Title: Potential Management of Powdery Scab and Mop Top Virus Using an Integration of Soil Fumigation and Genetic Resistance

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Executive Summary:

Soilborne diseases of potato are generally regarded as the one of the most serious economic constraints facing the potato industry when disease losses are coupled with the cost of control. The principle soil borne pathogens affecting potato are *Verticillium dahliae, Colletotrichum coccodes, Rhizoctonia solani,* and most recently *Spongospora subterranea,* the cause of powdery scab. The powdery scab pathogen is also the vector of potato mop top virus (PMTV), an important tuber necrosis virus recently detected in North Dakota for the first time in 2010 (David, et al., 2010). Powdery scab was first reported in North Dakota in 1997 (Draper, et al., 1997) and has since emerged as one of the most important soil borne diseases of potato in the region.

Rationale:

A number of important soilborne pathogens affect potato development and tuber quality. Among the most important of these diseases is powdery scab, caused by *Spongospora subterranea*, The powdery scab pathogen forms galls on the roots of infected plants which can girdle the roots and compromise their function in water and nutrient uptake. However, the tuber lesion phase of this disease is the most recognizable since infected tubers are unmarketable. When the powdery scab pathogen carries the mop top virus (PMTV) and transmits it to potato plants, the resulting tuber necrosis exacerbates the yield loss potential from this pathogen causing a disease the potato industry in the United Kingdom refers to as 'spraing'. The occurrence of spraing in several French fry processing fields in North Dakota caused significant economic hardship for one grower but the threat to other growers in the region is real. A survey of potato soils in the state have identified two additional farms that have powdery scab fungus present on the farm that is infected with PMTV.

At current time, the only method of controlling powdery scab in potato is to avoid it. The methods to determine the presence and concentration of important soil borne potato pathogens have historically been costly, time-consuming, and in the case of powdery scab, nonexistent. The development of a multiplex real-time PCR method in my research laboratory capable of detecting and quantifying soil inocula of three soilborne pathogens has assisted growers in making management decisions. The NPPGA supported this research in previous years and, as a result, growers are testing soils before planting in order to avoid planting potatoes into soils with high levels of powdery scab. The red growers in MN and ND have been particularly supportive of this testing method.

Unfortunately, many potato soils in our region are already contaminated with high levels of powdery scab and, in some cases, PMTV also exists. There are currently no disease management strategies available for these producers. Research proposed here would provide

short and intermediate control strategies for potato producers already faced with serious powdery scab and mop top disease problems.

The goal of the research proposed here is to investigate the ability of chloropicrin fumigation to reduce soil levels of *S. subterranea*, We have established three field trials in which several rates of chloropicrin were applied during the fall of 2010, two in MN and one in ND. We will establish another chloropicrin fumigation trial in ND in a field with mop top virus infestation. Within these trials we will determine the level of soil borne inoculum reduction of the powdery scab pathogen and we will screen a wide variety of potato varieties and germplasm for resistance to powdery scab and mop top virus.

Research Objectives:

1) Determine the degree of *S. subterranea* soil inoculum reduction that can be achieved using chloropicrin soil fumigation.
2) Screen red, white, and russet-skinned potato varieties for their susceptibility to powdery scab and mop top virus.

Research Plan:

The studies on powdery scab and on potato mop top will be conducted by two Ph.D. students, Francisco Bittara and Owusu Domfeh, respectively.

Two field trials were established in two fields with a history of potato production and with known infestations of powdery scab. One field trial was also established in which the powdery scab infestation was infected with PMTV.

One field was used to perform chloropicrin fumigation trials. The goal in this experiment was to assess whether or not chloropicrin would reduce powdery scab incidence and severity on roots and tubers across several cultivars. These fields will be treated with four rates of in-row chloropicrin (0, 100, 137.5 & 175 lb a.i./a) in a replicated, randomized block design. Within each of these fumigation rates and methods of application seven French fry russet cultivars (Russet Burbank, Russet Norkotah, Ranger Russet, Umatilla Russet, Alpine Russet, Bannock Russet, and Dakota Trailblazer), three white cultivars (Ivory Crisp, Shepody, and Kennebec), three red cultivars (Red Lasoda, Red Pontiac, and Red Norland) and one yellow cultivar (Yukon Gold) were planted. The fumigation trial was planted on April 25-27, 2012, and harvested on September 6-7.

In the second set of experiments we assessed susceptibility to powdery scab and susceptibility to mop top virus in potato cultivars, advanced clones, and breeding selections representing every market class. Eighty eight cultivars and advanced clones were assessed for susceptibility to tuber necrosis caused by PMTV. The powdery scab trial was planted on April 30 to May 1, 2012, and harvested on September 5-6. Cultivar susceptibility to powdery scab was assessed by determining the severity of galls that form on roots and the severity of tuber lesion development. The PMTV susceptibility trial was planted on May 24-45, 2012 and harvested on October 5. Mop top susceptibility was determined by the degree of internal tuber necrosis that developed in potato tubers and was assessed post-harvest.

Results:

We detected wide variability in susceptibility of potato cultivars and germplasm to both powdery scab and PMTV. However, the use of chloropicrin soil fumigation did not reduce powdery scab incidence or severity on potato tubers, although there were some numerical reductions at the higher use rates (Table 1). However, root gall formation caused by powdery scab significantly increased after chloropicrin soil fumigation (Table 2).

As expected, potato cultivars such as Russet Burbank, Russet Norkotah, Ranger Russet, Umatilla Russet, Alpine Russet and Bannock Russet did not develop powdery scab lesions on potato tubers compared to white or red-skinned potato cultivars (Table 3). Interestingly, powdery scab lesions were observed on the russet cultivar Dakota Trailblazer. Root gall formation was independent of tuber skin color (Table 4). While russet-skinned potato cultivars appear resistant to the formation of powdery scab on tubers, the roots of cultivars such as Umatilla Russet, Alpine Russet and Russet Burbank are very susceptible to gall formation. In contrast, the roots of russet-skinned cultivars Ranger Russet, Dakota Trailblazer, Russet Norkotah and Bannock Russet were the most resistant to gall formation among the cultivars evaluated.

Tuber necrosis caused by PMTV also varied among cultivars (Tables 5-8). Wide variation in the incidence of tuber necrosis caused by PMTV was observed among all cultivars and selections in each market class in the screening trial (Tables 5-8). Russet-skinned and yellow-fleshed cultivars and selections tended to have a lower incidence than white- or red-skinned clones. Tuber necrosis ranged from zero in some cultivars to over 45% in some advanced breeding selections.

PMTV caused tuber necrosis was not observed in the red-skinned cultivar Puyehue and a number of advanced selections (Table 5). Red-skinned cultivars such as Red Pontiac, Red Norland and Red Lasoda also had a low incidence of PMTV tuber necrosis. As previously stated, as a group, russet-skinned cultivars tended to have a lower incidence of tuber necrosis caused by PMTV (Table 6). It is interesting to note that in these trials, Russet Burbank did not develop any observable tuber necrosis from PMTV which is surprising since the field in which this field study was conducted had a field infection rate of >14% in this cultivar. White-skinned cultivars also appeared to be much more susceptible, as a group, compared to yellow-fleshed cultivars although there was substantial variability in tuber necrosis observed among clones in both market classes (Tables 7 & 8). No PMTV tuber necrosis was observed in Shepody and two advanced breeding selections (Tables 7).

Summary:

Based on these data, we believe we can use field trials to develop reliable susceptibility rankings for potato cultivars and provide growers with useful disease management information by having growers avoid the most susceptible cultivars. Furthermore, we believe we can begin to develop PMTV resistant germplasm that can be utilized in further breeding strategies. The results from 2011 and 2012 were consistent which has allowed us to identify cultivars in each market class that appear to resist the development of PMTV caused tuber necrosis. These data will assist growers in making the appropriate cultivar selection if and when they are faced with this devastating disease.

Table 1. Mean powdery scab severity and incidence on potato tubers in 2012 by soil treatment

Fumigant Concentration (lb a.i./acre)	Disease Severity (%)	Disease Incidence (%)
Control	0.53 A	17.1 A
Pic Plus 100	0.59 A	19.64 A
Pic Plus 137.5	0.62 A	18.34 A
Pic Plus 175	0.54 A	18.99 A

Table 2. Mean AUDPC for root gall formation on chloropicrin fumigated soil in 2012 by soil treatment

Fumigant Concentration (lb a.i./acre)	Area Under Disease Progress Curve (S.U.)
Pic Plus 100	2934.2 A
Pic Plus 175	2278.9 AB
Pic Plus 137.5	2106.3 B
Control	1254 C

Table 3. Mean powdery scab severity and incidence on potato tubers in 2012 by cultivar

Potato Cultivar	Disease Severity (%)	Disease Incidence (%)
Shepody	2.28 A	47.4 A
Kennebeck	2.01 A	47.16 AB
Red LaSoda	1.48 B	46.54 AB
Red Pontiac	1.03 C	42.11 B
Ivory Crisp	0.81 C	34.47 C
Red Norland	0.18 D	18.68 D
Yukon Gold	0.15 D	17.64 D
Ranger Russet	0.007 D	2 E
Russet Burbank	0.006 D	1.61 E
Alpine Russet	0.005 D	0.54 E
Umatilla Russet	0.001 D	0.52 E
Russet Norkotah	0.0009 D	0.34 E
Bannock Russet	0.0005 D	0.18 E
Dakota Trailblazer	0 D	0 E

Table 2. Mean AUDPC for root gall formation on chloropicrin fumigated soil in 2012 by potato cultivar

Potato Cultivar	Area Under Disease Progress Curve (S.U.)	
Red Pontiac	6873.0	A
Red LaSoda	5487.6	B
Kennebec	4340.2	B
Umatilla Russet	2644.1	C
Shepody	2619.5	C
Red Norland	1841.4	CD
Ivory Crisp	1604.4	CDE
Alpine Russet	1111.1	DEF
Russet Burbank	1098.8	DEF
Yukon Gold	803.6	DEF
Ranger Russet	682.0	DEF
Dakota Trailblazer	399.2	EF
Russet Norkotah	287.8	F
Bannock Russet	214.2	F

Table 5. PMTV tuber lesion incidence (%) of red-skinned cultivars and selections.

Cultivar/Selection	Tuber incidence (%)	
SPA 161	29.885	a
ND8314-1R	25.967	a
ND060728-5R	23.48	a
R90134-6	14.423	b
ND050167C-3R	12.518	bc
AND00272-1R	9.655	bcd
R90213-6	8.305	bcde
Dakota Jewel	8.298	bcde
ND8058-11R	8.235	bcde
RA 90213-60	7.498	bcde
T10-12	4.63	cde
ND028842b-1RY	4.335	cde
ND060733b-4RY	4.26	cde
Dark Red Norland	3.135	de
ND8555-8R	2.53	de
Viking	2.14	de
R 91129-11	2.083	de
Red Pontiac	1.96	de
R 90160-5	1.388	de
Red Norland	1.383	de
R 90070-8	1.053	de
ND4659-5R	0.935	de
Red LaSoda	0.095	e
Patagonia	0.058	e
ATND98459-1RY	0.018	e
RC 72-35	0.13	e
Puyehue	0	e
RA 20-6	0	e
RA 89044-45	0	e
$LSD_{P = 0.05}$	8.86	

Table 6. PMTV tuber lesion incidence (%) of russet-skinned cultivars and seclections.

Cultivar/Selection	Tuber incidence (%)	
ND060742C-1Russ	9.622	a
Alpine Russet	8.888	ab
ND6400C-1Russ	7.523	abc
ND049289-1Russ	4.167	abcd
ND8229-3	3.397	bcd
ND050082Cb-2Russ	2.973	cd
ND050105C-1Russ	2.972	cd
ND059769Ab-1Russ	2.412	cd
ND049423b-1Russ	1.112	d
ND8068-5Russ	0.013	d
ND060766b-4Russ	0	d
Bannock Russet	0	d
AND01804-3Russ	0	d
ND060796AB-1Russ	0	d
Dakota Trailblazer	0	d
ND049546b-10Russ	0	d
Russet Burbank	0	d
Russet Norkotah	0	d
Ranger Russet	0	d
Umatilla Russet	0	d
ND8413-7Russ	0	d
$LSD_{P = 0.05}$	**5.89**	

Table 7. PMTV tuber lesion incidence (%) of white-skinned cultivars and selections.

Cultivar/Selection	Tuber incidence (%)	
ND060601CAB-2	23.192	a
ND060715B-15	14.695	ab
ND8304-2	14.075	abc
ND7550C-1	11.937	bcd
ND060847CB-1	11.812	bcde
Nicolet	9.013	bcdef
MSL-292A	8.448	bcdef
RA 151-24	5.358	bcdef
ND060835C-4	5.352	bcdef
ND6956b-13	5.17	cdef
CO 95051-7W	4.178	def
Kennebec	3.333	def
R65A-70	2.875	def
W2717-5	2.705	def
ND7519-1	2.447	ef
ND8307C-3	2.245	f
ND8559-20	2.232	f
Snowden	2.225	f
NY-138	1.667	f
Lamoka	0.99	f
ND8331Cb-2	0.013	f
Ivory Crisp	0.013	f
Shepody	0	f
ND8331Cb-3	0	f
NY-139	0	f
$LSD_{P = 0.05}$	9.40	

Table 8. PMTV tuber lesion incidence (%) of yellow-fleshed cultivars and selections.

Cultivar/Selection	Tuber incidence (%)	
RA 82-4	9.652	a
RA 362-54	5.413	ab
Yagana	5.07	ab
Puren	3.03	b
R 87009-28	3.028	b
Yukon Gold	1.515	b
RA 519-50	1.293	b
RA 517-123	0.98	b
R 91007-5	0.927	b
R 89045-35	0.012	b
RA 16-5	0	b
RA 148-48	0	b
RC 06-109	0	B
$LSD_{P = 0.05}$	6.50	