Section A

Institution: University of St Andrews

Unit of Assessment: UoA 05: Biological Sciences

Title of case study: Integrated strategies and training to improve potato production in Sub-Saharan Africa

Period when the underpinning research was undertaken: 2010 – 31 December 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by HEI:
Lesley Torrance	Professor	01 September 2010 - present
John T Jones	Professor	01 February 2015- present

Period when the claimed impact occurred: 2014 – 31 December 2020

Is this case study continued from a case study submitted in 2014? No

Section B

1. Summary of the impact

The potato is a critical crop for food security and poverty reduction in sub-Saharan Africa, and production in the region is severely limited by disease, climate and availability of healthy planting material. In Kenya there are 800,000 potato farmers and more than 2,500,000 people employed in the potato value chain. Malawi is one of the biggest potato-producing countries in the region, and 70% of the crop is produced from only 2 varieties. Torrance, Jones and colleagues' research on stress biology and disease diagnostics has enabled the provision of advanced germplasm, commercial UK varieties and training to address these challenges. They have (a) introduced 12 new stress-tolerant, climate-resilient strains of potatoes and six established UK commercial varieties to Kenya and Malawi, (b) improved inspection and standards for disease-free and pathogen-resistant stock, (c) expanded the production to non-traditional potato growing areas. This work has supported the strategies of the Governments of Kenya and Malawi to boost potato yields to achieve food security, poverty reduction and economic growth.

2. Underpinning research

Underpinning research done by **Torrance, Jones** and collaborators has identified potato genotypes with traits suited to growing in Sub-Saharan Africa (SSA), including virus resistance [**R1**], stress tolerance [**R2**] and early maturity [**R3**]. Training and survey work on potato systems in Kenya and Malawi by **Torrance** early in this research revealed very high disease pressure in potato systems, and a major infestation of an introduced pathogen, the potato cyst nematode (PCN), has been reported from various countries in East Africa, most notably Kenya. Work by **Jones and colleagues** during 2017-19 contributed to the first formal identification of PCN in Uganda [**R4**]. Losses due to PCN can represent more than 50% of the total potato crop. This led the researchers to focus on advanced disease diagnostics, for example, next generation sequencing [**R5**].

Our early research focused on understanding the potato traits that farmers value and their strategies for dealing with problems such as disease. We found that farmers desire varieties that sprout quickly (for production of the next crop) because two to three crops of potato are grown per year. Moreover, tubers that cook quickly are favoured because this saves fuel costs. This knowledge of farmer-desired traits was subsequently incorporated into our research plans. Aphid-borne virus diseases, and particularly potato virus Y (PVY), one of the most prevalent viruses, are a major constraint on potato production systems in Kenya and Malawi, and the variety Mayan Gold introduced by **Torrance** to Kenya in 2014 meets the farmers' needs for agronomic properties and our research showed it was resistant to PVY.

In SSA, potatoes only form usable tubers in the cool environments found in the highland regions. There is strong demand to increase potato production, but land is limited and continuous cultivation on the same land results in build-up of diseases, leading to forest clearance to bring new land under production. Our fundamental research has discovered alleles and markers associated with heat tolerance, the mechanism of tuberization, and PVY resistance [**R1, R2, R3**]. Our hypothesis was that potato lines carrying alleles for these traits would grow and form tubers quickly, allowing production in lower altitude, warmer areas of Kenya and Malawi. **Torrance and colleagues** worked with SSA partners whose R&D is focussed on breeding new potato varieties, supporting the production of clean seed stocks and training farmers in selection methods through farmer field schools. Between 2017 and 2019, **Torrance** worked with the partners on a GCRF-funded project to trial 60 potato genotypes with different combinations of the newly discovered alleles. Out of the 60, 16 of the clones carrying the predicted favourable alleles performed well in warmer environments supporting our hypotheses. Twelve of these clones were subject to more detailed field and farmer preference evaluation in 2019/20, and they have been made available to the partners for development into new commercial varieties.

3. References to the research

The work reported in this ICS stems from fundamental peer-reviewed research published in appropriate leading journals in the field. R1 & R2 are publications submitted to REF.

R1. Natural resistance to Potato virus Y in *Solanum tuberosum* Group Phureja. **Torrance L**, Cowan GH, McLean K, MacFarlane S, Al-Abedy AN, Armstrong M, Lim T-Y, Hein I, Bryan GJ**.** Theoretical and Applied Genetics (2020). DOI: 10.1007/s00122-019-03521-y

R2. Engineering heat tolerance in potato by temperature-dependent expression of a specific allele of *HEAT-SHOCK COGNATE 70*. Trapero-Mozos A, Morris WL, Ducreux LJM, McLean K, Stephens J, **Torrance L**, Bryan GJ, Hancock RD, Taylor MA. Plant Biotechnology Journal. (2017) 16(1), p. 197-207. DOI: 10.1111/pbi.12760

R3. TERMINAL FLOWER-1/CENTRORADIALIS inhibits tuberization via protein interaction with the tuberigen activation complex. Zhang X, Campbell R, Ducreux LJM, Morris J, Hedley PE, Mellado-Ortega E, Roberts AG, Stephens J, Bryan GJ, **Torrance L**, Chapman SN, Prat S and Taylor MA. The Plant Journal. (2020) DOI: 10.1111/tpj.14898

R4. First report of potato cyst nematode *Globodera rostochiensis* (Wollenweber, 1923) infecting potato (*Solanum tuberosum* L.) in Uganda. Cortada, L., Omagwa, J., Kisitu, J., Adhiambo, M., Mburu, H., Kisitu, J., Orr, J., **Jones, J.T**., Wasukira, A., Kisingiri, B., Birenge, J.B., Okonya, J. & Coyne, D. Plant Disease (2020). DOI: 10.1094/PDIS-10-19-2110-PDN

R5. Kodoja: a workflow for virus detection in plants using k-mer analysis of RNA-sequencing data. Baizan-Edge, A., Cock, P., MacFarlane, S., McGavin, W., **Torrance, L.** & Jones, S. Journal of General Virology (2019). 100, p. 533-542 DOI: 10.1099/jgv.0.00121

R6. Viral diagnostics in plants using next generation sequencing: computational analysis in practice. **Jones S,** Baizan-Edge A, MacFarlane S, **Torrance L.** Frontiers in Plant Science, (2017) 8, Article No. 1770. DOI: 10.3389/fpls.2017.01770

4. Details of the impact

Potatoes are designated as a key food security crop by the Governments of Kenya and Malawi. However, average potato yields obtained with existing varieties are approximately one quarter of those obtained in countries with well-developed production systems. **Torrance, Jones and colleagues** have developed a strong partnership to **introduce new potato cultivars**, to **reduce the effects of disease and pest pressure**, to **expand areas of potato production** and to **support potato value chain growth**, working with growers to increase their productivity and bargaining power. In these endeavours, they have the support of key actors and government officials. This is a highly collaborative project involving Hutton collaborator, Taylor, and partners in the Consultative Group on International Agricultural Research (CGIAR); the International Potato Center (CIP); and International Institute for Tropical Agriculture (IITA based in Nairobi, Kenya; the Masinde Muliro University of Science and Technology (MMUST), Kakamega, West Kenya; and the Department of Agricultural Research Services (DARS), Bvumbwe, Malawi. Our work supports the Government of Malawi's strategy for diversification and to increase nutrition security and incomes and the Kenyan Government's aims for potato as one of the big four economic drivers of growth and food security.

a. Introduce new cultivars to improve potato quality and yield

Torrance and colleagues introduced the variety Mayan Gold to Kenya which passed National Performance Trials in 2014 and was made available to partners. Its properties of virus resistance as well as fast cooking and good taste made it highly desirable and partners experienced a huge demand for seed [**S1**]. The positive feedback from farmers about the properties of *cv* Mayan Gold helped to inform the work planned in the GCRF funded project to identify the 12 stress resilient cultivars described in Section 2. Since 2014, we introduced more commercially relevant potato cultivars from the UK. Five of these demonstrated improved quality and yield compared with local check varieties, passed National Performance Trials and were National Listed and approved for commercial production in Kenya in September 2018. Imported mini-tubers of these market-approved varieties are multiplied by Kenyan commercial seed producers to propagate at scale for sale to farmers. The Managing Director of the Kenyan Plant Health Inspectorate **(KEPHIS)** said "*we value the work being done [through the research described in Section 2] … to increase capability and make available potato varieties to farmers"* [**S2**].

Torrance and colleagues introduced 4 potato cultivars to Malawi in 2014, which demonstrated a 53% yield advantage when using clean seed. In 2014-16, we organised the clean-up and return of **disease-free mini tubers** of the Malawian **farmer-preferred cultivars 'Violet' and 'Rosita,'** which comprise 70% of the planted crop [**S3**]. High-health mini-tubers were provided to DARS and CIP Malawi who multiplied the stocks. This healthy material was **supplied to 8,500 people (farmers)** in 2018 with an estimated economic uplift of 100% [**S3**].

b. Improve inspection and standards for disease-free and pathogen-resistant stock

The quality and yield of potato is limited by a shortage of disease-free seed tubers of agronomically suitable varieties and high pest and disease pressure during the growing season. **Torrance** and colleagues partnered with MMUST to conduct pest and disease surveys in the major potato growing regions of Kenya [**S1**]. This work showed the extent of virus and other problems in the potato crops and raised awareness of tuber-borne diseases and the need to use healthy seed among small holder farmers including members of the Rural Agroeconomic Improvement Initiatives Programme (RAGIP) cooperative [**S1**].

In Malawi, in collaboration with the Scottish regulatory authority, Science & Advice for Scottish Agriculture, DARS and CIP, **Torrance** and colleagues conducted a training programme in Bembeke, Dedze, Malawi in 2014 for more than 50 people (technicians, agronomists and

government inspectors) providing training materials and demonstrations in seed potato evaluation techniques and diagnostics. Work was done to establish a **functional seed inspection service**, and we drafted **potato standards** for field inspectors, enabling, "*farmers to benefit from growing potatoes and in turn, improved their livelihoods and economic prosperity*", as stated by the Director of Agricultural Research Services, Ministry of Agriculture, Malawi [**S3**].

Torrance, Jones and colleagues also conducted widescale training of scientists, technical staff, agronomists and government officials in advanced disease diagnostics. This multi-pronged approach adopted to improve potato production using advanced diagnostics and multiple stress-tolerant genotypes has influenced activities across several areas. For example, the potato cyst nematode (PCN) poses a threat in Kenya and other SSA countries. We advised growers groups and government agencies (KEPHIS, the National Potato Council of Kenya (NPCK)) on management of PCN at a workshop held in Nairobi in 2018. Based on discussion and outputs from the workshop together with research findings in Uganda [**S4**], the Kenyan authorities asked us to help develop a region-wide response to the pest, including a genetic characterisation of the PCN present. This analysis allowed us to identify UK potato lines containing resistance suitable for management of these PCN pathotypes as well as other key traits found in the new stress resilient lines, such as low dormancy and quick cook time. Trials of these lines in Kenya are ongoing and in 2020 generated substantial public interest, e.g. Potato News Today and XinhuaNet (China).

c. Enable farmer access to varieties that can expand areas of potato production

The Chair of RAGIP in West Kenya, a cooperative which has more than 3,000 members said potato production was predicted to increase by 25% over the next 5 years and warmer non-traditional potato producing areas would be important in this expansion **[S1]**. **Torrance, Jones** and colleagues introduced 12 advanced potato clones in 2019 that are multiple stress tolerant and disease resistant to expand the area under production. We have enabled access to market-preferred varieties, engaged farmer cooperatives in new areas for potato production, such as RAGIP, West Kenya and Zomba district, Malawi, and we have brought these together with other stakeholders, including commercial off-takers who use the potato products during visits to stakeholders and at two large farmer field events between 2018-20 **[S1, S5]**. Between 2019 and 2020, the new, high performing, potato clones were grown in new areas of West Kenya (Bungoma county) and Zomba district, Malawi. The **Zomba District Agricultural Development Officer** wrote 'Heat tolerant potatoes were liked by farmers and will be beneficial to extend production to warmer regions such as Zomba', "*early maturity will enable rotation with other crops' 'moving production to new areas will benefit farmers economically' 'this initiative supports the Government of Malawi's strategy to diversify from the staple food which is maize, as well as increase farmers' food and nutrition and income security*" [**S5**]. These sentiments were echoed by the **Bungoma County Director of Agriculture** in Kenya who said the work demonstrated an exemplary partnership: "*The County relies on Agriculture to feed its people ... 5,000 [people] farmers have expressed their commitment to grow potato …This will benefit our small holder farmers in the lowland areas and vulnerable marginalized groups with market-oriented livelihood interventions to reduce hunger and attain food security*" [**S6**].

The **Kenyan Potato Council CEO** said "*The new varieties will meet the needs of small holder farmers and will provide a step change in productivity…. for long term food security not only in West Kenya but the East African region as a whole*." [**S7**]

5. Sources to corroborate the impact

S1 Letter from Chair of RAGIP cooperative, West Kenya

S2. Letter from Kenya Plant Health Inspectorate Service (KEPHIS) managing director

S3. Letter from Director of Agricultural Research Services, Department of Agricultural Research Services (DARS, Malawi),

S4 Letter from the office of the Permanent Secretary, Min of Agriculture, Animal Industries and Fisheries (MAAIG) Uganda.

S5. Letter from District Agriculture Development Officer, Zomba (Malawi) District Agriculture Office,

S6 Letter from Director of Agriculture, Bungoma County, Kenya

S7. Letter from the Chief Executive Officer National Potato Council of Kenya (NPCK).