climate change
Scotland's centre of expertise connecting climate change research and policy

# Future Risks of the Potato Cyst Nematode in Scotland

Peter Skelsey[1], Helen Kettle[2], Vivian C. Blok[1]
[1]*The James Hutton Institute, Invergowrie*
[2]*Biomathematics and Statistics Scotland, Edinburgh*

## 1. Key points

- Potatoes are a leading Scottish product with an estimated sector value of around £170 million.
- In Scotland, potato cyst nematodes (PCN) are the second most economically important pest or disease of potato after late blight.
- In this study, data on the distribution of Scottish potato crop locations were combined with climate change data and a newly developed empirical model for temperature-dependent hatching and female survival in the two PCN species (*Globodera pallida* and *G. rostochiensis*). These were used to project the future risk posed to potato crops from PCN for a range of time periods and $CO_2$ emissions scenarios (1).
- We found that projected increases in soil temperature will result in increased hatching and survival of mature females of both PCN species, but the projected risk *for G. rostochiensis* was much greater.
- There was considerable geographic variation in projected PCN risk among northern, western, and eastern potato crop locations.
- To guide adaptation strategies, we investigated the potential impact of improved pest management and climate-change driven shifts in the cropping season on PCN risk.
- We found that soil infestation levels would have to be reduced by approximately 25 and 55% for *G. pallida* and *G. rostochiensis*, respectively, in order to negate projected increases in PCN risk.
- The magnitude of risk reduction achieved by planting potato crops one month earlier was considerable under all climate change scenarios.

## 2. Introduction

Potatoes have an estimated sector value of around £170 million in Scotland, and are therefore vital to the Scottish economy (Economic Report on Scottish Agriculture 2015; http://www.gov.scot/Publications/2015/06/8844). In the United Kingdom, potato cyst nematodes (PCN) are the second most economically important pest or disease of potato after late blight, estimated to incur economic costs to the UK potato industry of £26M per year in lost yield (2) and an additional £10M per year in nematicides (3). The PCN complete their life cycle in the soil and host plant roots, and are very sensitive to the surrounding temperature. Different stages of their life cycle have different temperature sensitivities and the two species also differ in their temperature responses (4). A climate change risk assessment for PCN is therefore required to guide strategies for agricultural adaptation to climate change in Scotland.

## 3. Research undertaken

Annual data defining the spatial coverage of potato crops in Scotland (approximately 40,000 crop locations in total) were derived from the Scottish Integrated Administration and Control System, the June Scottish Agricultural Census, and the Seed Potato Unified Data Systems. Future climate variables were obtained

from the UK Met Office Climate Projections database (UKCP09 SCPs). These data provide probabilistic projections through multiple samples of future climate, enabling an estimation of the likelihood of realising various impacts. Data corresponding to two future time periods (2040s and 2080s) and two $CO_2$ emissions scenarios (low and high) were selected. These were converted to soil temperatures using a relationship derived from a 15 year time series (1999-2014) of soil and air temperature data from Mylnefield weather station (56°27'25.04"N, 3°4'23.77"W). To describe the effects of temperature on hatching and female survival in PCN, a new empirical model was developed and parameterised using data from a canister experiment (1). The number of females surviving to maturity was used as a measure of PCN risk. The model was then used together with the climate change data to project the future PCN risk in Scottish potato crop locations. We also evaluated two agronomic scenarios regarding adaptation to climate change: (1) improved integrated pest management to reduce initial soil infestation levels, and (2) planting crops earlier in the year.

*Projected risk of PCN for the 2040s and 2080s*

Projections suggest that as the weather in Scotland changes, the increase in soil temperatures will result in increased hatching and survival of mature female PCN (Fig. 1). For *G. pallida*, percentage change in PCN risk increased with time and emissions level until a high $CO_2$ emissions scenario in the 2080s. Under that scenario, soil temperatures in crop locations reached the optimum value for survival to maturity and PCN risk levelled off. Risk values were 3-5 times higher for *G. rostochiensis*, and increased consistently with time and emissions level. There has been a steady decline in the incidence of *G. rostochiensis* in Scotland over the last 25 years (5). Our results suggest that in the long-term there is potential for a climate-change induced shift in the prevalence of the two PCN species, as conditions are projected to become comparatively more favourable to *G. rostochiensis*. Risk values in Scottish seed potato locations were slightly higher than projected values for ware potatoes, for both PCN species. There was notable geographic variability in the response of PCN risk to climate change, with up to 54% difference in risk among northern, western, and eastern potato crop locations (data not shown).

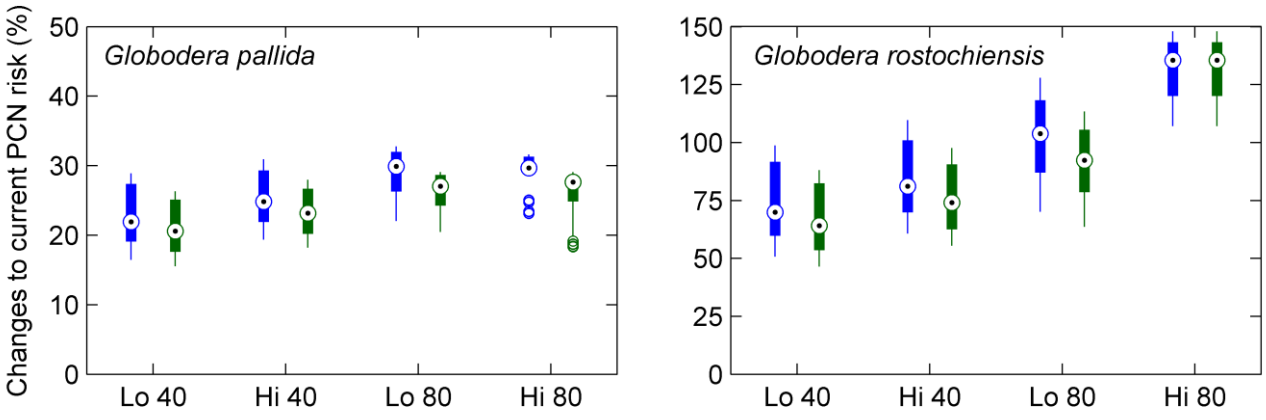


**Fig. 1.** Projected change in PCN risk in Scottish potato crops for four future emissions scenarios: low $CO_2$ 2040s, high $CO_2$ 2040s, low $CO_2$ 2080s, and high $CO_2$ 2080s. Blue and green boxplots show uncertainty due to internal climate variation and crop distribution for PCN risk in seed and ware potato crops, respectively. Projected values are expressed relative to the 1961-1991 baseline climatology to show the percentage response. Boxes extend from first to third quartile, medians are marked in each box, whiskers extend to the smallest and largest values excluding extremes, and circular markers outside of this range are extreme values.

*Future agronomic scenarios - improved pest management*

The (median) reductions in soil infestation levels required to negate (keep at or below 0%) the projected increase in emergence and survival of mature female PCN were twice as large for *G. rostochiensis* (Fig. 2). A long rotation period is the most reliable way of reducing PCN populations, because potatoes are the only widely grown field crop to act as a host. Rotation with non-potato crops is recommended for ware and compulsory for seed (minimum of 1 crop every 6 years) potato production in Scotland. Extending the rotation would therefore be an effective control measure to slow or reverse the projected increase in PCN risk.

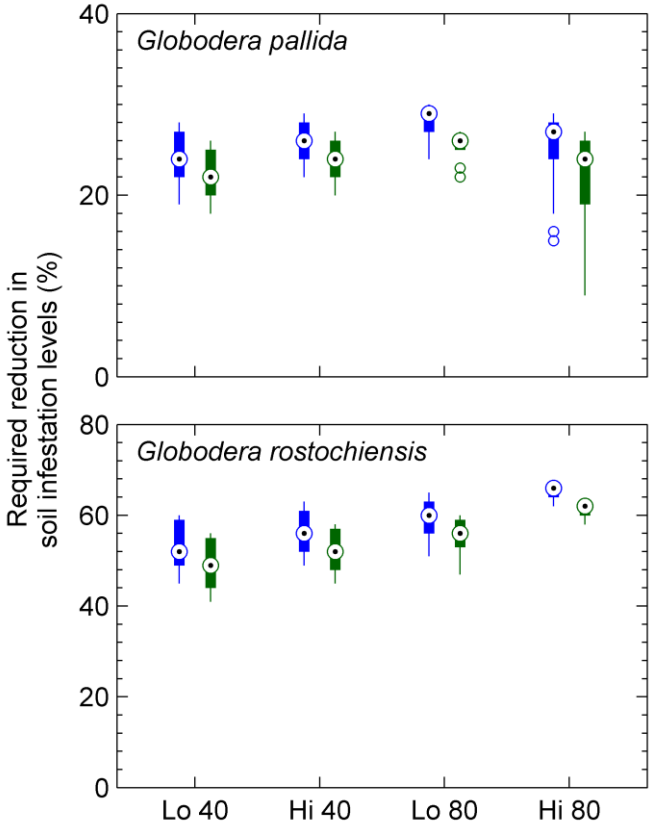


**Fig. 2.** Percentage reduction in soil infestation levels required to negate the projected increase in PCN risk due to climate change. Blue and green boxplots show uncertainty due to internal climate variation and crop distribution for PCN risk in seed and ware potato crops, respectively. Projected values are expressed relative to the 1961-1991 baseline climatology to show the percentage response. Boxes extend from first to third quartile, medians are marked in each box, whiskers extend to the smallest and largest values excluding extremes, and circular markers outside of this range are extreme values.

*Future agronomic scenarios – planting crops earlier in the year*

PCN risk is projected to increase consistently with time and emissions level when crops are planted one month earlier in the year (Fig. 3), but the magnitude of increase was not as great compared with the results for a 'standard' growing season (compare Fig. 3 to Fig. 1). Although growing seasons are primarily adjusted to optimise crop growth, these findings act as evidence to support earlier growing season start dates for potato in Scotland due to the contingent reduction of favourable environmental conditions for both PCN species.

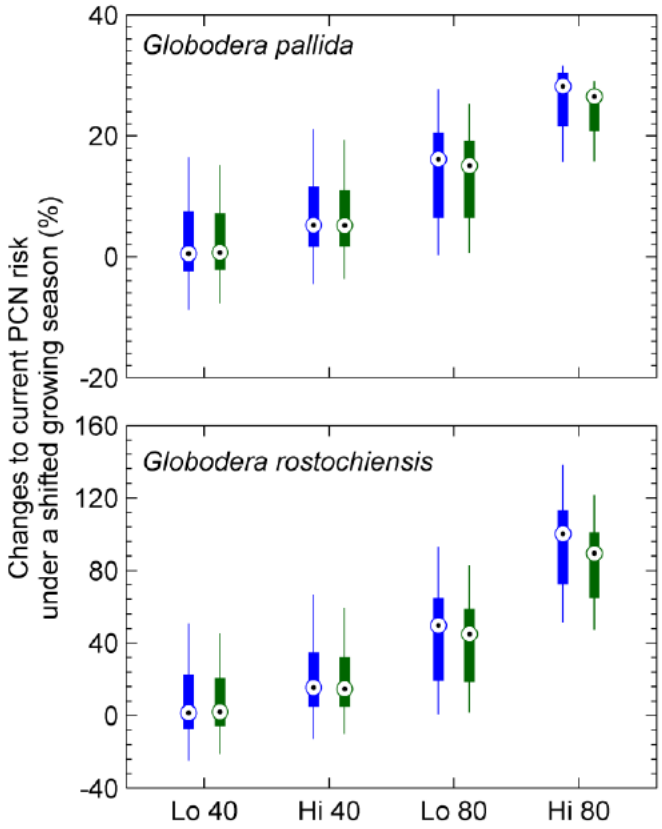


Fig. 3. Projected change in a PCN risk due to climate change under an adapted (April through July) growing season relative to baseline conditions under a standard (May through August) growing season. Blue and green boxplots show uncertainty due to internal climate variation and crop distribution for PCN risk in seed and ware potato crops, respectively. Projected values are expressed relative to the 1961-1991 baseline climatology to show the percentage response. Boxes extend from first to third quartile, medians are marked in each box, whiskers extend to the smallest and largest values excluding extremes, and circular markers outside of this range are extreme values.

## 4. Policy implications

These findings compound the importance of the crop inspections (all seed crops and 0.5% of ware crops) and PCN diagnostics that are administered by SASA in Scotland. A priority now is to develop adaptive resistance management strategies that respond proactively to the population information generated by the monitoring and PCN diagnoses, and to our increased understanding of PCN risk under climate change.

- Food security (6): There is an increased risk of yield reduction in potato crops in the future due to warmer weather providing more favourable conditions for the hatching and survival of PCN species.
- Common Agricultural Policy (7): Opportunities exist to plant potato crops earlier in the year to match the warmer conditions expected for Scotland, and this will also reduce the risk posed by PCN. This will contribute towards the proposed 'greening' of direct payments, by strengthening the environmental sustainability of agriculture.
- Water (8): PCN risk is projected to increase in the future, and increased use of nematicides to reduce soil infestation levels could increase the likelihood of runoff and pollution of water courses.
- Land use (9): The marked geographic variability in the response of PCN risk to climate change (data not shown) suggests there may be utility in shifting potato production to areas where the climate is less

favourable to PCN. This could be an attractive option to recoup land recorded by SASA as infested with PCN under the Seed Potato Classification Scheme (SPCS), and therefore prohibited from further seed production until such time that a PCN clearance certificate can be issued.

## 5. References


1. Skelsey P, Kettle H, & Blok VC (2016) Future geoclimatic risks of the potato cyst nematode in Scotland. *In preparation.*
2. Twining S*, et al.* (2009) Pesticide availability for potatoes following revision of Directive 91/414/EEC: Impact assessments and identification of research priorities. *Project Report 2009* 2.
3. Kerry B, Barker A, & Evans K (2003) Investigation of potato cyst nematode control. DEFRA report HH3111TPO. (Rothamstead Research, report commissioned by DEFRA).
4. Kaczmarek A (2014) Population dynamics of potato cyst nematodes in relation to temperature. (University of Dundee, Dundee).
5. Pickup J (2014) The status of potato cyst nematodes in Scotland. *The Dundee Conference. Crop Protection in Northern Britain 2014, Dundee, UK, 25-26 February 2014*, (The Association for Crop Protection in Northern Britain), pp 259-264.
6. Recipe for Success - Scotland's National Food and Drink Policy. http://www.scotland.gov.uk/publications/2009/06/25133322/0
7. The Common Agricultural Policy after 2013. http://ec.europa.eu/agriculture/cap-post-2013/index_en.htm
8. The Water Environment and Water Services (Scotland) Act 2003. http://www.legislation.gov.uk/asp/2003/3/contents
9. Land Use Strategy Progress Statement and Refreshed Action Plan 2014. http://www.scotland.gov.uk/Publications/2014/05/4575


## 6. Further information


E-mail: peter.skelsey@hutton.ac.uk

The James Hutton Institute, Invergowrie, Dundee DD2 5DA