SAFEGUARDING THE HEALTH OF POTATOES IN SCOTLAND

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Summary: An annual programme of testing and surveillance is undertaken by The Scottish Government in order to safeguard potato production in Scotland from quarantine and non-indigenous pests. This includes potato quarantine testing and pathogen testing of nuclear stock, specific surveillance for viroid, bacterial, nematode and insect pests, inspection of seed potatoes and varietal susceptibility testing for potato wart disease (*Synchytrium endobioticum*) and potato cyst nematodes (*Globodera* spp.).

INTRODUCTION

The Scottish Government (SG) undertakes measures to protect Scottish potato production from serious pests and diseases. Many are required in plant health legislation. Other measures are part of the Scottish Seed Potato Classification Scheme administered by the SG, such as the requirement for pathogen tested nuclear stock to be the starting point of seed potato production and official inspections of growing crops and tubers. These official controls are augmented by the actions of growers, industry and the public, for example the implementation of the Safe Haven Scheme, grower co-operation with the certifying authority and notifications by the public of the rare findings of *Leptinotarsa decemlineata* (Colorado beetle) or other suspect symptoms. This paper aims to describe some of the measures undertaken by SG to safeguard potato production in Scotland since 2004. Data from earlier years was presented in Scientific Reviews of SASA (1992-1997, 1997-2000 and 2000-2003; www.sasa.gov.uk).

LEGISLATIVE REQUIREMENTS

A number of potato pests are regulated in the EU as quarantine pests in the plant health directive (Council directive 2000/29/EC, PHD). These are either not present in the EU (listed in Annex IAI or Annex IIAI) or are under official control (listed in Annex IAII or IIAII). Potatoes for planting are prohibited from entering the EU (Annex III), unless they have been subjected to post-entry quarantine testing for quarantine organisms (Commission directive 2008/61/EC). Potatoes moving in trade within the EU must meet the specific requirements in the PHD for all the quarantine pests (Annex IV).

The UK has protected zone status for some organisms e.g. *L. decemlineata* (Annex IB of the PHD), which means that other member states must ensure that potatoes and other materials are free from Colorado beetles when destined for the UK. The UK is required to undertake surveys to demonstrate the continued absence of the pest. In addition, specific measures for four potato quarantine pests which occur in the EU are contained in control directives (*Clavibacter michiganensis* ssp. *sepedonicus* (potato ring rot) (Council directive 93/85/EEC as amended);

Globodera pallida and *G. rostochiensis* (potato cyst nematodes, PCN) (Council directive 2007/33/EC); *Ralstonia solanacearum* (brown rot) (Council directive 98/57/EC as amended); and *Synchytrium endobioticum* (wart disease) (Council directive 69/464/EEC)). These measures have to be applied in all Member States and all, apart from the wart disease directive, require surveillance to be undertaken. Finally, the EU passed emergency legislation for the potato pest, *Potato spindle tuber viroid* (PSTVd, Commission directive 2007/410/EC) and this includes a requirement to undertake surveillance.

As well as plant health requirements, Scottish seed potato regulations are more stringent than EU requirements. Scottish potato production is derived from pathogen-tested nuclear stock, which involves testing for common potato pests and also includes tests for some quarantine pests and tests that would detect many non-indigenous pests. In 2010 the SG introduced a nil tolerance for the damaging pests *Dickeya* spp. in The Seed Potatoes (Scotland) Amendment Regulations 2010 and The Plant Health (Potatoes) (Scotland) Amendment Order 2010. In order to justify this tolerance, annual surveillance for *Dickeya* spp. is carried out.

TESTED POTATO MATERIAL - PREVENTING THE INTRODUCTION OF PESTS

Potatoes for planting from non-EU countries are tested in post-entry quarantine by the UK Potato Quarantine Unit (UKPQU) and all starting material for the seed potato classification scheme (nuclear stock) is pathogen-tested by the Nuclear Stock Initiation Unit (NSIU) at SASA. These procedures ensure that potato production in Scotland is based on material that has been tested for freedom from quarantine pests and pathogens specified in the seed potato classification scheme. The Scottish seed potato certification system is a "flush through" system, which is generation limited and new tested material is produced annually to replace the material leaving the system. In addition to testing of potatoes for planting, official inspection, sampling and testing for the presence of pests is undertaken at ports of entry on ware potatoes from outside the EU. As most imports are via English ports, this work is largely done by The Food and Environment Research Agency (Fera) staff. Such testing is primarily for ring rot and brown rot, but inspections are also done for other non-indigenous pests, such as *Epitrix* spp.

Potato quarantine testing

In potato quarantine testing at SASA, specific tests are done for PSTVd, viruses (*Andean potato latent virus* (APLV), *Andean potato mottle virus* (APMoV), Arracacha virus B-oca strain (AVB-O), *Potato black ringspot virus* (PBRV), *Potato latent virus* (PotLV), *Potato leafroll virus* (PLRV), *Potato mop-top virus* (PMTV), *Potato virus A* (PVA), *Potato virus M* (PVM), *Potato virus P* (PVP = Potato rough dwarf virus), *Potato virus S* (PVS), *Potato virus T* (PVT), *Potato virus V* (PVV), *Potato virus X* (PVX), *Potato virus Y* (PVY), *Potato yellow vein virus* (PYVV), *Potato yellowing virus* (PYV), *Tobacco rattle virus* (TRV), *Tomato black ring virus* (TBRV), *Tomato spotted wilt virus* (TSWV)) and bacteria (*Candidatus* Liberibacter solanacearum, *C. michiganensis* ssp. *sepedonicus*, *Dickeya* spp., *Pectobacterium* spp., *R. solanacearum*). Sap from the potato material is inoculated onto test plants that will detect most of the listed pests and unknown pathogens and the potatoes are also grown for a complete vegetative cycle and observed for symptoms of pests (EPPO, 2004). Table 1 provides a summary of the number of lines submitted for quarantine testing since July 2003 and interceptions. Of particular note was the interception of PSTVd in one line from Korea in 2007-8. Infected lines are destroyed, or subjected to virus elimination techniques and retesting to verify freedom.

Table 1. Summary of numbers of potato lines tested by the UKPQU and interceptions (data from 1 July to 30 June annually)

	2003 -4	**2004 -5**	**2005 -6**	**2006 -7**	**2007 -8**	**2008 -9**	**2009 -10**	**2010-11**
No. lines; (Countries)[1]	1 (IL) 2 (NL)[2, 3] 12 (NZ) 12 (US)[4]	2 (CA) 3 (IN)	3 (CA) 1 (IT)[3] 2 (NZ) 7 (US)	2 (CA) 28 (US)	1 (CA) 1 (IN)[2] 15 (KR) 3 (NO) 2 (UA) 17 (US)	1 (BE)[2, 3] 2 (CA) 3 (UA) 26 (US)	3 (BY) 1 (CA) 1 (RU) 17 (US)	1 (PE) 6 (US)
Total	**27**	**5**	**13**	**30**	**39**	**32**	**22**	**7**
Pests intercepted	PVY (NL)			PVS (US)	PSTVd (KR) PVM (UA)	PVS (BE) PVY (BE)	PVS (BY) PVS (BY)	

[1] ISO country codes; [2] tubers; [3] lines which could not be issued with a plant passport; [4] seed and *in vitro* lines.

In addition to imported material, testing by the UKPQU is done on accessions from the Commonwealth Potato Collection (CPC), one of the World's major potato gene banks held at The James Hutton Institute (JHI), Dundee (Jeffries *et al.,* 1993) (Table 2).

Table 2. Testing of accessions from the Commonwealth Potato Collection

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
No. accessions			-		58	59	77	73
No. fully tested plants	587	3052	-	625	984	995	1181	1239

This collection was tested for freedom from PSTVd in the 1970s (Jeffries*,* 2001). However, in order to ensure that the collection is also free from seed transmitted quarantine viruses (APLV, AVB-O, PBRV, PVT and PYV), testing has been undertaken annually on accessions as they have been regenerated and retesting for freedom from PSTVd has also been done. In addition, testing of the "Hawkes (Birmingham) Collection" was done when it was integrated into the CPC (Jeffries, 1991). Testing for the same pests has also been done on breeding material used for the generation of new potato cultivars at the JHI. This ensures that new cultivars meet the requirements for freedom from these quarantine pests and can be issued with a plant passport.

Nuclear stock production

Pathogen testing at the NSIU includes specific testing for PSTVd, PLRV, PMTV, PotLV, PVA, PVM, PVS, PVV, PVX, PVY, TBRV, *C. michiganensis* ssp. *sepedonicus, Dickeya* spp., *Pectobacterium* spp. and *R. solanacearum* and inoculation of potato sap to indicator plants *Capsicum annuum, Chenopodium amaranticolor, C. murale, C. quinoa, Datura metel, Nicotiana bethamiana, N. bigelovii, N. clevelandii, N. debneyi, N. occidentalis*- P1, *N. tabacum* cv. White Burley will also detect most pests of potato. Potatoes are also grown for a vegetative cycle and observed for symptoms of pests. The numbers of clones tested since 2003 are given in Table 3. Every year a number of common pests have been detected. Infected plants are usually discarded; occasionally virus elimination is done.

Table 3. Number of clones tested annually by the NSIU

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
No. clones	156	157	147	139	153	132	185

SURVEILLANCE FOR QUARANTINE PESTS AND NON-INDIGENOUS ORGANISMS

Specific surveys are done for a number of quarantine and non-indigenous pests. In addition, official inspections are undertaken during the growing season and on harvested tubers before marketing. These inspections are required for all seed potato crops in the seed potato classification scheme, but they also underpin all plant health activities, providing evidence of freedom from pests. The SG employs more than 100 inspectors operating out of seven area offices to undertake inspections. The SG also audits micropropagation and minituber production systems and monitors the health of minitubers, with *ad hoc* surveillance and follows up where necessary. A proportion of ware crops are also inspected to ensure that the high health of potato production in Scotland has been maintained. These inspections are particularly important for verifying the absence of Colorado beetle and symptoms of wart disease, ring rot and brown rot. Samples of plants with suspect symptoms are sent to SASA for investigation.

Potato ring rot and brown rot

Annual surveys for the presence of *C. michiganensis* ssp. *sepedonicus* and *R. solanacearum* have been undertaken since the relevant EU control directives came into force and using the methods specified in the directives. The sampling strategy is based on risk and involves sampling of tubers, including samples from: each seed grower; potatoes from other parts of the EU (and UK) prior to planting and from the daughter crop; irrigated crops; and a proportion of targeted ware crops (Table 4). Samples from Scottish watercourses are also tested for *R. solanacearum*. *C. michiganensis* ssp. *sepedonicus* and *R. solanacearum* have never been detected in Scottish potatoes and the large numbers of samples tested provide confidence in the health of Scottish potato production.

Table 4. Laboratory samples (tubers and water) tested for quarantine bacteria.

	2004	2005	2006	2007	2008	2009	2010
Ring rot							
Domestic	1187	1219	1277	1330	1256	1261	1254
Imports[1]	97	11	5	26	10	50	12
Brown rot							
Domestic	1187	1243	1332	1437	1284	1261	1282
Water	476	594	585	375	303	423	471

[1] Tested for both ring rot and brown rot. Most imports are for trials purposes.

R. solanacearum was found in river water in 2000 (Wood *et al.,* 2002) and eradication of the alternative host *Solanum dulcamara* was undertaken (Saddler *et al.*, 2008). No *R. solanacearum* has been detected in Scottish river water since 2001.

***Dickeya* spp.**

Tuber samples and stems submitted during growing crop inspections were tested for *Dickeya* spp. from 2006. In 2010 Scottish legislation was introduced. Numbers of samples from 2006-2010 were 291, 123, 133, 511 and 949 respectively. Watercourses were also sampled and tested. There have been no findings in potatoes of Scottish origin.

Potato spindle tuber viroid

From 2007, EU Member States were required to survey host plants for PSTVd. Prior to this, samples had been taken from any tomato crops showing symptoms of yellowing and from potato material from non-UK sources received for trials purposes at SASA. Numbers of plants tested in Scotland using a DIG probe method (Jeffries & James, 2005) since 2004 are given in Table 5.

Table 5. Number of plants tested annually for PSTVd (apart from testing of quarantine, nuclear stock and gene bank material)

Host	2004	2005	2006	2007	2008	2009	2010
Ornamentals[1]	-	-	-	2578	1130	1090	2760
Tomato[2]	24	7	2	770	244	540	571
Potato	-	1676	1036	960	1320	1090	260
Other (*S. dulcamara*)			19				

[1] *Petunia* and *Solanum* spp.; [2] testing of leaves with symptoms until 2007

In 2007, PSTVd was detected in *Solanum jasminoides* plants moving in trade in Scotland, and a related pospiviroid, *Tomato chlorotic dwarf viroid* (TCDVd), was found in *Petunia* cuttings (James *et al.,* 2007). All infected material was destroyed under official control and related material was tested. TCDVd was also found in 2010. This viroid has never been found naturally occurring in potato, but under experimental conditions it can cause severe symptoms in potato and has been found naturally in tomato crops in some parts of the world. Publicity material on risks associated with pospiviroids has been distributed to minituber producers.

Colorado beetle

Surveillance for Colorado beetle involves official growing season inspections of seed potato crops (two inspections) and a proportion of ware crops. In addition, targeted inspections are undertaken of vegetables at wholesale markets and the public is required to notify any findings. The SG runs regular publicity campaigns, and posters alert the public to the risks associated with this pest. No beetles have been found in potato crops. Occasional findings are made in leafy vegetables and by the public (Table 6).

Table 6. Surveillance for Colorado beetle from 2004-10 (findings in brackets)

	2004	2005	2006	2007	2008	2009	2010
No. potato crops	4606	4410	4407	4540	4777	4831	13681*
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
No. inspected consignments	41	396	51	39	22	77	11
	(1)	(2)	(0)	(1)	(0)	(0)	(0)
No. findings by public	-	-	-	-	-	2	-

* Hectares

Potato cyst nematodes

The measures for control of PCN are explained in Pickup *et al*. (this volume). All land for seed potato production is required to be tested for the presence of PCN. Land where PCN is found is recorded in an official register. Seed potatoes, including farm saved seed, are not permitted to be grown in the land, and ware potato production is only permitted under an official control programme. Figure 1 shows the incidence of the two species of PCN in soil samples taken in Scotland in accordance with both the old and new EU PCN directives (respectively 69/465/EEC and 2007/33/EC) for the last 25 years. Directive 2007/33/EC also requires an annual survey of ware land, but with data only available for one year, the quantity of results from this survey is currently too small for any meaningful interpretation.

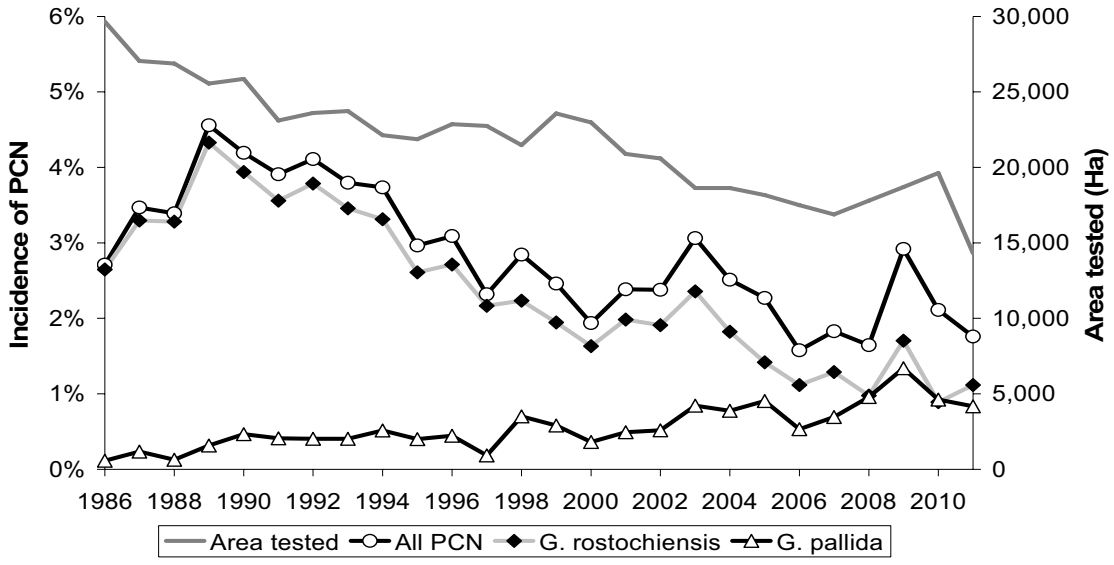

Figure 1. Incidence of PCN (*G. pallida* and *G. rostochiensis*) (left axis) and the area of land tested prior to cropping (right axis).

OTHER MEASURES TO PROTECT POTATO PRODUCTION

Wart diseases susceptibility testing

The EU control directive (69/464/EEC) requires new potato cultivars to be tested for their susceptibility to *S. endobioticum*. SASA tests cultivars for the UK using a modified Glynne-Lemmerzahl method (Browning & Darling, 1995) (Table 7). The directive specifies the measures to be taken in cases of outbreaks of potato wart disease and in the event of an outbreak SASA would test for the wart pathotype using a protocol based on the use of differential cultivars.

Table 7. Number of lines tested for wart and PCN susceptibility

	2004	2005	2006	2007	2008	2009	2010	2011
Lines	7	6	8	8	14	11	9	10

Susceptibility testing for potato cyst nematodes

As with wart disease, directive 2007/33/EC requires Member States to test new cultivars for susceptibility to pathotypes of PCN (Table 7). SASA undertakes this testing for the UK using the method in the directive. Knowledge of susceptibility to different pathotypes is important for management of any PCN outbreaks.

Training and quality assurance

The specific surveillance and monitoring by official inspectors is underpinned by comprehensive annual training in pest and symptom recognition at both growing season and tuber inspections. SG scientists are trained in diagnostic methods and operate at least to ISO 9001 (ELISA, bioassay and PSTVd methods used by UKPQU are accredited to ISO 17025). Where required, methods in the relevant EU directives are used and EPPO diagnostic protocols are also used as the basis for tests. The SG assesses new pest risks based on records of pest occurrences in the scientific literature, EPPO Alert lists and via contacts with colleagues World-wide.

CONCLUSIONS

The SG in partnership with industry stakeholders works hard to ensure the health of potatoes in Scotland. Scotland's high health status has been maintained, despite the liberalisation of the marketing requirements with the introduction of the single market in 1993. This is due to the good collaboration between government, industry bodies and growers.

REFERENCES

Browning IA, Darling M, 1995. Development of potato wart susceptibility testing in Scotland. Potato Research 38, 363-370.

Chard JM, Jeffries CJ, Pickup J, 2010. New pest risks for potato. In: Proceedings of the Crop Protection in Northern Britain Conference 2010, 165-170.

EPPO, 2004. Post-entry quarantine for potato. Phytosanitary procedures PM3/21. EPPO Bulletin 34, 439 –440

James T, Mulholland V, Jeffries C, Chard J, 2008. First report of *Tomato chlorotic dwarf viroid* infecting commercial petunia stocks in the United Kingdom. Plant Pathology 57, 400.

Jeffries CJ 1991. Saving a potato genebank. In Annual report 1990-91 of Agricultural Scientific Services, 15-16. ISBN 0 74 800 531 5.

Jeffries CJ, 2001. A History of Potato Quarantine Testing in the United Kingdom. *In* Scientific Review 1997-2000, Scottish Agricultural Science Agency, 63-65. http://www.sasa.gov.uk/sites/default/files/Science%20review%201997-2000.pdf+

Jeffries CJ, Chard JM, 2007. Phytosanitary regulation and potato quarantine. *In* Abstracts of the 13th EAPR Virology Section Meeting, Coylumbridge, Aviemore, Scotland, 17-22 June 2007, 35.

Jeffries CJ, Chard JM, Brattey C, 1993. Coping with plant health risks posed by gene bank collections of potato. In: Plant health and the European single market. British Crop Protection Council Monograph 54, 145–156.

Jeffries CJ, James C, 2005. Development of an EU protocol for the detection and diagnosis of *Potato spindle tuber pospiviroid.* EPPO Bulletin 35, 125-132.

Pickup J, Cole, Y, Reid A, Kerr J, Speirs J, MacRae D, 2012. Potato Cyst Nematodes: Initial impressions of the impact of the new EU Directive in Scotland In: Proceedings of the Crop Protection in Northern Britain Conference 2012, 227-232.

Saddler GS, Bryan JG, Danial J, Elphinstone JG, McHugh RC, Parkinson NM, van de Graaf P, Winfield MO, 2008. Potato brown rot: a threat to Scottish seed potatoes? In Proceedings Crop Protection in Northern Britain Conference 2008, 193-198.

Wood JR, Breckenridge K, Chard JM, 2002. Survey for Ralstonia solanacearum in Scottish rivers. In Crop Protection in Northern Britain Conference 2002, 237-242.