Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

A Research Progress Report Submitted to

The Potato Growers of Alberta
6008 – 46th Avenue
Taber, Alberta T1G 2P1

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Prepared by

Ron Howard, Plant Pathology Research Scientist
Sharon Lisowski, Senior Plant Pathology Technologist
Alberta Agriculture and Food
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta T1R 1E6

Introduction

Silver scurf (SS), caused by the fungus *Helminthosporium solani*, emerged as an economically important disease of tablestock and processing potatoes in Canada in the 1990s. Prior to that, it had mostly been considered a minor problem. SS causes metallic, silvery patches on tuber skins, which can reduce their suitability for direct sales and processing. Seed growers are also concerned about SS because it can be easily spread on seed tubers. Control recommendations for SS centre mainly on fungicides and cultural practices. Holley and Kawchuk (1993, 1996) demonstrated the widespread ocurrence of strains of *H. solani* resistant to the commonly used fungicide Mertect (thiabendazole) in Alberta. Mertect was widely used as a post-harvest treatment on potato tubers to prevent various storage diseases. Similar findings were reported from the U.S.A. and Europe, and prompted researchers to look at alternative products, e.g. imazilil, prochloraz, propiconazole, fludioxonil, L-carvone, and organic and inorganic salts. Several of these products have looked promising in research trials elsewhere, but few of them have been tested in Alberta. At present, three seed treatments (Senator PSPT, Maxim PSP and Maxim MZ) and two post-harvest fungicides (Mertect SC and StorOx) are registered in Canada for controlling SS. Despite the availability of these products, SS remains a widespread and serious problem. The inability of currently available products to control SS may be due to several factors, e.g. the development of resistant strains of *H. solani*, chemical dosages that are too low to be effective, improper application techniques to seed pieces or tubers in storage, or poor residual chemical activity. The possibility also exists that SS-like symptoms on tubers may be caused by another fungus, *Colletotrichum coccodes*, the black dot (BD) pathogen. BD can cause symptoms on tubers that are easily confused with SS, and the two diseases often occur together in the same fields. BD may not respond to fungicide treatments in the same way that SS does and vice versa.

Project Objectives

1. Surveys - Collect tubers of various varieties of seed, table and processing potatoes showing SS-like symptoms from fields and storages across Alberta to determine whether *H. solani* or *C. coccodes* is the primary cause.
2. Diagnostic Methods - Compare agar plate and molecular techniques for the isolation and characterization of *H. solani* and *C. coccodes* isolates to determine their speed, accuracy and cost.
3. Fungicide Performance - Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of *H. solani* present in Alberta fields and storages.
4. New Product Development - Determine the efficacy of promising new chemical treatments (conventional and reduced risk) in replicated trials in the lab, field and storage.
5. Technology Transfer - Use the information generated in this study to improve the techniques for managing SS, thereby reducing yield and quality losses for growers and processors.

Trials Conducted in 2006-07

1. Disease Surveys

No formal disease surveys were carried out in 2006; however, several samples of plants and tubers with symptoms of silver scurf and black dot were randomly collected from fields and storages. Isolates of the causal agents were obtained in the laboratory and stored for later use in developing diagnostic testing procedures and for testing their sensitivity to fungicides *in vitro*.

Organized surveys will be conducted in fields and storages in 2007-08.

2. Diagnostic Methods

The development of new diagnostic testing methods for silver scurf will be initiated in 2007-08.

3. Disease Management Trials at CDC South, Brooks

Efficacy of Nine Seed Treatments in a Field Trial

Nine different fungicide treatments were compared to each other and to an untreated check in a replicated trial at the Crop Diversification Centre South (CDCS), Brooks, AB in 2006 (Table 1). Russet Norkotah seed potatoes, which were naturally infested with the silver scurf pathogen (*Helminthosporium solani*), were obtained from Sunnycrest Seed Potatoes Inc., Lacombe, AB. The seed was planted in June 2006 in a field plot at CDC South, Brooks. The survival of silver scurf pathogen on both unplanted and planted, and treated and untreated, seed was evaluated. The survival trial will be repeated on tubers harvested from this trial in the laboratory in 2007. In March 2007, untreated tubers from the guard rows will receive fungicide treatments to assess whether they can control silver scurf in storage.

A randomized complete block (RCB) plot plan was prepared for this trial using the Agricultural Research Manager Version 7 computer software program (ARM 7). The experiment had four replications and ten treatments. Data collection sheets, plot plans and a treatment list were printed for future use. A field map was also designed using the MS Excel program, which consisted of a detailed the plot plan. The plan specified a 3-m spacing between replications, 8-m row lengths, 0.9-m spacing between rows, and 30.5-cm between seed-pieces within rows. In each replicate, there were two treatments per eight rows, with a guard row on either side of the block (10 rows; total block width = 9-m). A 3.2-m spacing was allowed between each block to allow for in-season pesticide applications.

Hand-cut Russet Norkotah seed was treated with seed piece fungicides as per Table 1. The seed was warmed prior to cutting to promote early stage sprout development. Treated seed pieces were placed into labeled paper bags, each containing 27 pieces. In addition to the four bags of seed prepared for each subplot (16 bags/replicate), four extra bags per treatment were also filled with treated seed pieces for later experiments aimed at recovering *H. solani* from the pieces. Seed treatments were applied as per the manufacturers' label instructions. In-furrow treatments were applied at planting. Treatments 1 (Maxim MZ PSP), 2 (Maxim MZ PSP + Quadris) and 3 (Maxim PSP) were applied within two-hours after cutting. Treatments 4 (Senator PSPT) and 7 (Captan 10% DU) were applied within half a day after cutting. Treatments 5 (Tuberseal) and 6 (Polyram 16D) were applied a few days after cutting. Treatment 9 (Heads-Up Plant Protectant) was prepared as a 1-L solution and each batch of 27 seed pieces was dipped in this solution to insure complete coverage. The tubers were left to dry in tote bins overnight and then were bagged the next day. Treatment 8 (AgGrand in-furrow and foliar spray), Treatment 10 (untreated check), and seed pieces for all guard rows were left in the paper bags and were not treated. The bags of seed were held in a controlled environment storage room until planting.

The trial was planted on June 1 and 2 using a double-row, three-point hitch potato planter for treatments 1, 3-7, 9 and 10, or by hand for treatments 2 and 8. The furrows for the latter two treatments were opened using a double-shank corrugator and the in-furrow treatments were applied to the open row using a CO_2-propelled hand sprayer. The seed pieces in these furrows

were hand-planted at a spacing of 30-cm and potato hiller was used to cover them. The trial was managed using conventional production practices for the remainder of the growing season.

Interim samples of seed pieces were taken from the outer rows of each subplot for disease observations. Plant emergence data were taken from all four rows in each subplot on July 4. The mean percent emergence was calculated for each subplot and recorded on a MS Excel spreadsheet. The Applied Research Manager Program Release 7 (ARM 7) was used to analyze these data (Table 2).

During the first week in August, symptoms of verticillium wilt were noticed in the plot, so visual disease ratings of the plant canopies were done on both August 10 and 21. The percentage of wilted plants per subplot was determined. Data for wilt incidence (DI %) were transformed and subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$) (Table 3).

Treatment 8, AgGrand, was also applied to the foliage on both July 18 and August 18 with a backpack sprayer using 1200-mL of solution per subplot. The entire experiment was top-killed at maturity with Reglone on September 6, and a single-row harvester was used to dig the potatoes in the two middle rows of each subplot on September 27. All of the harvested tubers were bagged by hand. Potatoes from guard rows were also dug and retained for future storage experiments.

The harvested tubers were gradually suberized in storage, with the final environmental conditions set at 8°C and 95% relative humidity. The tubers were weighed and graded on November 22-23 to obtain total and marketable yields. Total yields were the weights (kg) of all tubers harvested per subplot, whereas marketable weights did not include smalls, deformed tubers and culls. Tubers with a diameter of a least 1⅞" and at least 2" long with no growth cracks or extensive knobbiness (deformed) and not rotted or severely sliced (culls) were considered to be marketable. Yield data were summarized and analyzed using ARM 7. Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$).

Assessing the Survival of Helminthosporium solani on Unplanted Seed
On June 12, two weeks after fungicide treatments, ten seed pieces from the four spare bags of unplanted, treated and untreated check seed /subplot were placed into two moist chambers, after first being washed free of the adhering seed piece treatments. The bags were then placed into a storage room set at 15°C and 90% RH until June 21, when they were examined microscopically for the presence of *H. solani* conidiophores and conidia on the skin. Disease incidence (DI%) and disease severity (DS) ratings were taken. DS was rated on each tuber using a 0-3 point scale, where 0 = no colonization by *H. solani*, 1 = slight colonization (<10% tuber surface covered), 2 = 10-30% of surface colonized, and 3 = ≥30% colonized. These data were entered into an Excel spreadsheet where the average DS values for each subplot were calculated using the formula:

$$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3)]/N_t$$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, and N_t = total number of tubers examined per subplot. DI was then calculated

from the DS ratings as the percentage of tubers colonized by *H. solani*. The tubers were re-examined on July 12 and rated using the same criteria as before, and all results were recorded on a spreadsheet. This procedure was repeated after ca. five weeks post-treatment (June 28). There were insufficient tubers to do a 6-week sampling. All data were summarized and statistical analyses were performed with the ARM 7 program.

Assessing the Survival of Helminthosporium solani on Planted Seed
On June 27 and July 14, at 4 and 6 weeks after planting, respectively, ten seed pieces were dug up from the two outside rows of each subplot, bagged and taken into the laboratory where they were washed free of adhering soil and fungicide. The washed pieces were placed into high humidity plastic bags (5 pieces/bag) and the bags were then placed into a storage room set at 15°C and 90% RH. The seed pieces were rated for growth of *H. solani* at 10 and 21-day intervals as described above for the unplanted seed. The 4-week samples were rated on July 10 and 19, and the 6-week samples on Aug. 4 only. All data were summarized and analyzed with the ARM 7 program. Duncan's Multiple Range Test was used to compare means where F-tests were statistically significant ($P \leq 0.05$).

Silver Scurf Ratings on Tubers from the Replicated Field Trial at CDC South
During grading, a 100-tuber sample from each subplot was removed and bagged for initial silver scurf evaluations. A 50-tuber subsample was randomly selected from each of these bags and visually examined for both silver scurf and black scurf DI and DS levels. Each tuber was rated on a 0-5 point scale, where 0 = no colonization by *H. solani*; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = very heavy colonization (>50% tuber surface covered). These data were recorded onto a MS Excel spreadsheet, where the average DS for each subplot was calculated by using the following formula:

$$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4= no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined per subplot.

DI, the percentage of tubers with black scurf or silver scurf infection, was also calculated for each subplot. Data for all ratings were summarized and analyzed using the ARM 7 program.

A 10-tuber subsample was removed from the 100-tuber sample described above and placed into two moist chambers, which were held in a storage room at room temperature, on December 1. An initial evaluation for silver scurf only was done on December 21, using the same rating criteria described above for DS and DI. After the tubers were rated, they were placed back into storage and received a second silver scurf evaluation after 4 weeks of incubation (January 23, 2007). Data for all ratings were summarized and analyzed as per the 50-tuber sample described above. Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$) for all disease rating data.

Post-harvest Quadris Application

On January 11, a 400-tuber subsample was removed from the guard row bags, which had been placed into storage after harvest, and the potatoes were divided equally into four replications for a post-harvest application of Quadris fungicide. The rate used was 19.55 mL of Quadris + 2 L water /tonne of potatoes and this mixture was applied with a 600-mL spray bottle. After drying, the tubers were placed into a storage room, where they will be evaluated for silver scurf DI and DS in late March, 2007.

Post-harvest Fungicide Evaluations (to be completed)
StorOx (hydrogen dioxide), Mertect (thiabendazole) and several unregistered fungicides will be applied to silver scurf-infected tubers harvested from the guard rows of the 2006 field trial to compare their efficacy against silver scurf in storage. DI and DS data will be taken over a three-month period and used to determine the relative performance of these products.

Survival of Helminthosporium solani on Fungicide-treated Seed Pieces (to be completed)
Seed piece treatments will be applied onto naturally infested silver scurf tubers from the harvested guard rows of the 2006 field trial described previously. Half of the treated tubers will be planted in totes of field soil in a greenhouse and allowed to grow for two weeks. A portion of these seed pieces will then be dug up and washed free of the adhering soil and seed treatments, while others will be left unwashed. The washed and unwashed seed pieces will be placed in a moist chamber for 7-10 days and examined for *H. solani*. This protocol will be repeated at a 4-week interval. The other half of the treated tubers will not be planted, but instead will be placed between moistened burlap sacks on the floor in a storage room set at 15°C. At 2- and 4-week intervals, tuber samples will be removed and some will be washed free of the adhering seed treatments, while others will not be washed. The seed pieces will be placed in a plastic bag moist chamber for 7-10 days and examined microscopically for the presence of conidiophores and conidia of *H. solani* on the skin.

Data Summaries
Data collected from the experiments described above are summarized in Tables 2-6.
Table 2 – Percentage of plants that had emerged from the field trial at CDCS by July 4 and the total and marketable yields after harvest on September 27.
Table 3 – Verticillium wilt evaluations (DI %) on plants in the field trial at CDCS on August 9 and 21.
Table 4 – DI and DS ratings for silver scurf on unplanted treated seed pieces examined at 2-week (June 12) and 5-week (June 28) intervals. For June 12, the potatoes were first rated on June 21 and again on July 12. The 5-week sampling was rated only on July 26.
Table 5 – DI and DS ratings for silver scurf on planted treated seed pieces where the pieces were dug up at 4-week (June 27) and 6-week (July 14) intervals after planting. The 4-week samples were rated on July 10 and July 25, while the 6-week samples were evaluated only on August 4.
Table 6 – Post-harvest DI and DS ratings for silver scurf on harvested tubers. A 50-tuber sample from each subplot was rated directly out of storage without a moist chamber treatment. The same tubers were also rated for black scurf on November 30. A 10-tuber sample from each subplot was placed in moist chambers and rated for silver scurf on December 21, 2006 and January 23, 2007.

Interim Results and Discussion
Efficacy of Nine Seed Treatments in a Field Trial at CDC South

There was abundant rainfall at Brooks in June 2006, which helped to establish the plot. During July and August, however, there was very little precipitation, so irrigation was necessary. The experiment was watered only when the soil moisture levels became depleted. Emergence ratings taken on July 4 showed that subplots treated with AgGrand and Maxim MZ PSP + Quadris (treatments 2 and 8) had significantly ($P \leq 0.05$) higher stand counts than the untreated check (treatment 9) (Table 2). The next best stands occurred in treatments 5, 6 and 7 (Tuberseal, Polyram 16D and Captan 10% DU, respectively); however, these treatments were not significantly different from the check. Total and marketable yield data failed to show any statistically significant ($P \leq 0.05$) differences between the ten treatments. Maxim MZ PSP + Quadris (treatment 2) had the highest marketable yield amongst treatments, with fewer culls, smalls and deformed tubers. The other treatments had 5-9 kg fewer tubers per plot compared to treatment 2. All of the chemical treatments had more marketable tubers than the check treatment.

Verticillium wilt occurred at moderately high levels in this trial (Table 3). Infection may have resulted from soil-borne inoculum of *Verticillium albo-atrum* and *V. dahliae* carried over from potato trials done in this field at various times over the previous 20 years. DI ratings taken at 2-week intervals (August 9 and 21) failed to show any significant ($P \leq 0.05$) differences between treatments. Subplots grown from seed treated with Maxim MZ PSP + Quadris (treatment 2) had about one-half the amount of wilt as the untreated check. All of the chemical treatments had less wilt than the check on both of the dates that disease assessments were made.

Assessing the Survival of Helminthosporium solani on Unplanted Seed

Fungicide efficacy evaluations for the unplanted seed pieces revealed statistically significant ($P \leq 0.05$) differences between treatments, except for the DI readings taken on July 26, when all the tubers were found to be diseased (Table 4). The moist chambers set up on June 12 and examined on June 21 showed that treatments 3 (Maxim PSP) and 8 (AgGrand) had DS and DI readings that were not significantly different from the untreated check. By contrast, significantly lower DS and DI readings were seen in treatments 1, 2, 4, 5 and 6 (Maxim MZ PSP, Maxim MZ PSP + Quadris, Senator PSPT, Tuberseal, and Polyram 16D, respectively) compared to the check. The lowest DS and DI ratings were seen in treatment 5 (Tuberseal). When these same tubers were placed back into moist chambers and re-examined on July 12, treatment 10 (untreated check) had higher DS ratings than all nine of the chemical treatments. Regrettably, it was not possible to compare the DS means statistically as the Bartlett's Test for homogeneity of variance was significant ($P \leq 0.05$). DI ratings were significantly lower than the check in only two treatments, i.e. nos. 4 (Senator PSPT) and 5 (Tuberseal). Once again, Tuberseal had the lowest DS and DI ratings amongst the nine chemical treatments. For the moist chambers prepared on June 28 and rated on July 26, the untreated check still had the highest DS rating (2.75), which was significantly greater than all nine of the chemical treatments. Polyram 16D (treatment 6) had the lowest DS rating amongst the nine chemical treatments, but it was not significantly different from treatments 2, 5 and 8 (Maxim PSP + Quadris, Tuberseal and AgGrand, respectively). All of the tubers examined on July 26 had a DI of 100%. Under the conditions of this trial, none of the seed treatments tested was able to eradicate tuber-borne silver scurf infection; however, several were able to significantly reduce infection levels compared to the untreated check.

Assessing the Survival of Helminthosporium solani on Planted Seed

The analysis of variance for the DS and DI ratings of seed pieces dug on June 27 and examined on July 10 was statistically significant ($P \leq 0.05$), as was the ANOVA for DS ratings taken on

July 25 (Table 5). Unfortunately, however, it was not possible to compare the DS means for July 10 statistically as the Bartlett's Test for homogeneity of variance was significant ($P \leq 0.05$). On July 10, DS ratings for the nine chemical treatments were all lower that the untreated check. The lowest DS values were seen on the Tuberseal and Polyram 16D (treatments 5 and 6) treated seed pieces, followed by Maxim MZ PSP + Quadris and AgGrand (treatments 2 and 8). Tuberseal (treatment 5) had the lowest DI rating on July 10 and was the only one of the nine chemical treatments that was significantly different from the check. The were no significant differences between treatments for DI ratings of the seed pieces examined on July 25 or for DS and DI ratings for seed pieces dug on July 4 and examined on August 4. By July 25, DI ratings were extremely high (97-100%) in all treatments. For the seed pieces examined on August 4, the lowest DS and DI ratings were seen in treatments 2 (Maxim MZ + Quadris) and 3 (Maxim PSP), while the highest DS and DI ratings occurred in treatments 7 (Captan 10% DU) and 9 (Heads Up Plant Protectant). Under the conditions of this trial, none of the seed treatments tested was able to eradicate tuber-borne silver scurf infection, although several brought about a small reduction in DS and/or DI levels.

Silver Scurf Ratings on Harvested Tubers from the Replicated Field Trial at CDC South
As the silver scurf evaluations were being done on the harvested tubers on November 30, it was noted that black scurf was much more prevalent; therefore, it was decided to rate the DI and DS for this disease as well. There were no significant ($P \leq 0.05$) differences in DS or DI between treatments for either silver scurf or black scurf (Table 6). Disease levels for silver scurf were extremely low for the November 30 ratings, whereas levels were moderately high for black scurf. Treatments 3 and 4 (Maxim PSP and Senator PSPT) had even higher DS and DI ratings for black scurf than the untreated check did. Treatment 2 **(**Maxim MZ PSP + Quadris) had much lower DS and DI levels for black scurf than the other eight chemical treatments. When the 10-tuber subsamples were examined for silver scurf on December 21, 2006 and January 23, 2007, disease levels had increased substantially over those seen in November, and statistically significant differences in DS and DI were noted between treatments. On December 21, five of the nine chemical treatments had DS and DI ratings that were not significantly different from the check. In contrast, the other four treatments, i.e. Polyram 16D, Captan 10% DU, Maxim MZ PSP, and Maxim MZ PSP + Quadris (treatments 6, 7, 1 and 2, respectively), had significantly lower DS and DI ratings than the check. By January 23, only treatment 6 (Polyram 16D) still had significantly lower DS and DI levels compared to the check.

Conclusions
None of the seed treatments evaluated in these trials succeeded in eradicating *Helminthosporium solani* from the skin of infected seed pieces, although several significantly reduced the incidence and/or severity of silver scurf compared to an untreated check and/or some of the other chemical treatments. On unplanted treated seed, Maxim MZ PSP, Maxim MZ PSP + Quadris, Senator PSPT, Tuberseal and Polyram 16D were generally did the best job of suppressing *H. solani* growth and sporulation on the skin. On planted seed, Tuberseal and Maxim MZ PSP + Quadris had the greatest impact on reducing the incidence and severity of silver scurf. On tubers harvested from the field trial at CDCS, Maxim MX PSP, Maxim MZ PSP + Quadris, Polyram 16D and Captan 10% DU had the lowest levels of silver scurf after about five months of refrigerated storage. Maxim MZ PSP + Quadris also seemed to retard the development of verticillium wilt on plants in the field and on black scurf on tubers in storage. A second season of evaluation of these products will be undertaken in 2007 to confirm the results obtained in 2006.

4. Disease Management Trials at CDC North, Edmonton

A replicated field trial originally designed to test the efficacy of seed- and soil-applied chemical treatments against powdery scab, caused by the fungus *Spongospora subterranea* ssp. *subterranea*, was conducted by Mrs. Patricia McAllister and staff at the Crop Diversification Centre North, Edmonton, during the 2006 growing season. At harvest, it was noted that there was a heavy silver scurf infection on the tubers, so it was decided to critically assess the incidence and severity of SS on these tubers. There were seven chemical treatments and one untreated check in this trial (Table 7).

Sixty-four small bags of potatoes (two bags per subplot) were shipped to the CDCS on January 9, 2007. Upon receipt, the potatoes were stored at 8°C and 93% RH. On January 15, an initial evaluation of the untreated control showed very little evidence of growth and/or sporulation of *Helminthosporium solani*, so plastic bag moist chambers containing a 10-tuber subsample for each treatment in every replicate were set up on January 17. The moist chambers were kept at room temperature in a dark storage room for two weeks to promote sporulation. On January 31, the potatoes were examined for the presence the pathogen by using a magnification lamp and a microscope. A sample of tubers from each subplot was rated for DI (% tubers infected) and DS (0–5 scale). These ratings were repeated on February 14 after four weeks of incubation. All data were summarized and a statistical analysis was performed with the ARM 7 program.

None of the products evaluated effectively controlled silver scurf infection on the harvested tubers (Table 8). DS and DI ratings were relatively high on both examination dates. There were no statistically significant ($P \leq 0.05$) differences between treatments for DS and DI on either date. The Tuberseal, Ranman 400 SC and Blinix treatments consistently had amongst the lowest disease ratings on both dates, with Tuberseal being the best-performing product overall.

Project Cooperators

The following individuals, organizations and companies provided technical assistance and/or financial/in-kind contributions

- BASF Canada Inc.
- Engage Agro Corporation
- Heads Up Plant Protectants Inc.
- ISK Biosciences Corp.
- Jeneil Biosurfactant Co.
- Norac Concepts Inc.
- Potato Growers of Alberta
- Sunnycrest Seed Farms and Parkland Seed Potatoes, Lacombe, AB
- Syngenta Crop Protection Canada Inc.

Project Team Members

- Dr. Ron Howard, Sharon Lisowski, Stacie Mobbs, Brenda Scherger, Carol Pugh, Tetyana Matviyenko, Dustin Burke and Dr. Michael Harding, Alberta Agriculture and Food, Crop Diversification Centre South, Brooks
- Dr. Larry Kawchuk, Agriculture and Agri-Food Canada, Research Centre, Lethbridge
- Mrs. Tricia McAllister, Alberta Agriculture and Food, Crop Diversification Centre North, Edmonton

Table 1. Treatment list for silver scurf fungicide trials at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment No.	**Product Name**	**Application Rate/100 kg seed**
1	Maxim MZ PSP *Syngenta Crop Protection Canada Inc.*	500g
2	Maxim MZ PSP + Quadris *Syngenta Crop Protection Canada Inc.*	500 g Maxim + 4 mL Quadris/100 m of row
3	Maxim PSP *Syngenta Crop Protection Canada Inc.*	500 g
4	Senator PSPT *Engage Agro Corporation*	500 g
5	Tuberseal *Norac Concepts Inc.*	500 g
6	Polyram 16D *BASF Canada Inc.*	550 g
7	Captan 10% DU* *ICI Americas Inc.*	780 g
8	AgGrand *Amsoil Inc.*	4.0 L/150 L water/ha + 3.0 L/150 L water/ha
9	Heads-Up Plant Protectant *Heads Up Plant Protectants Inc.*	1 g/L water
10	Untreated check	- -

* Captan 10% DU was made up of 437.5 g of potato /cornstarch + 62.5 g of Captan 80-WP.

Table 2. Mean plant emergence and total and marketable yields of tubers from a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Emergence on July 4 (%)[1]	Total weight of harvested tubers ($kg/14.4m^2$)[2,4]	Marketable weight of harvested tubers ($kg/14.4m^2$)[3,4]
1	90.98 cd *	73.45	56.45
2	97.48 ab	73.46	64.50
3	90.98 cd	71.31	55.96
4	89.35 d	68.63	58.28
5	93.50 bcd	72.50	59.11
6	93.53 bcd	70.59	55.99
7	94.43 bc	71.07	56.50
8	98.83 a	68.18	55.66
9	90.05 d	70.39	58.54
10	91.20 cd	67.76	55.58
ANOVA P-Value	0.0001	0.9958	0.9946
LSD (0.05)	3.727	14.587	13.331
CV (%)	2.76	14.21	15.99

[1]Plant emergence ratings were performed on July 4 and were based on the percentage of plants per subplot that had emerged by this date. Raw data were used for analysis and were significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.
[2]Total yields were the tuber weights (kg/subplot) that were harvested on September 21.
[3]Marketable yields were the tuber weights (kg/subplot) that were harvested on September 21 and did not include deformed, small or cull tubers.
[4]Raw data were used for analysis and were not significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 3. Mean disease incidence (DI) of plants displaying verticillium wilt symptoms on August 9 and 21 in a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	**Wilt DI on Aug. 9 (%)[1]**	**Wilt DI on Aug. 21 (%)[1]**
1	29.53	30.57
2	21.38	23.26
3	13.88	19.58
4	25.28	26.88
5	22.56	25.03
6	25.80	27.73
7	25.77	28.85
8	26.89	30.65
9	24.25	24.25
10	31.54	34.02
ANOVA P-Value	0.6628	0.8472
LSD (0.05)	16.219	16.957
CV (%)	45.28	43.15

[1]DI ratings were based upon the percent of plants per subplot that had wilt symptoms by Aug. 9. Raw data were used for analysis and were not significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.

Table 4. Silver scurf disease severity and disease incidence levels on unplanted potato seed treated with nine fungicide treatments placed into moist chambers on June 12 and 28 in a silver scurf fungicide trial at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Moist chambers set up on June 12				Moist chambers set up June 28	
	Examined June 21*		Examined July 12*		Examined July 26*	
	Tuber DS (0-3)[1,2]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,5]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,2]	Tuber DI (%)[3]
1	0.13 c	12.23 b	1.23	96.19 ab	2.18 b	100.00
2	0.20 c	12.91 b	1.05	96.19 ab	1.80 bcd	100.00
3	2.00 a	100.00 a	2.03	100.00 a	2.13 b	100.00
4	0.33 c	21.61 b	0.75	76.29 bc	1.95 bc	100.00
5	0.13 c	9.44 b	0.65	65.45 c	1.78 bcd	100.00
6	0.30 c	18.76 b	1.10	92.53 ab	1.48 d	100.00
7	1.28 b	90.56 a	1.50	100.00 a	2.10 b	100.00
8	1.73 a	100.00 a	1.95	100.00 a	1.63 cd	100.00
9	1.33 b	96.19 a	1.30	99.35 a	2.20 b	100.00
10	2.05 a	100.00 a	2.45	100.00 a	2.75 a	100.00
ANOVA P-Value	0.0001	0.0001	0.0001	0.0016	0.0001	1.0000
LSD (0.05)[6]	0.380	-	0.323	-	0.376	0.000
CV (%)	27.73	30.25	15.91	15.82	12.98	0.00

[1]Silver scurf disease severity (DS) means per treatment are on a 0-3 point scale, where 0 = no colonization of the tuber surface by *Helminthosporium solani*, 1 = <5% colonization, 2 = 5-30% colonization, and 3 = > 30% colonization.
[2]Raw data were used for analysis and means were significantly different according to a Duncan's Multiple Range Test at $P \leq 0.05$.
[3]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[4]Arcsine-transformed data were used for analysis and means were significantly different according to Duncan's New Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Raw data were used for analysis. Bartlett's Test for homogeneity of variance was significant ($P = 0.05$), so DMRT was not conducted.
[6]Least significant differences were not calculated for transformed data.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 5. Silver scurf disease severity and incidence levels on potato seed that was planted on June 1-2 in a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Dug up from the soil on June 27				Dug up from the soil July 14	
	Examined July 10*		Examined July 25*		Examined August 4	
	Tuber DS (0-3)[1,2]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,5]	Tuber DI (%)[3]	Tuber DS (0-3)[1]	Tuber DI (%)[3]
1	1.73	100.00 a	1.60 e	100.00	1.15	97.50
2	1.35	100.00 a	1.13 f	97.50	0.95	92.50
3	1.55	100.00 a	1.95 cd	100.00	1.00	87.50
4	1.48	99.35 a	1.20 f	100.00	1.03	90.00
5	0.90	91.83 b	1.28 f	100.00	1.20	92.50
6	0.98	99.35 a	1.83 de	100.00	1.10	97.50
7	1.65	100.00 a	1.30 f	100.00	1.15	100.00
8	1.33	100.00 a	2.63 b	100.00	1.23	97.50
9	2.05	100.00 a	2.23 c	100.00	1.28	97.50
10	2.70	100.00 a	3.00 a	100.00	1.18	97.50
ANOVA P-Value	0.0001	0.0407	0.0001	0.4635	0.2875	0.3169
LSD (0.05)[6]	0.367	-	0.278	2.294	0.268	10.670
CV (%)	16.09	7.87	10.58	1.59	16.4	7.74

Subsamples were pulled from the ground at 4 and 6 weeks after planting (June 27 and July 14) and were incubated and examined at various intervals.

[1]Silver scurf disease severity (DS) means are on a 0-3 scale, where 0 = no colonization of the tuber surface by *Helminthosporium solani*, 1 = <5% colonization, 2 = 5-30% colonization, and 3 = > 30% colonization.
[2]Raw data were used for analysis. Bartlett's Test for homogeneity of variance was significant (P = 0.05), so a Duncan's New Multiple Range Test was not conducted.
[3]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[4]Arcsine-transformed data were used for analysis and means were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Raw data were used for analysis and means were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.
[6]Least significant differences were not calculated for transformed data.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 6. Silver scurf and black scurf disease severity and disease incidence levels on stored tubers harvested from a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	50-tuber subsample ratings on November 30				Moist chambers set up on November 30			
	Black scurf		Silver scurf		Examined December 21*		Examined January 23, 2007*	
	DS (0-5)[1]	DI (%)[2]	DS (0-5)[1]	DI (%)[2]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]
1	0.58	52.00	0.00	0.00	0.25 cde	25.00 bc	0.70 bc	67.50 ab
2	0.35	28.50	0.01	0.50	0.33 b-e	27.50 bc	0.78 abc	67.50 ab
3	0.88	78.50	0.00	0.00	0.55 ab	52.50 a	1.10 a	87.50 a
4	1.08	79.00	0.00	0.00	0.48 abc	45.00 ab	1.00 ab	85.00 a
5	0.60	52.50	0.00	0.00	0.50 ab	45.00 ab	0.93 ab	85.00 a
6	0.73	65.00	0.00	0.00	0.13 e	12.50 c	0.48 c	47.50 b
7	0.63	54.50	0.00	0.00	0.23 de	22.50 bc	0.83 ab	72.50 a
8	0.70	67.00	0.00	0.00	0.50 ab	45.00 ab	0.98 ab	82.50 a
9	0.60	57.50	0.01	0.50	0.45 a-d	45.00 ab	0.95 ab	85.00 a
10	0.75	68.00	0.00	0.00	0.63 a	60.00 a	1.05 ab	85.00 a
ANOVA P-Value	0.2528	0.3477	0.4635	0.4635	0.0010	0.0006	0.0115	0.0090
LSD (0.05)	0.481	39.757	0.006	0.612	0.220	19.864	0.311	20.671
CV (%)	48.18	45.48	421.64	421.64	37.73	36.03	24.45	18.62

DS and DI were evaluated on a 50-tuber subsample on Nov. 30 after ca. two months of storage. A 10-tuber subsample was later placed into moist chambers and rated on two dates.

[1]Black scurf/silver scurf disease severity (DS) means are on a 0-5 point scale, where 0 = no colonization by the pathogen; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = heavy colonization (>50% tuber surface covered).
[2]Black scurf/silver scurf disease incidence (DI) means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[3]Raw data were used for analysis and were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 7. Treatment list for the powdery scab fungicide field trial at the Crop Diversification Centre North, Edmonton, AB in 2006.

Treatment number	Product name	Application rate (per ha)
1	Allegro 500F (in furrow)	3.5 L ha
2	Tuberseal (SPT) [1]	0.5 kg/100 kg
3	Dithane DG (in furrow)	4.0 kg/ha
4	Ranman 400 SC (in furrow /at hilling)	0.45 L/ha (in furrow) 0.20 L /ha (at hilling)
5	Ranman 400 SC (in furrow /at hilling)	1.43 L/ha (in furrow) 0.20 L/ha (at hilling)
6	Blinix (SPT and at hilling)[1]	4.0 mL /45.4 kg of seed (SPT) [1] 593 mL/ha (at hilling)
7	Blinix (at hilling)	593 mL/ha (at hilling)
8	Untreated check	- -

[1]SPT = Seed piece treatment.

Table 8. Silver scurf disease severity and incidence levels on potatoes harvested from the 2006 powdery scab fungicide field trial at the Crop Diversification Centre North, Edmonton, AB.

Treatment number	Moist chambers set up on January 17, 2007			
	Examined January 31		Examined February 14	
	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,4]
1	1.98	97.50	3.50	100.00
2	1.28	85.00	2.78	100.00
3	2.35	92.50	3.40	100.00
4	1.98	92.50	3.33	100.00
5	2.08	92.50	3.33	97.45
6	1.98	92.50	3.13	97.45
7	1.95	95.00	3.35	97.45
8	2.48	95.00	3.38	100.00
ANOVA P-Value	0.5352	0.8542	0.7624	0.6320
LSD (0.05)[5]	1.111	15.856	0.873	-
CV (%)	37.65	11.62	18.14	01.54

DS and DI were evaluated on a 50-tuber subsample on January 15 after ca. four months of storage. A 10-tuber subsample was placed into moist chambers and rated on two dates.

[1]Silver scurf disease severity (DS) means are on a 0-5 point scale, where 0 = no colonization by *Helminthosporium solani*; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = very heavy colonization (>50% tuber surface covered).
[2]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[3]Raw data were used for analysis.
[4]Square root-transformed data were used for analysis and means were not significantly different according to Duncan's New Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Least significant differences were not calculated for transformed data.