Building Disease and Pest Resistance Through Breeding
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What I thought I would do is give you a bit of an overview of how breeding is done in a conventional or classical manner. If you look at this slide, here the central core is really the key activities that take place every year. Superimposed on that are the circles on the edges which are activities that take place in support of the program.

First and foremost is the choice of parents. As Robert was saying, mating does take place, and that's what the name of the game is. The choice of parents does depend a great deal on the objectives and the desired output–what you're looking for. At Fredericton and in the Canadian breeding program we are very fortunate to have a strong history in germplasm enhancement and parent development, and it's to these new parents that we look for new attributes that can really help us along the way. In any given year the parents are chosen according the objectives, the crosses are made, and from then on it's really a numbers game. We start out with a great many, and each successive generation in the field we apply different selection pressures and eliminate the ones that are less desirable, keeping the ones that are more superior for more complete evaluation and further assessment.

As I said, the germplasm resource is great. With potatoes we're very fortunate really because there are approximately 200 or so cultivated relatives and wild species that are related to the potato, and it's to these that we can look for sources of resistance to diseases and pests, plus many other attributes such as to biotic stresses such as drought, salinity, and nitrogen (N) use efficiency.

Of course we know that the potato originated in South America and Central America, and there are a number of germplasm collections around the world that preserve germplasm, and it's to these collections that breeders look for new sources of many of these attributes. So, broadly speaking, the breeding scheme focuses on determining the objectives. This is done every year in conjunction with the people who are using the potatoes–the manufacturers, the consumers, and the other scientists. We make a choice of what parents to use, we make the crosses, select the superior clones, and then the evaluation begins.

The evaluations are many and numerous, and they focus on agronomic features and quality attributes as well as disease and resistance traits. As many people have said today, the objectives are really very closely related to the end use of the potato–what they're going to be used for, whether or not they're going to be used for table consumption, the attributes of a potato that is going to be boiled or served mashed or baked may be quite different from one that's chipped or made into french fries. And all of these things are subject or respond to breeding efforts and there are heritable traits that are associated with each of those different end uses.

This is a pictorial review. I'm not sure how many people are familiar with the actual process of conventional breeding, but it takes place very often in a greenhouse under controlled conditions where we grow the parents to be used as either males or females depending on the objectives and the attributes of those parents which, by the way, we try to categorize so that we have a pretty good idea of the characteristics of each parent that's being used. The crosses are made in a somewhat controlled fashion. The pollen that's going to be contributed from the male parent is collected and applied to the female. If that is a successful event and fertilization occurs, after a period of some time you'll get the development of the fruit.

The fruit is actually a berry. It resembles a small tomato actually. You may have seen these in the field. Occasionally people wonder why their potatoes are bearing fruit, but this occurs naturally, and it's these fruits that we harvest. The seeds within these fruits are removed, counted, and put in an inventory. These are botanical seeds, the very first part of a classical breeding program. They're sown in a greenhouse much as you would sow a bedding plant. They're sown by families. In other words, parent A x parent B produces 5000 seeds that we grow as a family, and we keep them all together. You could think in terms of these all being like brothers and sisters. They share the traits of the parents, but each one of them is an individual. So after they're grown in the greenhouse in individual cells, they're harvested and taken to the field the following year, and that's the beginning. That's the first vegetatively propagated part of the whole process. So here in a field you might have in the order of 60,000 individual plants, all different.

You can clearly see here that there is variation. This presumably is a cross between a parent that has red skin and a parent that may have white skin. Variation is easily apparent. You can see differences in skin colour, shape, and eye depth. Some of them are much more deep. That's considered to be an undesirable trait because soil collects in them and makes them more difficult to peel. But there are quite a few other traits that are not quite so apparent, and these have to be measured and assessed and data collected. These are what we call qualitative traits. Into this category would fall such things as disease and pest resistances. Here we have segregation for scab resistance in a family. Another qualitative trait is culinary quality; there are a great many things that contribute to what is considered quality. Other qualitative traits are dry matter, the internal characteristics, and the nutrient composition of the tubers. Yield is another one.

As a pathologist, something that I'm particularly interested in are the disease resistances. Here we have a number of diseases for which we assess each selection; obviously not each selection, but some of the more advanced ones. For ease of recordkeeping what we do is assign a 1-9 score. So for instance if this selection was subjected to scab, that's a no-no. A score of 9 is totally unacceptable. That's at the high end of the susceptibility range, and it's something which we would routinely discard on that basis. Some of these other diseases we've heard a lot about–late blight, *Verticillium* wilt, wart, and the viruses. And let's not forget the pests, particularly the potato beetle. Cyst nematodes are of interest in some areas.

Just to put this in perspective, if you come up with a selection that has a number of good resistances and multiple disease resistances then it is certainly important to look at some of the agronomic traits as well because it's really a question of trying to get as many of these things as possible together in one package. Here's an F number that has a number of disease resistances that are quite useful. When you compare it with Kennebec it's early vigour is comparable. It's shape is acceptable–it's a round oval; Kennebec is oval-oblong. Appearance is not quite as good as Kennebec. Again, this scale goes on a 1-9 basis. Tuber size is acceptable, if a little smaller than Kennebec. The skin colour and flesh colour are all acceptable. But where we begin to fall down is the specific gravity–it's quite a bit lower, and this is reflected in the boiling scores and the chipping scores. So while we clearly have multiple disease resistances in this, we're losing on the other side of the equation. Also, the yield is significantly lower. However, this selection wasn't suitable for release by the 1990 standards because it didn't really measure up in some of these other qualities that I'm talking about.

But maybe we should look back at some of these selections and have another look. Walter Arsenault here in Charlottetown is having a look at 6 or 8 cultivars that may have some potential from the point of view of sustainable production. But in any story there are a number of parts, and for a cultivar to be accepted or even be marginally accepted there needs to be a combination of a great number of things. You need to have acceptable agronomic features such as growth, maturity, and yield. The quality has to be acceptable; likewise the dry matter, texture, colour, cooking attributes, and disease and pest resistances. You have to have a market niche for it and, particularly germane today, what production system that cultivar might find itself in.

I, too, wanted to spend a little bit of time on late blight because this is probably recognized as one of the number one problems worldwide in potato production. We've heard that it attacks the foliage as well as the tubers; that makes it more difficult to control. When you're looking at inheritance or breeding for resistance, you're looking at a number of things, and again it's multigenically controlled. We think that if we can look at the rate of infection and the subsequent extent of sporulation, that will probably be the most effective way to go. So we are doing some work under controlled environment conditions. This is an incubation chamber where the plants under test are inoculated and placed for 24 hours under conditions of ideal suitability for disease development. They are incubated in these mist tents which are maintained at about 18° C; we have the capacity to apply mist because we know that late blight favours cool, moist environments. So if we can identify selections that have a long latent period and small lesion size and reduced intensity of sporulation, we will make a contribution to slowing down the epidemic and allowing the crop to grow for a longer period of time before it is decimated by the disease. I think this morning we heard something on the order of 30 days being a target to slow down the disease development.

In summary, I would like to say that the other association with late blight resistance very often comes with late maturity in cultivars. This represents a summary of some data taken from an institute in the Netherlands where they looked at the area under the disease progress curve over four years. This represents an average, and these are the earlier cultivars on this end. Higher histogram, higher bars represent higher susceptibility. We know Bintje is one of the most susceptible. Sterling here is demonstrating very nice levels of disease resistance, but it is quite late–it's toward the later end of the continuum, and that may make it less desirable for production practices. The other thing that's really hamstringing us is the lack of a field trial for late blight evaluation. This particular place is just about perfect. You can see that it has high humidity and a cool climate. It happens to be in the Andes, but I'd like to think that we could find a trial location a little bit closer than South America, and that would really help to potato breeders to evaluate selections for blight resistance.

I'll close by saying that a great many things take place from the time the initial cross is made through the field evaluations, lab, greenhouse, and cooking quality until finally, if lucky, we end up with a cultivar suitable for the table.

Q: Is late blight a problem in the Andes?

A: Yes, very much so. In fact, that area there that I show, that field trial, is the testing site for the International Potato Centre, and that's where they take their selections and evaluate them. They have wonderful exposure to late blight.

Q: Historically, has there always been a problem with late blight in the Andes.

A: I think it’s probably fair to say that the pathogen and host co-evolved and that’s why we look to the Andes for the sources of resistance, because the natural selection pressure has taken place there.