Potatoes Need More Than Good Looks: The Role of Pathology In a Potato Breeding Program

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The components and objectives of a potato breeding program can vary depending on market requirements, e.g., russet processing/fresh pack, red-skinned for fresh pack, or round, white for chipping. However, a few common factors needed in any market are yield and grade, tuber appearance, and disease resistance. For example a fresh market cultivar needs acceptable "eye appeal" and good culinary characteristics. A processing cultivar must have acceptable dry matter, low sugar after storage or reconditioning, and tuber size and shape. Traditionally a breeding program's focus has been on yield, as this is necessary to provide economical return. This article will cover disease screening in a breeding program, the cooperative nature of disease screening, and successes in developing late blight and virus resistant cultivars.

Before the Irish late blight epidemic of the 1840s, European cultivars had a more diverse genetic base originating from South America *Solanum tuberosum* subspecies *tuberosum* and *andigena*. Survivors of the late blight epidemic had some level of field resistance. A limited number of 19^{th} and early 20^{th} century introductions then provided this newly "narrowed" genetic base with more diversity. These introductions included exotic species and some primitive relatives from concentrated breeding efforts to introduce more *andigena* germplasm into the genetic base. Today, there is a United States Potato Genebank formally known as the National Research Support Project or NRSP-6. This genebank holds more than 5000 accessions that represent approximately 150 wild species. These accessions have some characterization for disease resistance and are available to breeders for use in adding resistance genes to new potato cultivars.

Resistance to late blight, root knot nematode, and viruses have been successfully incorporated into new cultivars and advanced breeding lines. For late blight resistance, the RB gene from the wild species *Solanum bulbocastanum* has been identified and used to confer late blight resistance by the genetic modification of previously susceptible potato varieties. Resistances to late blight and viruses from Polish breeding stocks have also been utilized in the USDA-ARS breeding program. The resistance in the Polish stocks can be traced to two wild species, *S. demissum* and *S. stoloniferum*. Finally, resistances to potato leafroll virus and potato virus Y (PVY) have also been incorporated to breeding lines from *S. etuberosum*, a wild species that doesn't even produce tubers!

Every new cultivar must be described and named. A review of referred journal articles for new cultivars shows that the following components are common to each: A description of the flower, tuber, and vine; yield and specific gravity; disease and physiological disorders; suitability for processing or fresh, nutrition components, and total glycoalkaloids or TGA. TGA have been shown to play a role in protecting the plant against pathogens. TGAs are associated with a bitter taste in potato and levels above 20 mg per 100 g fresh weight are considered unacceptable for human consumption; thus the necessity for evaluating TGA levels over years prior to the release of an advanced selection as a cultivar. Besides yield and other improved agronomic characteristics, the development of new cultivars is driven by the need for resistance to existing and newly discovered diseases.

Control of disease is accomplished by an integrated approach consisting of pesticides, cultural management, and host resistance. Host resistance can provide a long term, economical solution to a pest problem. Disease problems can arise from new pathogen strains or simply introduction of a disease to a new area. The following list gives an understanding on the rate of disease discovery in the U.S. and Canada: 1992- PVY necrotic strains in Canada; 1994- new late blight strains in North America; 1996- Potato virus A in Idaho; 2000- PVY necrotic strains in the Pacific Northwest (PNW); 2001- potato wart in Prince Edward Island, Canada; 2002- potato mop top virus in Maine, Canada, and reported in other parts of the U.S.; 2002- potato tuber moth in the PNW; 2004- a number of bacterial ring rot cases in Washington; 2006- potato cyst nematode in Idaho and golden nematode in Southern Quebec.

A look at scientific journal publications over the years shows that with each new cultivar, more disease information is available. Four disease factors were listed in the cv. Kennebec release in 1948 and in 2006, twelve factors were listed for cv. Defender. The information available each year is also more detailed and comes from the collaborative work of many researchers. Disease information in early releases was often included in the text, if mentioned at all. More recent releases include disease information in a table, in a more detailed format, and with comparisons to similar standard cultivars. Much more information on cultivar disease reaction is also available via the internet. Wisconsin has a site which lists results from their disease trials (http://www.plantpath.wisc.edu/wivegdis/) and all of the Tri-State, Western Regional, Chip, and Specialty trials from the past few years are available at www.ars.usda.gov and by clicking on "find an ARS location". This link displays a U.S. interactive map. Clicking on the Aberdeen, Idaho location will take you to the home page of the Aberdeen, Idaho research unit. Also a Google search of "USDA Aberdeen" will produce a link that will also take you to this location. The reports are listed under "Western Regional & Tri-State Potato Variety Trial Reports".

Since the best disease information comes from trials that are done across multiple locations, many researchers collaborate to produce the results. For the Aberdeen Breeding Program, collaborative researchers in Oregon, Washington, Idaho, Wisconsin, Michigan, and in Mexico are involved. In return the breeding program also cooperates in disease work from other projects. There is additional information gathered from national disease trial plots across the U.S. for scab, late blight, and other diseases.

An outline of the late blight screening that is done in multiple locations will give an idea of the locations and amount of collaboration necessary to effectively screen for disease resistance. At Aberdeen up to 2500 individual plants from late blight resistant parent crosses are grown in the greenhouse. A minituber from each plant is sent to Toluca, Mexico for late blight screening and a tuber from the same plant (its genetic identical twin) is planted in Aberdeen to be evaluated for its tuber shape and type. The Toluca site is important as it is the center of diversity for *Phytopthora infestans*, the pathogen that causes late blight. Plants that are resistant to late blight at Toluca should be resistant against most isolates. At harvest time in Idaho, with Toluca late blight results in hand; the best tubers are selected based on a visual assessment and foliar late blight resistance. The next year, the clones that were selected are grown in Corvallis, Oregon and inoculated with a US8 late blight strain. This site is conducive for tuber blight, so now foliar and tubers results are recorded. Clones selected through this process are then further evaluated for yield, processing, and other components. Success of this screening program includes the release of late blight resistant Defender in 2004. Defender produces long, white tubers suitable for processing and is resistant to foliar and tuber infection by late blight. In addition to late blight resistance, Defender has moderate resistance to PVY. Another clone, AWN86514-2, also selected by this process has the ability to transmit high levels of late blight resistance to its progeny and is used extensively as a parent in late blight crosses and was published as a germplasm release.

The virus screening conditions under which these two cultivars were trialed is used to screen all advanced clones, as well as clones early in the variety development process originating from virus resistant parents. This virus screening involves planting these clones among 'spreader rows' that have infected PVY and PLRV plants in them, and allowing aphid s to move virus into the test clones.

Test plants are also inoculated with indigenous, common strains of PVX and PVY. At harvest, tubers are collected from each plot and then grown-out in a greenhouse during the winter and checked for the presence of potato X, Y, and leafroll viruses. Again some recent successes (and their PVY^{O} percentages under conditions where Russet Burbank is 70%) from this virus resistant program include Defender (4%), Yukon Gem (NDA5507-3Y) (7%), Premier Russet (A93157-6LS) (0%), Bannock Russet (7%), and Highland Russet (A9045-7) (21%). Because of new PVY strains in North America, additional screening for these strains has been added. PVY necrotic strains have the ability to cause ringspot symptoms on the tubers. These ringspots become necrotic and can destroy the marketability of the affected tuber. Resistance to one strain of PVY doesn't guarantee resistance to all strains. PVY^{O} is the common, predominant strain of PVY that causes yield loss. PVY^{NTN} can cause yield loss and produce the ringspots mentioned. In addition, another strain, $PVY^{N:O}$, a recombination between N and O, can cause ringspots. New screening against these PVY strains is now done in a secure greenhouse. Premier Russet has shown field immunity to PVY^{O}, but is susceptible to PVY^{NTN} and $PVY^{N:O}$ strains.

The emergence of new diseases and the changing nature of existing diseases will continue to challenge seed and commercial growers. Disease screening is an essential and integral part of any breeding program. Cultural practices and effective pesticide programs will help to reduce the amount of loss from diseases, but cultivar resistance offers a better long term and environmentally friendly approach. In the end, potatoes need both good looks and disease resistance in order to provide a profitable return to the grower.