Final Report

Testing potato varieties for susceptibility to potato mop-top virus (PMTV)

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Work undertaken between April 2007-December 2008

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1. Summary

Potato mop-top virus (PMTV) is both seed- and soil-borne, with primary infection from soil occurring by transmission by the vector, *Spongospora subterranea*, the cause of powdery scab. Planting seed tubers in soil contaminated with *S. subterranea* carrying PMTV can, therefore, lead to infection of plants and daughter tubers. Foliar symptoms developing on plants derived from infected seed tubers can vary in expression from severe to very mild. PMTV also causes spraing, necrotic arcs or flecks in the flesh of tubers which can result in the rejection of seed or ware. Global awareness of this disease is, in part, increasing pressure on seed growers, as buyers are demanding stricter disease tolerances, and on ware producers, as packers require a product essentially free from blemishes and internal defects such as spraing.

At the start of the project, only limited evidence was available on the relative susceptibility of potato cultivars to PMTV infection and only anecdotal evidence relating to symptom expression on plants and tubers of commonly grown cultivars. The assessment of cultivar susceptibility to PMTV is more complex than many other diseases because it is transmitted to plant and tubers, both by a vector which cannot be cultured artificially and by planting infected seed tubers. In addition disease expression on both plant and tubers is affected by environmental conditions which have not been fully elucidated. Research was required to establish the approaches that could be used reliably to generate information on varietal susceptibility to PMTV and the different facets of the disease. Experiments were conducted over 2 seasons with ten potato varieties grown commonly in the UK to assess whether the use of naturally infested soil could form the basis for conducting a varietal susceptibility test for PMTV. . This was done by exposing PMTV-free tubers to infection from soil inoculum in the first year at two sites in Great Britain (Perthshire and Yorkshire) and by planting the produce of the 1st year plants in PMTV-free land the following year. Tubers from the trial in Perthshire were planted at sites in Midlothian and Norfolk. Tubers from Yorkshire were planted at the site in Norfolk. The varieties tested were Maris Piper, Desiree, Hermes, Estima, Saturna, Cara, Slaney, Winston, Nicola and Rooster.

At the Perthshire site in 2007, PMTV was found in soil samples from all plots collected both before planting and after harvest. PMTV was detected in 28 out of 40 plots before planting at the Yorkshire site but in only 12 plots after harvest. The mean incidence of PMTV in tubers ranged from 62.5 to 91 % in the Perthshire trial and was c. 10 times greater than in Yorkshire trial in which the incidence of tuber infection ranged from nil to 16%. In both trials, var. Desiree was one of the most susceptible varieties and vars Hermes and Winston were amongst the most resistant. No symptoms of PMTV infection developed on plants at either site in 2007.

The proportion of PMTV-infected tubers which developed spraing at the Perthshire site ranged from 66.4 % to nil. Spraing did not develop in tubers of vars Desiree and Maris Piper and only low amounts occur in those of vars Winston and Estima. In the Yorkshire trial, most spraing developed on tubers of var. Saturna. However, spraing was recorded in tubers of vars Hermes and Winston in which no PMTV had been detected so the results for spraing at this site must be treated with some caution.

In 2008, the development of foliar symptoms was generally low at both sites although slightly greater at the Midlothian site than at the Norfolk site. Most symptoms were generally mild, with the incidence and severity being greatest on plants of var. Desiree but the disease did not

significantly affect tuber yield. The overall incidence of tuber infection by PMTV at the Midlothian site was similar to that for daughter tubers derived from Perthshire seed at the Norfolk site and 10 times greater than that for daughter tubers derived from Yorkshire seed. Varietal differences could not be detected in the latter trial but varietal rankings for the experiments at the Midlothian and Norfolk sites using Perthshire seed were correlated.

Overall, tubers of var. Hermes were most resistant to PMTV infection and those of vars Slaney, Desiree and Saturna were most susceptible. Little or no spraing developed in tubers of vars Maris Piper, Desiree and Winston but the reaction of the other varieties with respect to spraing was variable, overall. The most susceptible varieties to spraing were Rooster, Saturna and Cara.

The rankings of variety means for PMTV tuber infection from soil inoculum (2007 Perthshire trial) were in good agreement with those for infection from infected seed tubers (2008 Midlothian trial), suggesting that varietal response to the virus may be the same with both infection pathways. Only one test may, therefore, be necessary to determine varietal reaction to infection by PMTV. A test which exposes varieties to infection from inoculum in the soil would seem adequate for assessing susceptibility to infection by PMTV and would have a greater chance of obtaining adequate amounts of spraing to allow differentiation amongst varieties.

Recommendations:

1. Testing potato varieties for susceptibility to PMTV should concentrate on assessing susceptibility to transmission and spraing over one season by exposing test material to infection from inoculum in the growing medium. The development of foliar symptoms is significantly influenced by environmental conditions and is a poor indicator of PMTV infection and, thus, not a suitable tool for assessing varietal resistance.

2. If a field test is used for varietal testing, the plot area should be tested for PMTV before planting to ensure that inoculum is uniformly distributed across the intended area. However, the current test using tomato as bait plant followed by detection of PMTV in roots by real time PCR cannot give an accurate assessment of the amount of infestation in the soil because the bait plant acts as an enrichment step distorting the amount of inoculum originally in the sample. A pot test, using amended compost, could be considered as an alternative to conducting field tests but further work is required to establish the reproducibility of the test.

3. Tests should be conducted for more than one year because differences amongst varieties in susceptibility to PMTV infection, as with the ten tested here, may be relatively small and differences in respect to spraing appeared to be variable amongst years and trials. The reasons for this variability in spraing reaction are unclear and factors affecting spraing development may merit further investigation, both for testing and grower management purposes.

4. Planting PMTV-infected seed in clean land gave variable results in terms of infesting the soil and the risks involved for growers merit further study.

2. Experimental Section

2.1 Introduction

Potato mop-top virus (PMTV) causes spraing, necrotic arcs or flecks in the flesh of tubers. Foliar symptoms are generally considered to develop only on plants derived from infected tubers and not on plants infected from soil inoculum. The expression of symptoms can vary widely among varieties, ranging from severe to very mild effects (Calvert and Harrison, 1966; Calvert 1968). PMTV is both seed- and soil-borne, with infection from soil occurring by transmission by the vector, *Spongospora subterranea*, the cause of powdery scab (Arif *et al.*, 1995). Planting seed tubers in soil contaminated with *S. subterranea* carrying PMTV can, therefore, lead to infection of plants and daughter tubers

PMTV-spraing has become more important in recent years. Its incidence has increased in Sweden and it is known to cause severe problems in Finland and Denmark (Kirk, 2008). In addition, it has recently been reported for the first time in North American potatoes (Lambert *et al.*, 2003). Global awareness of this disease is, in part, increasing pressure on seed growers, as buyers are demanding stricter disease tolerances, and on ware producers, as packers require a product essentially free from blemishes such as spraing.

Most evidence on the relative susceptibility of potato varieties to PMTV relates to symptom expression on plants (Calvert and Harrison, 1968) and tubers (Neilson and Molgaard, 1997). If growers are to make informed choices with respect to the risk of growing varieties susceptible to PMTV, it is essential to establish the relative susceptibility of the most popular varieties to infection by PMTV *per se* and not just to symptom development. The assessment of cultivar susceptibility to PMTV is more complex than for many other organisms because it is transmitted to plant and tubers, both by a vector which cannot be cultured artificially and by planting infected seed tubers. In addition, disease expression on both plant and tubers is affected by environmental conditions which have not been fully elucidated. Research was required to establish the approaches that could be used reliably to generate information on varietal susceptibility to PMTV and the different facets of the disease. Experiments were conducted over 2 seasons with ten potato varieties grown commonly in the UK to assess whether the use of naturally infested soil could form the basis for conducting a varietal susceptibility test for PMTV. In the first year, this was done by planting PMTV-free tubers in a field soil naturally infested with PMTV. The following year, samples of the 1st year daughter tubers were planted in soil that was free from PMTV infestation in order to assess the degree of symptom development on plants produced by infected seed tubers and the amount of transmission of PMTV from seed to daughter tuber occurring within the plant. In addition, the degree of contamination resulting from planting PMTV-infected seed in PMTV-free soil was also assessed in the 2nd year.

2.2 Material and methods

The varieties chosen for testing were Maris Piper, Desiree, Hermes, Estima, Saturna, Cara, Slaney, Winston, Nicola and Rooster. In 2007, the initial seed tubers, 35 x 55 mm, of each variety were obtained from a number of seed potato producers in Scotland (Table 1). All seed potatoes were from crops which had been accepted at inspection as class PB or SE seed potatoes. After receipt at SASA, half of seed tubers were sent to CSL. For each lot of seed potatoes, samples of 150 tubers free of PMTV were obtained by testing rose- and heel-end cores from each tuber by ELISA for PMTV.

TABLE 1. ORIGIN OF SEED POTATOES OBTAINED FOR PLANTING IN 2007

Variety	Class	Crop i.d. number	Grower	Farm
Maris Piper	PB2	0117604501	J Cruickshank	Bruckhills
Desiree	PB2	0117604502	J Cruickshank	Bruckhills
Hermes	PB3	0175055201	J Cruickshank	Ardmiddle
Estima	PB3	0175604401	J Cruickshank	Darley
Saturna	PB3	0175055601	J Cruickshank	Darley
Cara	SE3	2439909201	J Orr	Chapelton
Slaney	SE2	0239925501	R Watson	Middle Brighty
Winston	SE3	1612401301	R Doig	Hatchbank
Nicola	PB4	0500442401	J Cruickshank	Feithhill
Rooster	SE3	2439906101	H Corrigal	Dalreoch

Scottish Field Trials

2007

A field known to be infested by PMTV was identified in west Perthshire and permission was obtained to conduct an experiment in a small part of this field. A soil sample of *c.* 600 g was collected in early April and tested for PCN. Land was ploughed, cultivated and ridged by a contractor. On 27 April 2007, plots were marked by canes and *c.* 360 g of soil consisting of 40 cores, 10 from each drill, were collected from each plot area. The soil samples were laid out on clean paper in a glasshouse, covered and then allowed to air-dry for 3-5 days before being replaced in sample bags and stored at 4-6^{o}C. Seed tubers were then planted by hand into the drills using bulb planters loaned by SCRI. A compound fertiliser (N:P:K ratio of 11:22:22) was then spread over each plot area at the rate of 1.48 kg per plot, which was equivalent to 1480 kg ha^{-1}.

The experiment was laid out in a randomised block design with 4 replications. A plot consisted of 4 drills, each comprising of 10 tubers spaced 0.37 m apart. Each plot was separated across the drill by planting tubers of var. Edzell Blue (blue skinned tubers) and was also surrounded lengthwise by planting tubers of var. Estima (2 blocks) or var. Nadine (2 blocks). Plants were inspected for symptoms characteristic of PMTV infection on at least 4 occasions from June to early August. Leaflets were collected from any suspect PMTV-affected plants and plants affected by other virus and tested by ELISA for PMTV and nine other viruses (PVX, PVY^{O}, PVY^{N}, PLRV, PVV, PVS, PVA, PVM and TBRV).

Weeds were controlled by applying linuron and a formulated mixture of diquat and paraquat when the first plants were emerging. Six applications of chemicals to control late blight were made during the growing season. Haulm was destroyed in mid-August by applying a half dose of diquat (Reglone, Syngenta) followed by a second application a few days later.

Tubers were hand harvested on 20 September by fork into new hessian sacks and then *c.* 40 cores of soil were collected from each plot area for testing for PMTV. Tubers were held at ambient for a few weeks. Samples were taken from produce of each plot, washed and subjected to a regime of storage at 16^{o}C for 2 weeks, followed by further storage at *c.* 5^{o}C for at least 2 weeks to induce spraing development (Harrison and Jones, 1971) before commencing testing and disease assessment. The remaining tubers were held in plastic seed potato trays at *c.* 5^{o}C.

2008

Two samples of 120 seed sized (35-55 mm) tubers were collected for each variety from the bulked produce of the 2007 experiment. One sample was delivered to CSL and the other was sub-divided into lots of 40 tubers for planting at SASA's Gogarbank Farm, Midlothian. The experiment was laid out in a randomised block design with 4 replications. Each plot consisted of 4 drills, each of 10 tubers spaced 0.38 m apart. Seed tubers of var. Nadine (2 blocks) and var. Saturna (2 blocks) were planted lengthwise in the drills surrounding each plot and one seed tuber of var. Edzell Blue which produces blue skinned tubers were planted across the drills to separate the plots. In addition, 2 sets of 10 tubers of each test variety grown at SASA's Gogarbank Farm in 2007 were planted between blocks 1 and 2, and blocks 3 and 4 to provide healthy reference plants. All tubers were planted by hand on 29 April.

The plants were inspected on 25 June, 2 July and 17 July for symptoms characteristic of PMTV infection and affected plants marked with a distinctive cane. The number of missing plants was also recorded and any plants of another variety marked for removal prior to harvesting. Plants with symptoms suspected of being caused by other viruses were tested by ELISA, as in 2007.

A soil sample was taken from each plot on 4 June by collecting 5 cores from each side of every drill ensuring that the corer did not touch any of the roots. Soil samples were then air-dried and stored as in 2007. Haulm was destroyed on 31 July by applying diquat at the manufacturer's recommended rate. After discarding the produce of any rogue plants and plants of var. Desiree affected by mosaic, daughter tubers from each plot were harvested by fork on 24 September into hessian bags. In all plots of var. Desiree and three plots of var. Slaney, the produce of affected plants was harvested separately from that of unaffected plants. After harvest, 10 cores of soil were collected from each drill in a plot. Soil was then air dried in a glasshouse, as in 2007, and stored at 4-6^{o}C until testing.

The tubers of affected and unaffected plants of vars Desiree and Slaney were separated into three size fractions, <30 mm, 30-50 mm and >50 mm, by passage over a reciprocating riddle and fractions weighed. Samples of 50 tubers, sized c. 40-55 mm, were collected for each plot, washed and assessed for the incidence and severity of powdery scab. The tubers were held in trays in an ambient store until 28 October before storing in a glasshouse at 18^{o}C for 1 week under black polythene, then at 4-6^{o}C for 13 days before testing for PMTV.

English Field Trials

2007

A field known to be infested by PMTV was identified in North Yorkshire and permission was obtained to conduct an experiment in a small part of this field. Land was ploughed, cultivated and ridged by a contractor. On 13 April 2007, plots were marked by canes and *c.* 360 g of soil consisting of 40 cores, 10 from each drill, were collected from each plot in order to test for presence of PMTV and tobacco rattle virus (TRV) at planting. Seed tubers were then planted by hand into the drills. Fertilisers and other agrochemicals were applied according to the normal agronomic practice for potato crops on the farm.

The experiment was laid out in a randomised block design with 4 replications. Each plot consisted of 4 drills, each comprising of 10 tubers spaced 0.32 m apart. Plants were inspected for symptoms characteristic of PMTV infection on at least 2 occasions from June to early

August. Leaflets were collected from any suspect PMTV-affected plants and plants affected by other virus and tested by ELISA for PMTV

Tubers were hand harvested on 20 September by fork into new paper sacks and then *c.* 40 cores of soil were collected from each plot for testing for PMTV. Samples of 100 tubers, sized c. 40-85 mm, were collected from each plot, washed and assessed for the incidence and severity of powdery scab. The tubers were held in trays at 4°C until mid November then transferred to a glasshouse facility at *c.*18°C for *c.*1 week under black polythene before testing for PMTV. Initially, very few tubers tested positive for PMTV. The samples were stored at 4°C and re-tested in January 2008.

2008
Two samples of 120 seed sized (35-55mm) tubers were collected for each variety from the bulked produce of 2007 trials. One sample was from the North Yorkshire site and the second sample was from the Perthshire site in Scotland. Each sample was sub-divided into lots of 40 tubers for planting at a site in Marsham, Norfolk that was known to be free of PMTV. The experiment was laid out in a split plot design with seed source as the main plots and variety as sub-plots. There were four replicates for each sub-plot. Each plot consisted of 2 drills, each of 15 tubers spaced 0.30 m apart. All tubers were planted by hand on 9 May. Irrigation, fertilisers and other agrochemicals were applied according to the normal agronomic practice for potatoes on the farm.

The plants were inspected on 16 and 30 June for symptoms characteristic of PMTV infection and affected plants marked with a distinctive cane. The number of missing plants was also recorded and any plants of another variety marked for removal prior to harvesting.

Haulm was destroyed on 29 August by applying diquat (Reglone, Syngenta) at the manufacturer's recommended rate. Just prior to harvest, a soil sample was taken from each plot on 30 September by collecting a minimum of 5 cores from each side of every drill ensuring that the corer did not touch any of the roots. While covered, the soil samples were then air-dried in a glasshouse for 3-4 days before being replaced in sample bags and stored at 4-6°C.

After discarding the produce of any rogue plants, daughter tubers from each plot were harvested by elevator digger and the tubers were hand picked from the soil surface and placed into clean, labelled paper sacks for transport to CSL on the day of harvest. The first harvest, on 30 September, had to be abandoned after harvesting one quarter of plots because of heavy rain. Harvesting was completed on 9 October. Crop from each plot was placed into labelled plastic seed trays. Trays were loaded into a temperature controlled store at 4°C within 12 hours of receipt.

Samples of 50 tubers, sized c. 40-85 mm, were collected for each plot, washed and assessed for the incidence and severity of powdery scab. The tubers were held in trays at 4°C until 24 November before storing them in a glasshouse at 18°C for *c.*1 week under black polythene before testing for PMTV.

Disease testing and assessment

PMTV and spraing
At SASA, 50 tubers from each plot were tested in 2007 and 46 from each plot in 2008. At CSL, 25 tubers from each plot were tested in 2007 and 2008. Cores, 25-30 mm in length and 5

mm in diameter, were taken from rose- and heel-end of each tuber and were tested for PMTV by direct tuber testing using DAS-ELISA as described by Fox *et al.* (2005). Tubers were then cut lengthwise to expose 6 surfaces and the most severely affected surface was scored for severity of spraing in 4 categories: nil, slight, moderate and severe (Anon, 1976).

Powdery scab
At SASA, the number of tubers affected by powdery scab was recorded and severity of symptoms assessed in 6 categories (Anon, 2002). A severity index was then calculated by multiplying the number of tubers in each category by the mid point for the category and dividing the total for all categories by total number of tubers examined. At CSL, a minimum of 100 tubers and 50 tubers from each plot was assessed for powdery scab severity in 2007 and 2008 respectively.

PMTV and TRV in soil
Material was tested by growing a two-week old tomato seedling (var. Moneymaker) for two weeks under natural light conditions, either in 20 g of test soil or in compost to which scab tissue had been added. Three replicates were tested for each sample. RNA was extracted from *c.* 100 mg of root tissue from each tomato plant using the Kingfisher mL™ system (Thermo Labsystems, Finland) and Magextractor®-RNA-reagents (Toyobo, Japan), according to the manufacturer's instructions. Real-time, reverse transcriptase-PCR (RT-PCR) assays for PMTV and TRV were performed as described by Mumford *et al.* (2000). Reactions were recorded as C_T (cycle threshold) values which decrease with increasing amounts of RNA in the test sample. At SASA, an RNA 2 primer was used in PMTV assay (Carnegie *et al*., 2007*)*. TRV testing was only done for soils from English sites.

Direct testing for S. subterranea *in soil*
In addition to the contracted testing, CSL also tested the plot soils from English sites for *S. subterranea.* Air dried samples of soil (*c.* 250 g) from each of 40 plots at the Yorkshire site in 2007 and 80 plots at Norfolk site in 2008, were placed in 1 L polypropylene sealable bottles with 300 ml extraction buffer (120mM phosphate buffer (pH8), 1.5 M NaCl, 2% CTAB with 2% antifoam B) and 24 stainless steel ball bearings then milled for 4 min using a paint shaker (Merris Automix) until a fine soil suspension was created. DNA was extracted from duplicate 1.5 ml aliquots of soil suspension using the Kingfisher mL™ system (Thermo Labsystems, Finland) and Promega Food Kit FF3750 (Promega, USA), according to the manufacturer's instructions. Real-time PCR (QPCR) was performed as described by van der Graaf *et al*. (2003).

Statistical analysis

The percentage data for incidence of infection and disease, and severity of powdery scab were angularly transformed before conducting an analysis of variance. Data on the relative susceptibility of varieties to PMTV across different sites and years were analysed by a regression approach using a generalized linear model (GLM). Analyses were carried out using Genstat Release 10.2 (Lawes Agricultural Trust).

2.3 Results

2007

Scottish field trial, Perthshire

PCN was not detected in the soil sample. None of the plants showed symptoms characteristic of infection by PMTV. Five plants of var. Winston were found to be infected by PVX. The incidence of PMTV in daughter tubers varied significantly ($P < 0.01$) amongst the varieties, being greatest (91%) in var. Desiree (Table 2). The proportion of infected tubers was least for vars Hermes and Winston (62.5 and 70% respectively). No spraing was found in tubers of vars Desiree and Maris Piper and only traces in those of vars Winston and Estima. Spraing was most common and most severe in tubers of vars Rooster, Cara, and Slaney. There was good agreement between the rankings of varieties based on incidence of spraing and those based on the severity index for spraing. While the incidence of powdery scab amongst the varieties differed significantly ($P < 0.05$), the differences were much greater for the severity of powdery scab ($P < 0.001$). Powdery scab was considerably more severe on var. Estima than on any other variety, followed by var. Desiree. The remaining varieties did not differ significantly ($P = 0.05$) with respect to the severity of powdery scab.

PMTV was found in soil from every plot, both before planting and after harvest. For 38 out of 40 plot samples collected before planting, PMTV was found in all 3 replicates and in 39 out of 40 plot samples collected after harvest. The mean C_T value was 14.5 +/- 0.33 for the before planting samples and 18.0 +/- 0.61 for after harvest samples. The greater mean value for the harvest sample means that there was less RNA detected in samples collected after harvest than before harvest. However, the correlation between C_T values for pre-planting samples and those collected after harvest for individual plot was not significant.

TABLE 2. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB ON DAUGHTER TUBERS OF TEN VARIETIES PRODUCED IN LAND KNOWN TO BE INFESTED BY POTATO MOP-TOP VIRUS (PMTV) (PERTHSHIRE SITE).

Variety	%* tubers infected by PMTV	%*tubers affected by spraing	Severity of spraing (0-4 index)	%*tubers affected by powdery scab	Severity of powdery scab (index)
Maris Piper	62.6	0	0	41.1	0.6
Desiree	73.0	0	0	60.5	1.5
Hermes	52.3	13.9	0.09	34.2	0.4
Estima	67.2	7.0	0.02	70.1	5.4
Saturna	64.9	35.2	0.45	42.4	0.5
Cara	59.9	44.1	1.00	43.6	0.6
Slaney	65.9	41.5	0.92	53.7	1.0
Winston	57.2	2.9	0.01	45.0	0.6
Nicola	62.5	17.2	0.17	35.7	0.5
Rooster	67.5	47.4	0.91	52.4	0.7
LSD ($P = 0.05$)	9.46	10.87	0.345	20.75	1.01

*% presented as angular transformation

English field trial, Yorkshire

Twenty-eight of the forty samples (70 %) of soil taken from the prospective field site tested positive for PMTV. However, PMTV was detected in only 30% of samples collected after harvest. None of the soil samples collected pre-planting or post harvest tested positive for TRV. *S. subterranea* was detected in all plots. None of the plants showed foliar symptoms characteristic of infection by PMTV except for 5 plants of var. Slaney derived from tubers which had tested positive for PMTV by ELISA in the screening of the initial seed potatoes and which had been planted out with the experiment. The incidence of PMTV in daughter tubers varied from 0 to 16% and significant differences (P = 0.003) occurred amongst the varieties (Table 3). Var. Nicola was most susceptible to tuber infection by PMTV and no infection was found in tubers of vars Hermes and Winston. Spraing-type symptoms were seen in all varieties. However, spraing was recorded in tubers of vars Hermes and Winston in which no PMTV had been detected. Spraing was severest and most prevalent in tubers of var. Saturna. The incidence and severity of powdery scab differed significantly amongst the varieties (P < 0.001 and P = 0.019, respectively). In general, the severity of powdery scab on affected tubers was low, with only a few pustules being present. Powdery scab was more severe on var. Estima than on any other variety, followed in susceptibility by vars Nicola, Desiree and Saturna.

There was no significant correlation (P = 0.205) between the number of plots with PMTV-infected tubers and detection of PMTV in soil before planting. Similarly, there was a poor relationship between the number of plots with PMTV-infected tubers and detection of PMTV in the soil after harvest (P = 0.329).

TABLE 3. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB ON DAUGHTER TUBERS OF TEN VARIETIES PRODUCED IN LAND KNOWN TO BE INFESTED BY PMTV (YORKSHIRE SITE).

Variety	%* tubers infected by PMTV	%*tubers affected by spraing	Severity of spraing (0-4 index)	%*tubers affected by powdery scab	Severity of powdery scab (Index)
Maris Piper	4.1	11.6	0.05	23.8	0.14
Desiree	11.6	5.2	0.01	43.1	0.39
Hermes	0.0	7.0[1]	0.03	13.6	0.04
Estima	2.8	11.7	0.05	42.4	0.56
Saturna	2.8	24.7	0.21	34.9	0.34
Cara	5.8	9.7	0.05	21.1	0.11
Slaney	5.8	10.7	0.06	26.8	0.16
Winston	0.0	16.4[1]	0.08	18.7	0.10
Nicola	18.9	14.6	0.08	44.9	0.46
Rooster	7.0	5.6	0.02	27.0	0.19
LSD (P = 0.05)	8.53	7.56	0.075	13.20	0.293

*% presented as angular transformation

[1] Spraing symptoms may be internal rust spot

2008

Scottish field trial, Midlothian

No symptoms developed on any of the plants of vars Maris Piper and Rooster (Table 4). More plants of vars Desiree and Slaney were affected by PMTV symptoms than those of the other

varieties. Around 40% of symptom development on affected plants of var. Desiree occurred in early July towards the end of flowering. On most varieties, the symptoms were relatively mild, being distortion or discolouration of leaflets on one stem, accompanied by some reduction in length of the affected stem. Classic symptoms of yellow chevrons were rare, occurring only on a plant of var. Estima and one of var. Hermes. Some plants of var. Estima were seen to be affected by other viruses so leaf samples from all plants were tested by ELISA and this revealed that 10.2% of plants were infected by PVV, 1.3% by PVY^N and 0.6% by PVA. PMTV was detected in 8.9% of plants. Some plants of var. Desiree also developed mild mosaic symptoms caused by PVA. These plants were not included in the yield assessments.

The mean weight of tubers per plant did not differ significantly (P <0.05) between affected and unaffected plants of vars Desiree and Slaney. The incidence of tubers affected by powdery scab was generally much less after harvest than before planting (Table 4). However, the mean incidence of powdery scab before planting and after harvest for the varieties was significantly correlated (r = 0.80, 8 df). At both times of assessment, the incidence and severity of powdery scab was greatest on tubers of var. Estima, followed by var. Desiree.

The incidence of PMTV in tubers was greatest for vars Desiree and Slaney and least for vars Hermes, Nicola and Rooster (Table 4). The incidence of spraing was generally low, with none being seen in tubers of vars Estima, Winston, Nicola, Hermes and Maris Piper. The highest incidence of spraing occurred in tubers of var. Saturna but the severity in most tubers was slight.

PMTV was not detected in any of the soil samples collected at full emergence or after harvest.

TABLE 4. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB IN 2008 ON DAUGHTER PLANTS AND TUBERS OF TEN VARIETIES DERIVED FROM SEED TUBERS PRODUCED IN PMTV-INFESTED SOIL THE PREVIOUS YEAR (MIDLOTHIAN SITE).

Variety	% * plants affected by PMTV	% *tubers infected by PMTV	% tubers affected by spraing	% * tubers affected by powdery scab	
				before planting	after harvest
Maris Piper	0	22.4	0	21.3	16.8
Desiree	26.4	32.4	0.3	52.9	22.2
Hermes	8.7	11.2	0	13.8	13.9
Estima	6.5	26.7	0	74.1	26.5
Saturna	12.6	24.3	12.5	21.7	14.2
Cara	6.2	21.3	2.2	26.7	4.6
Slaney	20.9	32.1	0.7	15.8	3.5
Winston	5.9	22.9	0	21.3	6.8
Nicola	4.7	17.3	0	12.0	8.5
Rooster	0	17.2	0.5	12.0	8.8
LSD(P = 0.05)	10.91	7.54	-	11.08	7.83

*% presented as angular transformation

English field trial, Norfolk

No PMTV symptoms developed on any of the plants grown from seed produced at the North Yorkshire site in 2007 (Table 5). However, a small proportion of plants grown from seed

produced at the Perthshire site in 2007 did develop symptoms that were characteristic of PMTV infection. ELISA tests of leaflets from these plants confirmed the presence of PMTV. The incidence of plants with PMTV symptoms ranged from nil (var. Nicola) to 5% (vars Estima and Rooster; Appendix 4) but significant differences could not be detected amongst the varieties (P = 0.544). As was the case at the Midlothian site, on most varieties, the symptoms were relatively mild, being distortion or discolouration of leaflets on one stem, accompanied by some reduction in length of the affected stem. Classic symptoms of yellow chevrons were rare, occurring only on a plant of var. Slaney and one of var. Maris Piper. Plants of various varieties were seen to be affected by other viruses. Testing leaflets by ELISA revealed that *c.* 6% of Estima plants were infected by PVV, and c. 3% of Desiree and c. 3% of Rooster were infected by PVY^N. PVA, PVY^o, PVS or PVX were not detected in plants showing mild mosaic symptoms.

TABLE 5. INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB ON DAUGHTER PLANTS AND TUBERS OF TEN VARIETIES DERIVED FROM SEED TUBERS PRODUCED IN PMTV-INFESTED SOIL THE PREVIOUS YEAR (NORFOLK SITE).

Variety	% * plants affected by PMTV	% *tubers infected by PMTV	% tubers affected by spraing	% * tubers affected by powdery scab	
				before planting	after harvest
Yorkshire seed					
Maris Piper	0.0	3.2	0.0	19.5	21.2
Desiree	0.0	3.2	1.3	41.1	20.3
Hermes	0.0	0.0	0.0	13.9	3.2
Estima	0.0	3.2	1.3	54.4	25.2
Saturna	0.0	3.2	3.8	43.2	9.7
Cara	0.0	4.6	0.0	16.4	6.5
Slaney	0.0	4.6	0.0	30.4	6.5
Winston	0.0	3.3	1.7	18.8	9.6
Nicola	0.0	3.2	0.0	49.9	20.8
Rooster	0.0	0.0	0.0	18.8	10.3
Perthshire seed					
Maris Piper	8.0	33.6	0.0	21.3	27.0
Desiree	2.6	28.9	1.3	52.9	12.3
Hermes	7.2	13.5	3.8	13.8	12.1
Estima	11.0	33.1	5.0	74.1	24.2
Saturna	4.6	34.0	17.5	21.7	16.0
Cara	5.3	36.1	17.5	26.7	0.0
Slaney	5.3	41.2	5.0	15.8	11.5
Winston	3.8	30.0	8.3	21.3	7.0
Nicola	0.0	24.7	3.8	12.0	6.5
Rooster	11.0	20.3	3.8	12.0	6.6
LSD (*P* = 0.05)	-	10.4	-	13.2[1]	8.5

*% presented as angular transformation

[1] LSD presented for results of tubers derived from Yorkshire seed only

There was no difference in incidence and severity of powdery scab in tubers derived from either Yorkshire or Perthshire seed ($P < 0.710$ and 0.238, respectively) (Table 5). As was the case in the 2007 trial, the incidence and severity of powdery scab in the 2008 harvested crop differed significantly amongst the varieties ($P < 0.009$ and 0.021, respectively). In general, the severity of powdery scab on affected tubers was low, with only a few pustules being present. Powdery scab was more severe on tubers of vars Estima and Maris Piper than those of any other variety, irrespective of the origin of the seed potatoes.

S. subterranea was detected in the soil collected from ten plots prior to planting at the Norfolk site, and appeared to be randomly dispersed across the site. At the end of the season, after harvest on 30 September, *S. subterranea* was detected in all plots.

PMTV was not detected in soil from any of plots sampled prior to planting. For samples collected immediately after harvest, PMTV was detected in the soil from six plots, each planted with Perthshire seed potatoes and each of a different variety.

Site and year comparisons

Over-trial means of the incidence of PMTV and spraing were calculated for all the trials grown in Scotland and the 2008 Norfolk trial using Scottish seed. The amounts of detectable PMTV in the 2007 Yorkshire trial and the 2008 Norfolk trial using Yorkshire seed were low and also could not be used because they skewed the analysis.

PMTV

Overall, in 2007, the incidence of PMTV tuber infection was c. 10 times greater at the Perthshire site than at the North Yorkshire site (Table 6). Although the incidence of tuber infection was much less at both sites in 2008, the difference between the sites was proportionately similar to the difference between the sites in 2007. However, the incidence of PMTV infection on daughter tubers produced from seed tubers from Perthshire site was similar at both Midlothian and Norfolk sites in 2008.

TABLE 6. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB AT SCOTTISH AND ENGLISH SITES IN 2007 AND 2008.

			Mean % (angular transformation) tubers infected/affected by		
Year	Site	Seed source	PMTV	Spraing	Powdery scab
2007	Perthshire	Scottish	63.3	22.9	47.9
2007	Yorkshire	Scottish	5.9	11.7	29.6
2008	Midlothian	07 Perthshire	22.5	1.6	12.6
2008	Norfolk	07 Yorkshire	2.9	0.8	13.3
2008	Norfolk	07 Perthshire	29.5	6.6	12.3

The variety means for PMTV tuber infection of plants grown at the Perthshire site were significantly correlated (r = 0.69, 8df) with those for 2008 Midlothian site but not with those for North Yorkshire site (r = 0.45, 8df) or for Norfolk site (r = 0.25, 8df, Yorkshire seed; r = 0.37, 8df, Perthshire seed). However, variety means for 2008 Midlothian site were significantly correlated with those for 2008 Norfolk site for both seed sources. Overall, the incidence of tuber infection by PMTV was less ($P < 0.05$) on var. Hermes than on the other varieties (Table 7). Var. Slaney had the highest incidence of PMTV infection but it was not significantly different from that for vars Cara, Desiree, Estima, Maris Piper and Saturna.

TABLE 7. OVER-TRIAL MEANS FOR % (ANGULAR TRANSFORMATION) OF TUBERS INFECTED BY PMTV AND AFFECTED BY SPRAING FOR TRIALS IN SCOTLAND IN 2007 AND 2008 AND NORFOLK TRIAL IN 2008 (PERTHSHIRE SEED ONLY).

Variety	PMTV	spraing
Maris Piper	39.5 bc	0.0 a
Desiree	44.8 bc	0.5 a
Hermes	25.7 a	5.9 ab
Estima	41.3 bc	4.0 ab
Saturna	41.1 bc	21.7 ab
Cara	39.1 bc	21.3 ab
Slaney	46.4 c	15.7 ab
Winston	36.7 b	3.7 ab
Nicola	34.8 b	7.0 ab
Rooster	35.0 b	23.9 b
LSD (*P*=0.05)	*7.54*	*21.72*

Different letters within rows indicate significantly different values (P = 0·05) obtained by analysis of contrasts within the Generalized Linear Model.

Spraing

The incidence of spraing was greater in 2007 than in 2008 at both sites and was greater for tubers from the Perthshire site than those from the North Yorkshire site in 2007 (Table 6). In 2008, spraing was equally prevalent at both sites although, at the Norfolk site, it was slightly more prevalent on daughter tubers produced from Perthshire seed than from Yorkshire seed. The variety means at the two sites in 2007 were not significantly correlated (r = -0.07) but this may be largely attributed to the low incidence of PMTV at the North Yorkshire site and some of the spraing not being attributable to infection by PMTV. For example, with var. Winston, spraing was recorded in absence of PMTV. The incidence of spraing was too low in 2008 to allow meaningful comparisons to be made.

No spraing was found in tubers of var. Maris Piper at the Perthshire, Midlothian and Norfolk sites (Table 7). However, because of the large variability in the data, there was no significant difference between this variety and most of the other varieties in terms of spraing susceptibility except for var. Rooster, which developed most spraing.

Powdery scab

In 2007, the mean incidence of powdery scab was 1.5 times greater on tubers from Perthshire site than on those from Yorkshire site (Table 6). However, in 2008, the incidence of powdery scab was similar at both sites and for both sources of seed at Norfolk site. The variety means for Perthshire site in 2007 were not significantly correlated with those for Yorkshire site in 2007 or with those at either site in 2008. Variety rankings for Yorkshire site in 2007 were significantly correlated (r = 0.76, 8df and r = 0.69, 8df respectively) with those for Midlothian and Norfolk sites (Yorkshire seed only) in 2008.

2.4 Discussion

The degree of infestation of soil by PMTV at the Perthshire site was very high with the samples from every plot being infested. At the Yorkshire site, only 70 % of soil samples were infested by PMTV, despite *S. subterranea* being detected in all samples. This suggests that not all of the powdery scab population on this site was carrying PMTV. As a result of this difference in the degree of soil infestation at the two sites, a large difference in the amount of daughter tuber infection was found between the sites in 2007. Despite this difference, vars Hermes and Winston were amongst the most resistant at both sites and var. Desiree was amongst the most susceptible. The reaction of the other varieties was more variable between the sites. These results demonstrate that, in conducting a field test to determine varietal susceptibility to PMTV, it is essential to have a site in which the intended plot area is extensively infested by PMTV but a potential difficulty could be that too much inoculum pressure could minimise varietal differences. However, at present, it is not possible to quantify the amount of inoculum in soil which may be important in this type of testing. For example, PMTV-infested soils at the North Yorkshire site produced a maximum of 16% infection by PMTV of tubers whereas, at the Perthshire site, the minimum incidence of infection was greater than 60%. This suggests that either the amounts of inoculum in the soils at the two sites were considerably different or the environmental conditions at the Perthshire site were more favourable for infection than those at the North Yorkshire site. Cooper and Harrison (1973) reported that PMTV developed when the annual rainfall in an area was greater than 740 mm. Rainfall is unlikely to have been a limiting factor in 2007; drills at the North Yorkshire site were standing in water for periods during July.

Tenerio *et al.* (2006) tested 21 varieties from USA for susceptibility to PMTV infection from soil inoculum and detected differences amongst these varieties. The amount of tuber infection ranged from 0 to 25%. The most susceptible variety was Kennebec and vars Atlantic, Chieftain, Red Pontiac and Shepody were among the least susceptible. In the Perthshire trial, the amount of tuber infection on any variety was greater than 60%, with most infection occurring on tubers of var. Desiree. The rankings of variety means for PMTV tuber infection from soil inoculum (2007 Perthshire trial) were in good agreement with those for infection from infected seed tubers (2008 Midlothian trial), suggesting that varietal response to the virus may be the same with both infection pathways and that only one test is necessary to determine varietal reaction to the virus. Overall, the most susceptible varieties to PMTV infection were Slaney, Desiree, Cara, Estima, Saturna and Maris Piper with var. Hermes being most resistant. However, although it is clear that varietal differences in susceptibility to PMTV could be detected amongst this group of varieties, none of the varieties was strongly resistant and all can acquire considerable amounts of PMTV given favourable conditions, unlike in the tests in the Peruvian Andes in which no infection by PMTV was found in a number of varieties (Tenerio *et al.*, 2006).

The susceptibility of varieties to spraing appeared to differ from susceptibility to PMTV. For example, vars Desiree and Maris Piper which were amongst the most susceptible varieties to PMTV, developed no or negligible amounts of spraing. In addition, susceptibility to spraing appeared to differ depending on whether the source of infection was soil inoculum or infected seed tubers. A much greater proportion of the tubers infected by PMTV in the first year, 2007, at the Perthshire site developed spraing than those in the second year, 2008, at the Midlothian site (Table 8). The reaction of the varieties also appeared to differ markedly with year. The proportion of infected tubers which developed spraing in 2008 at the Midlothian site was considerably greater for var. Saturna (71.8%) than any other variety whereas, in 2007, only 41% of the tubers of var. Saturna had developed spraing, ranking it 4th out of ten varieties. By

contrast, Rooster which had 64% of its infected tubers affected by spraing in 2007, had spraing affecting only 5.4 % of its tubers in 2008. Also, in 2008, no spraing was found on five of the varieties. The spraing data for North Yorkshire site in 2007 illustrates the difficulties in being sure that spraing symptoms recorded are attributable to PMTV. Clearly, many of spraing-like symptoms recorded in these tubers must have been caused by other agents e.g. physiological effects leading to internal rust spot or browning. It is unlikely that the spraing-like symptoms were caused by tobacco rattle virus because TRV was not detected in the soil sampled before planting and after harvest. However, tubers were not tested for TRV so infection by this virus cannot be completely excluded. The issue of non-uniform distribution of inoculum in the soil is a potential difficulty if variety tests for PMTV were to be done in the field. Conducting variety tests in a glasshouse using PMTV-infested scab scrapings rather than the field would, potentially, help to reduce the risk of such interactions and allow uniform, controlled conditions to be applied to give more consistent inoculum pressure and results over years. One problem with such an approach is the necessity of obtaining PMTV-infested scab each year, either by finding appropriately infected potatoes with powdery scab or by specifically multiplying PMTV in special plots each year. SASA has conducted a number of experiments on PMTV using this technique which could probably be deployed for conducting routine variety testing. However, one issue observed in the experiments at SASA appears to be the reproducibility of varietal reaction amongst experiments but this may just reflect the lack of major differences in the susceptibility of the varieties tested so far. However, similar variability in varietal reaction has been recorded in Norway and Denmark (Carl Spetz and Hanne Kirk respectively, personal communication). This has been particularly pronounced with spraing, for which the environmental conditions during growth and storage which lead to severe spraing appear to be less well understood than previously considered.

TABLE 8. PROPORTION (%) OF PMTV-INFECTED DAUGHTER TUBERS WHICH DEVELOPED SPRAING AT PERTHSHIRE SITE IN 2007 AND AT MIDLOTHIAN SITE IN 2008.

Variety	Perthshire, 2007	Midlothian, 2008
Maris Piper	0	0
Desiree	0	1.0
Hermes	12.0	0
Estima	2.3	0
Saturna	40.9	71.8
Cara	66.4	12.2
Slaney	53.9	2.6
Winston	1.4	0
Nicola	11.5	0
Rooster	63.9	5.4

These trials confirm that foliar symptoms caused by PMTV develop only on plants produced from infected seed tubers and not on plants infected from inoculum in the soil (primary infection). Historically, symptoms on potato varieties have varied widely in their severity and Calvert (1968) considered that the severity of symptoms was increased by chilling in the early stages of growth. In 2008, symptoms on plants at both sites were generally mild and did not significantly reduce yield. Varieties did differ in the extent to which symptoms occurred, with var. Desiree being most susceptible at Midlothian site. Plants of var. Estima did, on occasions, develop leaflets with classic yellow chevrons. However, it is clear that the development of symptoms must be affected by environmental conditions. For example, acute mop-top affecting 15% and 30% of plants were observed in a seed crop of var. Hermes in 2000 and

another in 2005 respectively (Carnegie, personal communication). Assessments on paired samples of unaffected and affected plants showed that the yield of symptomatic plants was 67 and 57 % less than that of unaffected plants in the two crops respectively. However, in this trial, no symptoms of mop-top developed on plants of this variety at either site. This suggests that conditions resulting in the development of severe symptoms may occur relatively infrequently. Moreover, the self elimination of PMTV from stocks during vegetative propagation (Carnegie *et al*., 2007) means that the risk of such an economic effect occurring is likely only in the first year after primary infection when the incidence of infected tubers will be at its highest. For this reason, it would be inefficient to devote resources to determining the susceptibility of varieties to this phase of the disease.

Carnegie *et al*. (2007) reported that planting PMTV-infected seed potatoes of var. Cara in soils in which PMTV had not been detected before planting resulted in PMTV being detected 3 out of 6 soils when sampled after harvest. Planting PMTV-infected seed potatoes at the Midlothian site did not result in PMTV being detected in any of soil samples after harvest. However, at the Norfolk site, while PMTV was not found in any of soils planted with Yorkshire seed which carried only low amounts of PMTV (mean of 3% of tubers infected), the virus was detected in six out of forty plots (15%) planted with Perthshire seed potatoes which were much more heavily infected (mean of 79% tubers infected). This confirms that planting PMTV-infected seed potatoes carries a risk that PMTV will be introduced into the land. It may be that the risk is greater when the incidence of infected tubers is high. Surprisingly at the North Yorkshire site in 2007, PMTV was detected in 16 fewer plots after harvest than before planting. This result seems unexpected, given that it might be anticipated that more sporeballs infested with PMTV would be deposited in the soil after cropping potatoes. The reasons for this result are not clear but suggest that sampling for PMTV in soil is fraught with difficulty or that there are fluctuations in viruliferous *S. subterranea* throughout the season

3. Conclusions

The resistance of varieties to infection by PMTV and symptom expression in plant and tuber varied for each aspect of disease development. For example, var. Desiree was one of the most susceptible varieties to infection and to the development of foliar symptoms but was relatively resistant to spraing. Var. Maris Piper was relatively susceptible to PMTV infection but resistant to the development of both spraing and foliar symptoms. By contrast, var. Hermes appeared to be relatively resistant to all three phases of the virus. However it is worth bearing in mind that none of the varieties tested showed high resistance to infection by PMTV and screening of a much wider gene pool is necessary to see if improved resistance exists.

In 2007, the amount of tuber infection which developed at the two sites differed considerably, reflecting, to some extent, the difference in PMTV infestation at the two sites. PMTV was prevalent throughout the Perthshire site but much less so at the North Yorkshire site. Unfortunately, the test used to detect PMTV in soil did not allow the amount of PMTV to be quantified because the test involves multiplying the virus in a bait plant, essentially an enrichment process which may eliminate differences in the quantity of inoculum in the original sample. Nevertheless, it is clear that in conducting a field test to assess varietal susceptibility to PMTV that the intended site should be tested extensively to provide assurance that inoculum is present in all plots otherwise results may be compromised.

The ranking of varieties for tuber infection in year 1 when transmission was from PMTV in soil was in broad agreement with that in year 2 when transmission was within the plant from seed to daughter tuber. This indicates that the reaction of a variety to infection by PMTV is the

same regardless of whether the virus has been transmitted by the powdery scab organism or from the seed tuber. A test which exposes varieties to infection from inoculum in the soil would seem adequate for assessing susceptibility to infection by PMTV. Such a test could be conducted in the field or glasshouse. However, if spraing were to be part of the assessment, the evidence from the North Yorkshire trial shows the type of risk which would be present in a field test in correctly diagnosing the symptoms as attributable to PMTV. For example, spraing was recorded in 9 % of tubers of var. Winston but no PMTV was detected in the tubers. This risk might be obviated by conducting the test using compost amended with viruliferous powdery scab. In addition, optimising the conditions for spraing development would be necessary adjunct to implementing a variety test.

Planting PMTV-infected seed tubers has been highlighted as a route by which PMTV can be introduced into clean land. The results from this study are, however, somewhat contradictory on this aspect. None of the land at the Midlothian site was found to be contaminated by PMTV after planting PMTV-infected seed tubers while 15 % of samples from Norfolk plots were found to be infested after planting Perthshire seed but none were infested on land planted with Yorkshire seed. The latter result is perhaps not surprising given the low incidence of PMTV in the latter tubers but it might have been expected that PMTV could have been introduced in powdery scab sporeballs carried on the tubers and then multiplied on the plants. If the latter were the case, the apparent difference between the two sources is difficult to explain because the incidence of powdery scab on tubers from the two sources was broadly similar. However, this discrepancy might be related to intensity of PMTV infestation at the two sites in 2007 because it appeared from testing of soil from the North Yorkshire site that PMTV was present in only a proportion of the *S. subterranea* population at this site. Furthermore, PMTV-infested soil at North Yorkshire site produced a much lower proportion of infected tubers when planted with PMTV-free seed than resulted at the Perthshire site. Another surprising finding at the North Yorkshire site was that PMTV was detected after harvest in only 43% of plots which were found to be infested at planting, even although there was evidence that powdery scab infection had occurred during the growing season. This suggests that developing a robust sampling and testing method would be of value to industry, particularly as it is the “explosive” outbreaks occurring from soil inoculum which produce high amounts of PMTV infection in tubers with the concomitant risk of spraing and economic loss.

1. Testing potato varieties for susceptibility to PMTV should concentrate on assessing susceptibility to transmission and spraing over one season by exposing test material to infection from soil inoculum. The development of foliar symptoms is significantly influenced by environmental conditions and is a poor indicator of PMTV infection and, thus, not a suitable tool for assessing varietal resistance.

2. If a field test is used for varietal testing, the plot area should be tested to ensure that inoculum is uniformly distributed across the intended area. However, the lack of a suitable test to quantify the amount of inoculum in soil means that a proper assessment of its infectivity cannot be made as illustrated by the difference in tuber infection at the two sites in 2007. Workers also need to be aware of other possible influences which may result in spraing-like symptoms developing in tubers and thus affecting the reliability of any assessment. A pot test using amended compost may be considered as an alternative to conducting field tests to assess varietal susceptibility to PMTV.

3. Tests should be conducted for more than one year because differences between varieties in susceptibility to PMTV infection, as with the ten tested here, may be relatively small and differences in respect to spraing appear to be variable between years and trials. The reasons for

this variability in spraing reaction are unclear and factors affecting spraing development may merit further investigation, both for testing and grower management purposes.

4. Planting PMTV-infected seed in clean land gave variable results in terms of infesting the soil and the risks involved for growers merit further study.

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6. Knowledge transfer activities

Poster presentations:

- SGRPID Growing Crop Inspectors course entitled “Identification of potato varieties and their diseases”. (Gogarbank Farm, Edinburgh 24/6/2008).
- PCL’s Potatoes in Practice (Dundee, August, 2008)

Oral presentations:

- Results from R291 presented during four consecutive workshops on “Spraing caused by PMTV and TRV” at the CUPGRA Conference, Cambridge, 17 – 18 December 2008.

7. Project deliverables

This project generated data on the susceptibility of 10 common cultivars (Maris Piper, Desiree, Hermes, Estima, Saturna, Cara, Slaney, Winston, Nicola and Rooster) to PMTV infection and symptom expression on plants and tubers (spraing).

8. Appendix

APPENDIX 1. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB ON DAUGHTER TUBERS OF TEN VARIETIES PRODUCED IN LAND KNOWN TO BE INFESTED BY POTATO MOP-TOP VIRUS (PMTV) (PERTHSHIRE SITE).

Variety	% tubers infected by PMTV	% tubers affected by spraing	%tubers affected by powdery scab
Cara	73	48.5	47.5
Desiree	91	0	73.5
Estima	84	2	88
Hermes	62.5	7.5	32.5
Maris Piper	78.5	0	43.5
Nicola	78	9	35
Rooster	84.5	54	62
Saturna	82	33.5	43
Slaney	82.5	44.5	63
Winston	70	1	50

APPENDIX 2 MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB IN 2008 ON DAUGHTER PLANTS AND TUBERS OF TEN VARIETIES DERIVED FROM SEED TUBERS PRODUCED IN PMTV-INFESTED SOIL THE PREVIOUS YEAR (MIDLOTHIAN SITE).

Variety	% plants affected by PMTV	% tubers infected by PMTV	% tubers affected by spraing	% tubers affected by powdery scab	
				before planting	after harvest
Cara	2.5	19.8	2.2	20.5	2.5
Desiree	20.3	28.9	0.3	63.6	15.1
Estima	2.5	20.2	0	92	20.4
Hermes	3.2	4.4	0	8	6.1
Maris Piper	0	14.7	0	13.9	8.6
Nicola	1.4	9.2	0	5	3.4
Rooster	0	9.2	0.5	4.4	3.4
Saturna	6.8	17.4	12.5	13.7	6.5
Slaney	14.5	28.5	0.7	7.9	0.9
Winston	2.1	15.2	0	13.6	5.2

APPENDIX 3. MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB ON DAUGHTER TUBERS OF TEN VARIETIES PRODUCED IN LAND KNOWN TO BE INFESTED BY POTATO MOP-TOP VIRUS (PMTV) (YORKSHIRE SITE).

Variety	% tubers infected by PMTV	% tubers affected by spraing	%tubers affected by powdery scab
Cara	2.0	4.0	13.8
Desiree	6.0	2.0	46.7
Estima	1.0	4.5	45.5
Hermes	0.0	3.0	5.6
Maris Piper	2.0	4.5	16.8
Nicola	11.0	7.0	49.9
Rooster	3.0	2.0	22.3
Saturna	1.0	18.5	33.8
Slaney	2.0	5.0	21.1
Winston	0.0	8.0	11.1

APPENDIX 4 MEAN INCIDENCE OF POTATO MOP-TOP VIRUS (PMTV), SPRAING AND POWDERY SCAB IN 2008 ON DAUGHTER PLANTS AND TUBERS OF TEN VARIETIES DERIVED FROM SEED TUBERS PRODUCED IN PMTV-INFESTED SOIL THE PREVIOUS YEAR (NORFOLK SITE).

Variety	% * plants affected by PMTV	% *tubers infected by PMTV	% tubers affected by spraing	% * tubers affected by powdery scab	
				before planting	after harvest
Yorkshire seed					
Cara	0.0	2.50	0.0	8.0	2.5
Desiree	0.0	1.25	1.3	43.3	16.2
Estima	0.0	1.25	1.3	65.0	18.8
Hermes	0.0	0.00	0.0	5.8	1.3
Maris Piper	0.0	1.25	0.0	11.2	13.8
Nicola	0.0	1.25	0.0	58.5	15
Rooster	0.0	0.00	0.0	11.3	6.3
Saturna	0.0	1.25	3.8	47.0	3.8
Slaney	0.0	2.50	0.0	26.5	2.5
Winston	0.0	1.67	1.7	10.5	4.4
Perthshire seed					
Cara	1.7	35.00	17.5	20.5	0
Desiree	0.8	23.75	1.3	63.6	10
Estima	5.0	30.00	5.0	92.0	23.8
Hermes	3.3	7.50	3.8	8.0	8.8
Maris Piper	0.0	17.50	0.0	13.9	2.5
Nicola	4.2	31.25	3.8	5.0	32.5
Rooster	5.0	12.50	3.8	4.4	5
Saturna	2.5	33.75	17.5	13.7	10
Slaney	1.7	43.75	5.0	7.9	8.8
Winston	1.1	25.00	8.3	13.6	4.1