down on the main trait while still making up for major deficiencies. For example, we may use 'Gloria Grande' for the other parent because it also has good levels of scab resistance, thus doubling down on that trait, but 'Gloria Grande' is stable bearing and has a large nut size, making up for size and bearing habit deficiencies in 'Elliott'. Ultimately the choice is going to come down to what you have available as parents and your "feel" for what the best cross will be. This is why plant breeding is both an art and a science.

Let's look at some of the crosses I did my first year in 1999 and see how they came out. My very first cross was 'Elliott' x 'Desirable'. My thinking was to combine the scab resistance of 'Elliott' with the size and stable bearing of 'Desirable'. This cross was only marginally successful. Out of about 400 seedlings produced we are down to 3 that we are still evaluating. Unfortunately the

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scab susceptibility of 'Desirable' for the most part prevailed in this cross, and a large percentage were too scab susceptible to use. However, a different and unforeseen problem also arose in this progeny. When you look closely at the nut shape of 'Desirable' you will notice that it is actually fairly round in shape (Figure 2). When you cross it with the very round shape of 'Elliott' you produce a large percentage of large round nut shape seedlings. These seedlings are not very desirable from a shelling standpoint because they tend to be cupped on the kernel bottom, and if they are flat in profile like 'Desirable', have a tendency to break during shelling. However, the second cross made that year was 'Elliott' x 'Oconee'. This has been one of our better crosses. The longer nut shape of 'Oconee' mixed better with the round 'Elliott' and gave a more traditional pecan shape in many seedlings. Also the larger size and better scab resistance of 'Oconee' seemed to result in fewer seedlings being eliminated for scab and small nut size. Of the original 222 seedlings of this cross we are still evaluating five and 3 have advanced to grower trials.

Other crosses made that year include 'Elliott' x 'Barton' which was a case of doubling down on scab resistance. We got really nice scab resistance in that cross, but kernel quality was often poor as in the 'Barton'

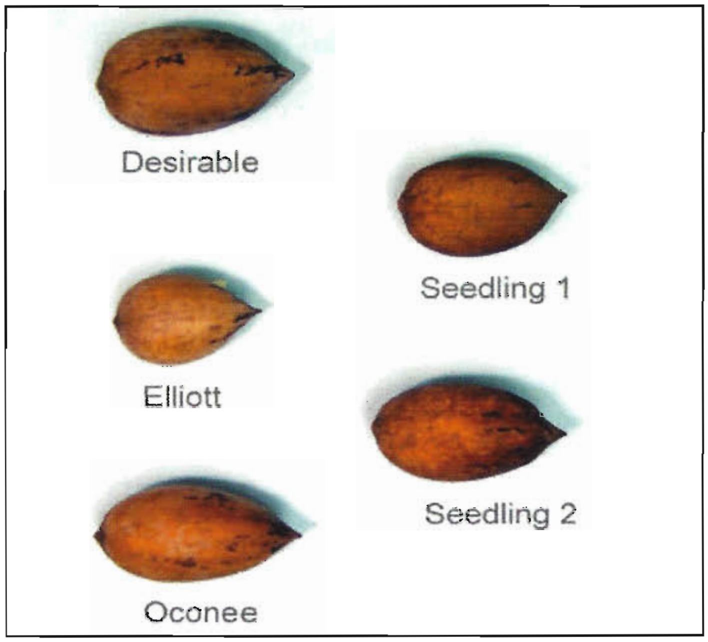

Figure 2. Nuts of 'Desirable', 'Elliott', and 'Oconee' pecans and Seedling 1 which is a typical 'Desirable' x 'Elliott' seedling and Seedling 2 which is a 'Elliott' x 'Oconee' seedling.

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parent. 'Pawnee' x 'Elliott' produced a couple of nice selections with early harvest and good resistance. However size is only medium, many of this progeny had to be removed due to kernel spotting like in 'Pawnee'. 'Forkert' x 'Pawnee' produced some seedlings with excellent kernel quality and large nut size. However, scab resistance has been poor in most of these. 'Forkert' x 'Cape Fear' again produce some nice nut quality but almost uniform scab susceptibility. We tried 'MoneyMaker' x 'Desirable', but the thicker shell and dark color of 'MoneyMaker' was often inherited and resulted in no selections. 'Kiowa' x 'Oconee' resulted in good nut size, but scab susceptibility and dark kernel color, again no selections. 'Pawnee' x 'Desirable' gave very high levels of scab susceptibility and only one selection. 'Oklahoma' x 'Kiowa' gave some good scab resistance and interesting tree branching patterns, but shells were too thick. A couple of these were kept for parents but won't be releases. In all, we had about 2,000 seed collected from the 13 crosses made in 1999. From those, 25 trees remain, the rest have been removed and the land replanted. Five of the 25 are now in replicated trials, and 2-3 more may enter into trials in the next year or two and the rest will be cut down. Each cross that you evaluate you learn a little more about how traits combine and get a little better about being able to predict which crosses will perform better.

Each year we make new crosses. Normally we will only make about 4-5 crosses with a parent over 2-3 years before we move on to something else. Only a few exceptional cultivars like 'Pawnee', which can contribute a rare mix of traits, in this case early harvest and large nut size, are used more frequently. For the first 5 years we made use of many traditional eastern cultivars like 'Elliott', 'Desirable', 'Gloria Grande', 'Barton', 'Schley', 'Sumner', etc. We then moved on to some USDA cultivars and selections that performed well in the Ponder variety test like 'Pawnee', 'Caddo', 'Oconee', 'Kanza', USDA 78-15-51, USDA 70-6-15 and others. I thank Dr. Tommy Thompson for making those cultivars available to us to use in our breeding work. In the last 5 years we used more scab and aphid resistant selections like 'Amling', 'McMillan', 'Faircloth', 'Tobacco Barn', Leger', and others. I thank Dr. Bill Goff and experienced growers for bringing these to our attention. There has also been an influx of very early ripening pecans like

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'Byrd', 'Morrill', and 'Lakota' that have been incorporated recently. Finally, we have begun using our own selections in crossing, which means we are now moving into the second generation of our breeding program. The goal of any breeding program is to continually improve the germplasm so that a stream of new cultivars with added traits are being produced.

Once you have decided on the crosses to make for the year you are down to the nuts and bolts of accomplishing the task. The first thing to do is evaluate the trees in the spring and determine, usually by catkin load, whether the given parent trees can be used that year. You then must decide which cultivar will be the female tree. In terms of what the progeny will look like, it doesn't matter much which parent is the female. A few rare traits are inherited from the female parent in some crops, but I don't know of any like this in pecan. Which parent may be used as the female will be determined by whether you have pollen stored for the parents. If not, you need to use a protandrous cultivar as the male parent so that you can collect and dry pollen in time to make the cross. If you do have stored pollen, the determination of which to use

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as the female parent can be based on the parent that has the most vigorous tree, or largest cluster size, or other factors. Overall, you try to plan your crosses so that you have female trees becoming receptive throughout the flowering season and you can accomplish the most crosses possible.

Female trees are bagged as soon as the female flower becomes large enough that you can see it and apply the bag to the tender shoot. Protogynous flowers in particular become receptive at a relatively small size and you must be quick. Because you are up in a lift, usually only one person can bag at a time, and there are time limits to the amount of bags that can be applied. Currently we are covering flowers with small paper bags (Figure 3). We have used a variety of things in the past including cellulose sausage casings, large paper bags, micropore tape, and small velvet bags. In general I haven't been happy with any of them. Nut set is usually low, and we often average only a single nut per bag applied or less in many crosses. It takes a lot of work to get progeny sizes up to the 100-200 nuts that we like to see.

Pollen is collected by getting a paper grocery bag of catkins

Figure 3. Paper pollination bag over female pecan flowers. Note the puncture mark where the pollination needle was inserted and then resealed.

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off the trees just as the pollen is starting to shed. Catkins are brought inside and laid out on butcher paper in a thin layer to dry and shed pollen. Once the pollen is shed and dried, the catkins are removed (the pollen has fallen off and collected on the paper below them), and the paper is rolled up and turned on its side to sift the pollen down through a sieve. This dried pollen is stored in tubes in the refrigerator for the pollination season, or frozen at -80 °C for the next year. Pollen can be held frozen for many years and still be used.

When female trees are receptive, the bags are pollinated. A rubber bulb is attached to a plastic syringe and needle which contains the pollen. The needle punctures the bag and a squeeze of the bulb puffs the pollen into the bag. The bag is then resealed with glue. We usually will go back 2-3 days later and pollinate the bags again in case some of the flowers were not yet receptive the first time. After pollination season is over, the bags are removed and the clusters are marked with flagging tape. As shucks begin to crack open, the nuts are collected from the flagged shoots, dried down, and stratified. Next time we will look at growing up the seedling progenies and making initial selections.