# Varietal Resistance to Common Scab

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## The Common Scab problem and significance of resistance breeding:

The importance of Common Scab of Potato (CS), a disease caused by the bacterium *Streptomyces scabies* and other species of *Streptomyces* is well known to Wisconsin potato growers and growers in other states. Common scab is observed in the most common potato disease in the growing conditions of the US and Europe adversely affecting the marketable yield of potato crops, either through occasional reduction of gross yield (Bang,1979) or, more importantly, through the alteration of tuber skin aspect, which is increasingly important for the fresh market.

In the United States early efforts for breeding for CS were reported by Clark et al. (1936). Since then, breeders have devoted efforts to CS resistance breeding. The efforts have been different from program to program depending on the importance given to the disease and no general trend with respect to having better scab resistant varieties has been found (Douches et al., 1996).

## Sources of Common Scab Resistance:

Most of the early varieties tested in the U.S. before 1955, were susceptible to CS (Stevenson, 1956); only a few, including Russet Burbank, Russet Rural and White Rose showed tolerance to this disease. Several foreign varieties such as Hindenburg, Jubel, Ostragis, Rheingold, Arnica and Ackersegen had CS resistance (Stevenson, 1956, Hougas and Ross, 1956). These varieties were not successful cultivars per se but were used as progenitors of many scab tolerant named varieties (Table 1). An analysis of the pedigree of CS tolerant varieties reveals that virtually all the CS resistant varieties released from 1944 to 2011 include in their pedigree the German varieties Jubel or Hindenburg (Table 1). These varieties have been used in the development of fresh market or chip processing round white varieties, fresh market or processing russets and even red potatoes. Very important varieties such as Russet Burbank, Goldrush, Superior, Pike and Dakota Pearl carry Jubel or Hindenburg in their pedigree and probably ought their CS resistance to them. It may be important to develop additional sources of common scab resistance. Germplasm enhancement work is currently under way at the USDA/ARS/University of Wisconsin program leaded by Shelley Jansky. This germplasm work may provide the common scab resistance of the future (See Jansky report to this proceedings). New sources of CS resistance may be needed to avoid narrowing the genetic base of CS resistant varieties as well as to preempt possible co-evolution of the bacteria *Streptomyces* spp defeating resistant varieties. The understanding of the variability on pathogenicity and virulence of different *Streptomyces* spp have been greatly enhanced by the work of Leslie Wanner and others in the last decade.

Table 1. Parental varieties used in the development of CS resistant varieties in the U.S.

| Parental Variety | Pedigree | Origin | Year | CS Tolerant Varieties Derived |
|---|---|---|---|---|
| Jubel | Victoria Augusta x 78 92 | Germany | 1908 | Hindenburg (1916), Menominee (1944), Ontario (1946), Cherokee (1951), Osage (1953), Pungo (1951), Redkote (1953), Antigo (1955), Superior [1] (1961), Salem[1] (1997), Pennchip, Kalkaska[1], MegaChip[1] |
| Hindenburg | Ismene x Jubel | Germany | 1916 | Cayuga (1946), Seneca (1946), Antigo (1955), Pennchip[1] |
| Russet Burbank | Early Rose | US | | Early Gem (1953), Coastal Russet (1988),Yukirasha (2002), Goldrush[1] (1992) |
| Menominee | Jubel x USDA S44537 | USDA-Cornell | 1944 | Antigo (1955), Liberator[1] |
| Ontario | Jubel x USDA S44537 | USDA-Cornell | 1946 | Snowchip (1974), Goldrush[1] (1992) |
| Cherokee | USDA 96-56 x USDA 528-170 | USDA-Cornell | 1951 | Wauseon[1] (1967), Allegany[1] (1990), Wischip[1], MegaChip[1] |
| Early Gem | Russet Burbank x USDA 96-56 | US | 1953 | Goldrush (1992) |
| Redkote | | | 1953 | Norland (1957), Red Norland, Dark Red Norland |
| Antigo | | UW | 1955 | Norchip[1], Goldrush[1] (1992), Dakota Pearl[1] (2005), Liberator[1] |
| Superior | USDA 96-56 x Minn 59-44 | UW | 1961 | Red Cloud |
| Pennchip | 3RD-5 x 3WH-9 | PSU | 1963 | Marcy |
| Wauseon | Katahdin x B5149-8 | Cornell-USDA | 1967 | |
| Norchip | ND4731-1 x M5009-2 | NDSU | 1968 | Dakota Pearl, Liberator[1] |
| Lemhi Russet | Pionner x A63126-8 | USDA-UI | 1981 | Goldrush (1992), Freedom Russet |
| Allegany | M297-17 x pollen mixture | Cornell-USDA | 1990 | Pike (1996), Reba |
| Goldrush | Lemhi Russet x ND450-3R | NDSU | 1992 | |
| Pike | Allegany x Atlantic | Cornell | 1996 | Tundra, Lamoka |
| Reba | Monona x Allegany | | | |
| Dakota Pearl | ND1118-1 x ND944-6 | NDSU | 2005 | |
| MegaChip | Wischip x FYF85 | UW | 2005 | |
| Freedom Russet | ND14-1Rus x W1005rus | UW | 2004 | |
| Kalkaska | USDA1251 x S440 | MSU | 2007 | |
| Lamoka | NY120 x NY115 | Cornell | 2011 | |

[1]Note: for these varieties the putative CS resistant donor is not the immediate parent, but a more distant relative.

An update on the biology of *Streptomyces* spp. will be given by Wanner in a separate report in these proceedings. The biology of the pathogen is an integral part of the CS disease triangle that affect the amount of CS present in a given location and year (Fig. 1).

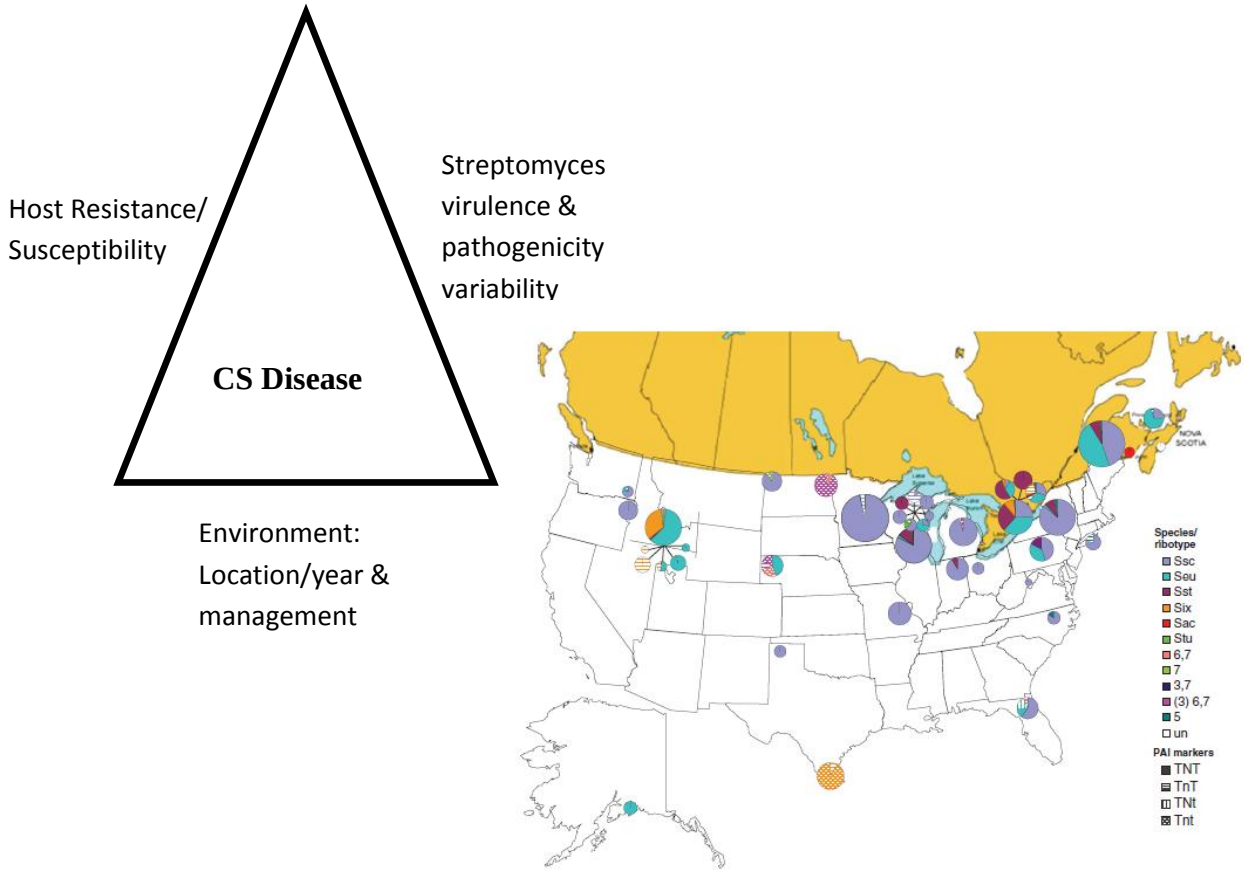



Fig. 1. Map of the putative pathogenic *Streptomyces* species (Wanner, 2009): Contribution to the understanding of the CS disease triangle in North America.

Wanner (2009) provided one of the most important contributions to the understanding of the genetic variability of *Streptomyces* spp. An extensive survey which included a large number of samples from different regions of North America was conducted. Putative pathogenic species were revealed by the presence of the *Thaxtomin* txtAB gene; this gene is 100% correlated with pathogenecity. A number of putatively pathogenic species, classified by their ribosomal type were found in different North American regions (Wanner, 2009). These include: *S. scabies*, *S. europascabiei*, *S. stelliscabiei*, *S. sp. Idaho X*, *S. acidiscabies* and *S. turgidiscabies*. This knowledge is of great importance to plant breeders to understand possible genotypic x location interactions that are really due to pathogen/host interactions. This knowledge helps better predict

the performance of potato varieties developed by breeding programs in one region that may be used in a different region.

**Breeding for CS Resistance in Wisconsin:**

**In 2006 we initiated a project**, to evaluate Wisconsin potato breeding lines under high common scab pressure. Collaborators in this project are Charlie Higgins at Heartland Farms and Eugenia Banks from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)/ University of Guelph. We wanted to know how good was the prediction of common scab in future years given the previous year's performance. The main objective is to improve selection for CS in Wisconsin. We also have established a permanent field for CS evaluation at Hancock WI.

**Materials and Methods:**

- Field with high scab potential were used in each case
- Permanent Field at Alliston, Canada.
- Permanent Field at the Hancock WI Agricultural Research Station
- Field with notorious CS history at Heartland Farms, Hancock, WI and Rhinelander WI.
- 160 (Year 4 and older) clones including checks tested between 2006-09
- Blocks within replication design 3 reps, plot size: 4-5 hills.
- 1-5 Common Scab Severity Index: 1= no symptom to 5 deep pits covering 60% or more of the tubers.
- Incidence= % tubers affected
- Tuber Area in %
- Severity (each tuber)= 1-5,

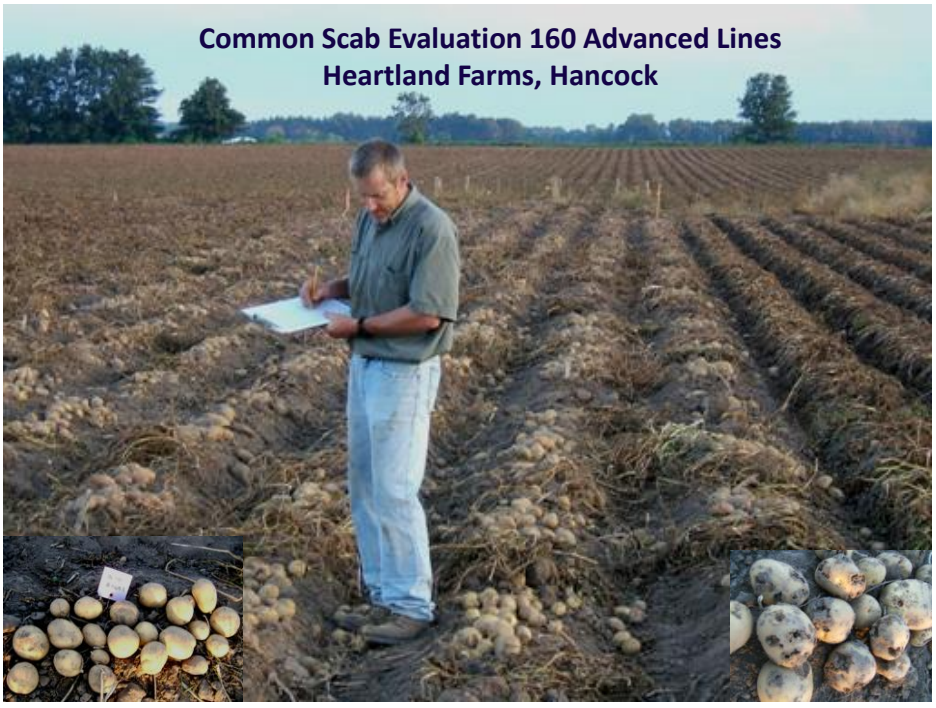



**Fig. 2. Evaluation of breeding clones at Heartland Farms, WI (B. Bowen in photo)**

**Experimental Techniques and Disease Predictability: Lessons from field based CS evaluations**

- ***Evaluating CS using regular replicated yield trials does not provide efficient means of selecting for CS resistance due to location and year variability:*** Yield trials are usually located in field with unknown or low CS incidence, yielding low heritability for CS and therefore, low predictability of performance and reduced selection efficiency.

Table 2. Comparison of efficiency to detect differences on scab performance of clones evaluated in yield trials in Hancock WI vs. permanent field under high disease incidence and severity at Alliston, ON.

| Clone | Hancock Yield Trial 2010 (1-9 Scale) 1 = 100% pitted 9= No scab | Hancock Yield Trial 2011 (1-9 Scale) 1 = 100% pitted 9= No scab | Alliston Scab Trial 2010 (1-5 scale) 1= No scab 5= 100% pitted | Alliston Scab Trial 2011 (1-5 scale) 1= No scab 5= 100% pitted |
|---|---|---|---|---|
| Atlantic | 8.6 | 8.9 | 4.5 | 3.1 |
| MegaChip | 8.7 | 8.9 | 3.4 | 2.7 |
| Pike | 8.7 | 8.9 | 2.2 | 2.4 |
| Snowden | 7.6 | 8.9 | 3.6 | 4.5 |
| W2133-1 | 8.5 | 8.9 | 3.2 | 2.5 |
| W2324-1 | 7.0 | 8.1 | 4.5 | 3.7 |
| W2717-5 | 8.6 | 8.6 | | 3.3 |
| W5015-5 | | 8.9 | | 3.0 |
| W6803-3 | | 8.9 | 2.5 | 2.4 |
| W8436-1 | 8.7 | 8.9 | 3.7 | 2.6 |
| W8603-1 | | 8.9 | 2.8 | 2.7 |
| W8615-5 | | 8.9 | 2.5 | 3.0 |
| W8639-3 | | 8.9 | **1.6** | 2.2 |
| W8819-10 | 8.7 | 8.9 | 2.8 | 2.4 |
| W8819-9 | 8.7 | 8.9 | **2.1** | 2.4 |
| W8822-1Y | 8.7 | 8.8 | 2.2 | **2.0** |
| W8822-2Y | 8.7 | 8.9 | **1.6** | 2.2 |
| W8822-3Y | 8.3 | 8.9 | 2.9 | 2.2 |
| W8832-1Y | 8.1 | 8.7 | 3.9 | 3.7 |
| W8835-1 | 8.5 | 8.9 | 2.9 | 2.6 |
| W8848-3 | 8.7 | 8.9 | **1.5** | **2.0** |
| W8867-5 | 8.7 | 8.9 | 2.3 | 2.9 |
| W8875-2 | 8.7 | 8.9 | **1.9** | 2.6 |
| W8877-3Y | 8.0 | 8.9 | 4.3 | 2.8 |
| W8882-2 | 8.5 | 8.9 | | 3.6 |
| W9667-1 | 8.4 | 8.9 | 3.9 | 4.1 |
| W9705-4 | 8.4 | 8.4 | 4.2 | 3.7 |
| W9706-1 | 8.4 | 7.8 | 4.0 | 4.1 |
| White Pearl | 8.2 | 8.4 | | 2.4 |
| Dark Red Norland | 8.2 | 8.6 | **2.0** | **2.0** |

Note: darker cell shading and underlined values indicate statistically significant, worse than average CS performance, lighter cell shading and boldfaced values indicate better than average CS performance

Table 2. (cont'd) Comparison of efficiency to detect differences on scab performance of clones evaluated in yield trials in Hancock WI vs. permanent field under high disease incidence and severity at Alliston, ON.

| Clone | Hancock Yield Trial 2010 (1-9 Scale) 1 = 100% pitted 9= No scab | Hancock Yield Trial 2011 (1-9 Scale) 1 = 100% pitted 9= No scab | Alliston Scab Trial 2010 (1-5 scale) 1= No scab 5= 100% pitted | Alliston Scab Trial 2011 (1-5 scale) 1= No scab 5= 100% pitted |
|---|---|---|---|---|
| W8370-2R | 8.5 | 8.9 | 3.5 | 2.9 |
| W8610-1R | | 8.7 | **1.8** | **2.0** |
| W8784-2R | 8.2 | 8.7 | 4.5 | 3.3 |
| W8886-3R | 8.5 | 8.9 | 2.7 | 2.5 |
| W8890-1R | | 8.9 | 3.2 | 2.2 |
| W8893-1R | 8.5 | 8.9 | 2.3 | 2.7 |
| W9726-1R | 8.3 | 8.6 | 3.5 | 2.4 |
| W9735-3R | | 8.4 | 3.1 | 2.9 |
| W9960-1R | | 8.9 | 3.5 | 2.7 |
| Bannock | 8.6 | 8.9 | | **2.0** |
| Goldrush | 8.8 | 8.9 | **1.6** | **2.0** |
| RBurbank | 8.8 | 8.9 | 2.7 | 2.4 |
| Rnorkotah | 8.9 | 8.9 | 3.3 | 2.7 |
| W8516-1rus | | 8.9 | **1.8** | 2.7 |
| W8713-3rus | 8.8 | 8.9 | 4.2 | 2.6 |
| W8718-1rus | 8.8 | 8.9 | | **1.8** |
| W8733-1rus | 8.8 | 8.7 | 2.4 | 2.7 |
| W8736-6rus | 8.7 | 8.9 | 3.4 | 2.5 |
| W8743-1rus | 7.7 | 8.0 | 4.2 | 3.3 |
| W8772-1rus | 8.6 | 8.9 | **1.3** | **1.8** |
| W8772-2rus | 8.8 | 8.8 | 2.7 | 3.1 |
| W9404-1rus | 8.8 | 8.9 | 2.6 | 2.4 |
| W9405-1rus | 8.6 | 8.9 | 2.2 | 2.8 |
| W9429-1rus | 8.5 | 8.9 | 2.9 | 2.8 |
| W9433-1rus | 8.5 | 8.9 | 3.1 | 2.8 |
| W9604-1Yrus | 8.3 | 8.7 | 4.6 | 4.5 |

Note: darker cell shading and underlined values indicate statistically significant, worse than average CS performance, lighter cell shading and boldfaced values indicate better than average CS performance

- ***The use of dedicated, permanent fields combined with experimental designs that account and remove spatial variation from the estimates of clone performance provide for efficient selection***: this is possible due to increased heritability and consequently increased predictability of the true resistance level of clones from one year to the next.

Results from Table 2 clearly indicate that based on the results of CS performance from the Hancock 2010 and 2011 yield trial, no progress in selecting for CS resistance or against CS susceptibility would have been achieved. Progress in detecting genetic variation for CS was a lot higher from dedicated CS common scab trials. In both cases experiments had three replicates and the only difference is that the CS trials at Alliston had 4 hills/plot whereas the Hancock yield trials had 20 hills/plot. It should be considered that clones with superior performance in permanent field plot may never be challenged with that level of inoculum in potato fields, so many clones with moderate resistance in those trials may perform as resistant in grower's fields.

***Field with mild to severe CS disease severity levels, combined with the use of appropriate standard varieties of known CS performance are best to properly identify CS resistance levels***.

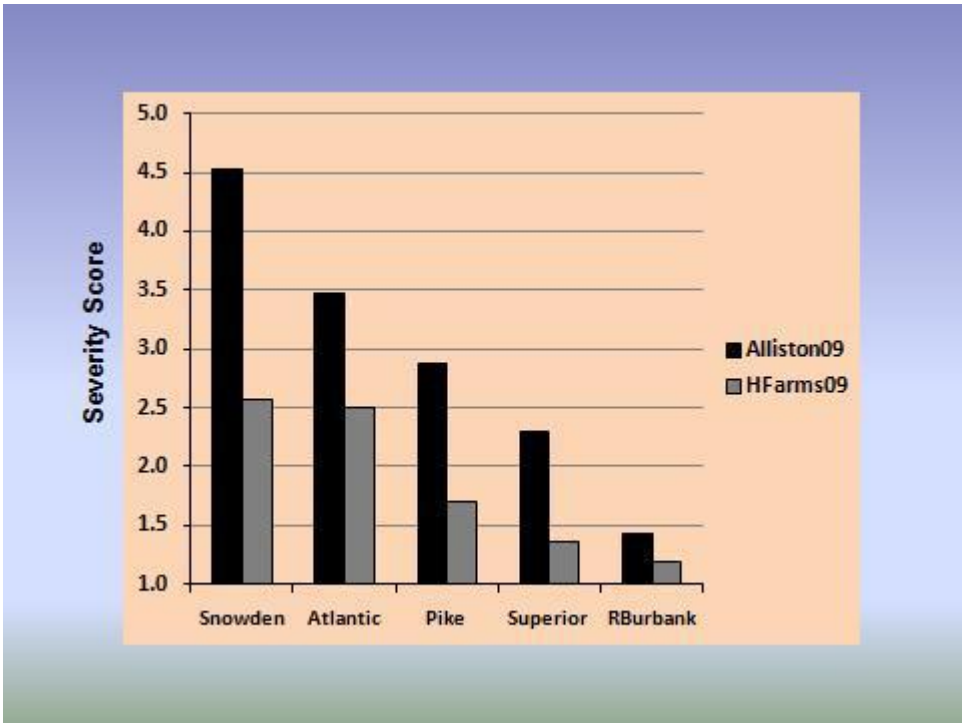


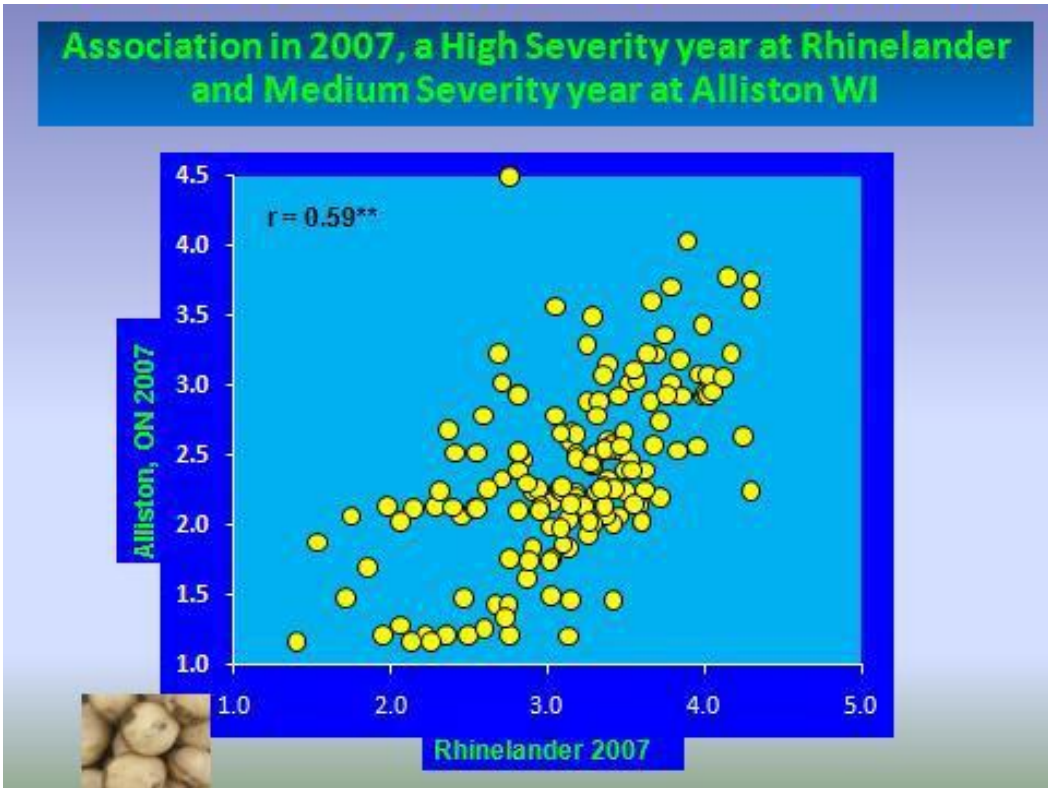

Fig. 3. Performance of standard cultivars used as checks for CS trials in 2009 in dedicated CS trials at Alliston, ON and Heartland Farms.

One of the most important elements of proper experimental design is the use of checks of known performance. The breeding program consistently uses a set of standard cultivars such as Snowden (susceptible), Atlantic (susceptible), Pike (resistant), Superior (resistant), Russet Burbank (resistant) and Yukon Gold (susceptible) to understand the level of incidence and severity present in experiments. These standards also help understand the level of resistance of the clones tested. Fig. 3 indicates consistent performance of five of these standard cultivars over two years of evaluation. Normally, varieties will be compared to these cultivars to determine their resistance level.

**Predictability of Common Scab Performance**

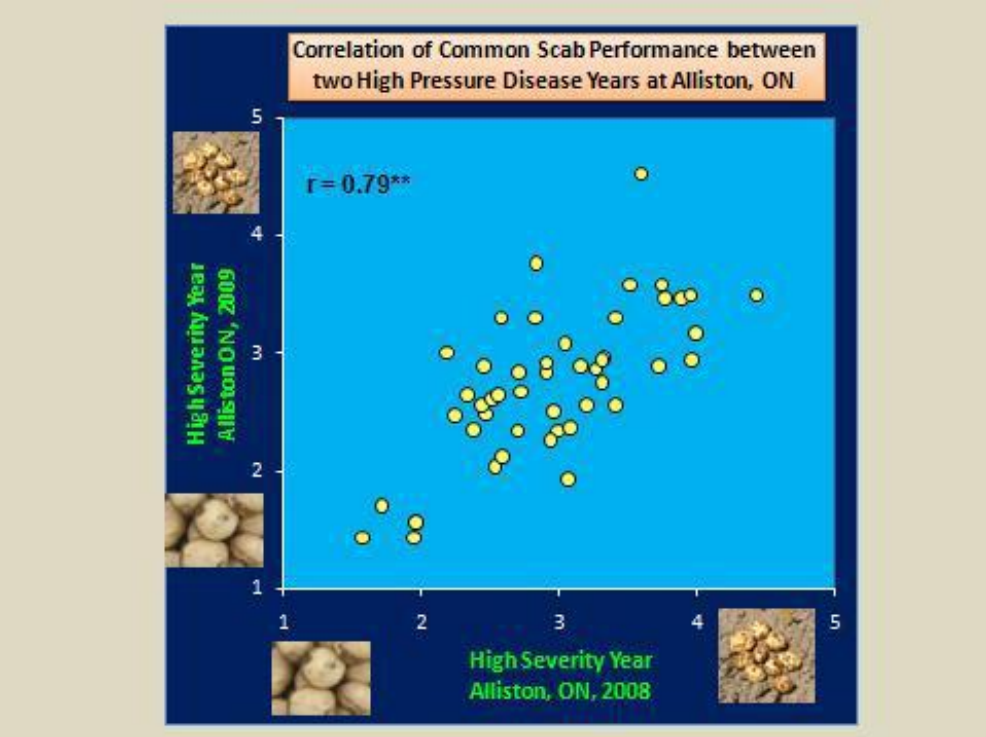
The use of permanent field at Alliston, ON, Hancock Agricultural Research Station and identified field with a history of high incidence and severity of CS has helped the UW breeding problem use common scab as a selection criterion. A number of new elite clones with CS resistance are now being considered for release. The consistency of the results through years of evaluation can be observed by the high association of the CS performance in earlier and later years of selection as noted in Table 2 for the 2010 and 2011 dataset and from Figs. 4a and 4b for the 2007-2009 datasets.

## Fig. 4a




The consistency of the ranking of varieties across locations, within a year (Fig. 4a); and across years within a location (Fig. 4b) has allowed the WI breeding program to efficiently assess the level of resistance of breeding clones. This information is heavily weighted as selection criterion to advance breeding lines.

## Fig. 4b




**Released Wisconsin varieties with common scab resistance:**

**MegaChip:**
Resistance is good, in some years, especially at Alliston, Ontario under high disease severity MegaChip resistance is lowered and CS symptoms can be observed. As a note, no variety seems to be immune to CS.

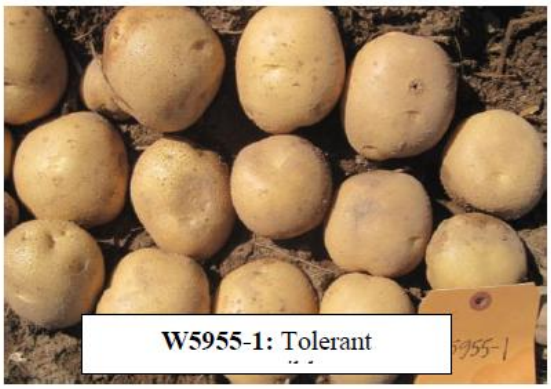
**Freedom Russet:**
Consistent resistance in all years and location tested

**Millennium Russet:**
Consistent resistance in all years and location tested

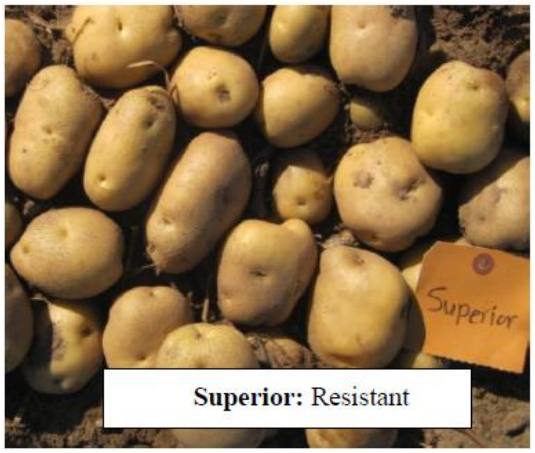
**Several advanced and elite clones with common scab resistance with potential for release as varieties** include W5955-1, W6483-5rus, W6609-3, W6703-1Y, W6703-5Y, W8152-1rus, and W8722-1rus,.

**Field performance of common scab of clones tested. Heartland Farms, Hancock 2011**


**Snowden:** Highly susceptible

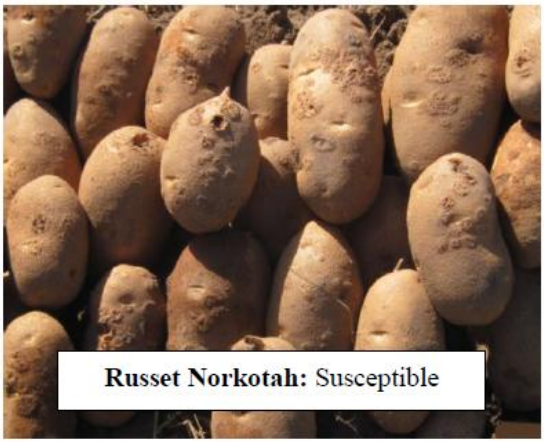


**W5955-1:** Tolerant




**Superior:** Resistant

**W6483-5:** Highly resistant



**Russet Norkotah:** Susceptible

**W8722-1rus:** Tolerant

Most susceptible clones looked like this . . .

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