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RESEARCH

The Voyages of a Potato Companion: *Phytophthora Infestans*

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Accompanying a shipment of potatoes in 1845, a fungus-like traveller unintentionally made it to Europe, after having maintained a low profile for centuries in Latin America. Decades later, scientists identified this stowaway as the basic ingredient for an outbreak of potato late blight and gave it a name—*Phytophthora infestans*. By following the potato on its travels back and forth between its cradle in the Andes and its development into a monocrop food staple in Europe over the last centuries, we trace the transatlantic trajectories of its fungal companion. We explore when and why a fungus such as *P. infestans* became known, and feared, as an invasive species, after centuries of spontaneous and invisible co-existence with the potato in Latin America. Why could *P. infestans* suddenly come out of its companion's shadow to cause a large-scale outbreak of the disease in Europe in the 1840s? How did it become a driving power for the development of plant sciences and related technological innovations in potato agriculture up until today? Since the late eighteenth-century, specific agricultural, scientific, and political practices have enacted a logic of 'potato modernity', subjecting the potato to an artificial monoculture regime. Abruptly interrupting centuries of multispecies co-habitation of a fungus, the potato, and humans, *P. infestans* was invented as an invasive intruder that needed to be contained and conquered.

Keywords: invasive species; P. infestans; potato late blight; Europe; Andes; monoculture

Introduction

At the end of June 1845 in the region of Courtrai—a Flemish city situated close to the French border of the young independent nation of Belgium—the first reports of an unknown potato disease appeared. The disease first revealed itself by the blackening or blighting of the foliage of potato plants, after which it spread to the tubers themselves, causing them to rot within a few days. By mid-July, the potato disease had spread all over Flanders, and had appeared in neighbouring parts of the Netherlands as well as northern France. On 23 July 1845, Felicitas Rommel—a local witness from the village of Rumbeke, situated some twenty kilometres to the north of Courtrai—noted in her diary that 'in many places, the potato plant is drying, turns black and releases an unpleasant smell; many people go on a pilgrimage to the Chapel of Saint Anthony, in order to ask for salvation' (authors' translation, Delbaere 1956: 74–76). On the fourth of August Rommel noted 'yesterday, on Sunday, between eleven to twelve thousand strangers came to the village on pilgrimage' (authors' translation, Delbaere 1956: 74–76).

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A new visitor made its appearance in Europe, after having maintained a low profile for centuries in Latin America. *Phytophthora infestans*—the scientific name this fungus-like visitor would receive decades later—is the basic ingredient for an outbreak of what became known as 'potato late blight'. *Phytophthora infestans* was moving fast. By mid-August, it appeared in the vicinity of Paris and the lower Rhineland, north-west France, the Channel Islands, and southern England. By mid-September, it went further to Denmark, through England, Wales, the borders of Scotland, and across the Irish Sea to the eastern counties of Ireland, as reconstructed in **Figure 1**. At its maximum range, the disease infected an area that stretched 1,600 kilometres from the western shores of Ireland to northern Italy, and 1,800 kilometres from northern Spain to the southern tips of Norway and Sweden (Reader 2009: 195). According to recent historiography, potato late blight caused the so-called 'Last European Subsistence Crisis' during the period 1845–1850, with the well-known Irish 'Great Famine' at its worst (Ó Gráda, Paping & Vanhaute 2007).

Potato late blight, and particularly the crises it provoked, has attracted diverse research interests. Social sciences and humanities research tends to focus on the societal causes and consequences of the famine, such as the differences in resilience, demographic impact, or diverging political and ideological reactions. The work

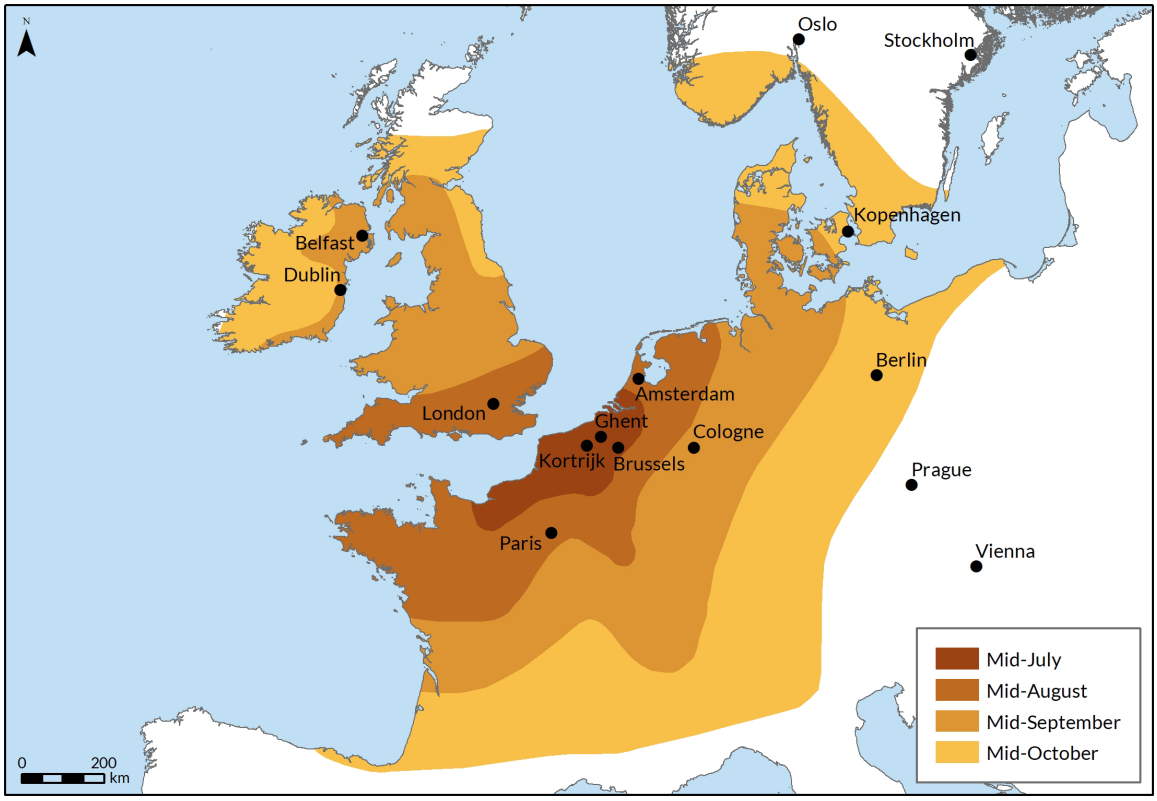

Figure 1: Spread of the potato blight in Europe, 1845. Credit: Hans Blomme, Ghent University, Ghent, Belgium.

of Cormac Ó Gráda is particularly important in this field (Ó Gráda 2000; Alfani & Ó Gráda 2017). Within natural sciences, the focus lies on the phytopathological causes of the famine, and its consequences in the development of phytopathology (Turner 2005). In this article, *P. infestans* takes central stage as the obvious but often overlooked protagonist of the 'Great Famine'. The work of John Reader (2009), and especially Rebecca Earle (2017; 2018; 2019; 2020), has already consolidated the protagonism of the potato (*Solanum tuberosum*) in the development of capitalism and modern state formation. Building on these insights, our story centres on the interplay between potatoes and a water mould—a fungus-like organism also called oomycete—allowing us to acknowledge *P. infestans* as a key world-historical player.

By following the potato on its travels back and forth between its cradle in the Andes and its development into a monocrop food staple in Europe, we trace the trajectories of its fungal companion. Inspired by Anna L. Tsing's work, we read these transatlantic voyages as a tale of 'multi-species' or 'more-than-human' world-making, understanding that every organism makes worlds—by actively changing its environment into habitable places—in collaboration with others (Tsing 2009; Tsing et al. 2017). From the potato's early-modern introduction on the European continent to its current day embeddedness in a globalised economy, these trajectories were not uniquely shaped by humans, but also by the often-unexpected responses by potatoes and fungi. Multi-species encounters form the driving force of agrarian, socio-economic, cultural, and scientific change. As such, they allow us to tell an alternative history of the potato and its role in the making of the modern world. With the *Solanum tuberosum*, the humble potato, and its companion *P. infestans* as our guides, we unravel how key global agrarian developments proceed through the oxymoron of 'unintentional design', to borrow Tsing's words once more (2014).

From this multispecies vantage point, we explore when and why a fungus such as *P. infestans* became known, and feared, as an invasive species, after centuries of natural and invisible co-habitation with the potato in Latin America. Why could *P. infestans* suddenly come out of its companion's shadow to cause a large-scale outbreak of disease in Europe in the 1840s, and to become a driving power for the development of plant sciences and related technological innovations in potato agriculture up until today? In this story, the multispecies perspective exposes the emergence and operation of a modernist, Cartesian logic that explains human-nature relations in a dualistic and mechanistic way. We define this logic as 'potato modernity'; a form of modernity enacted through monoculture practices that have dominated potato agriculture, science, and policies since the late eighteenth-century. By presuming 'humans (…) to transcend and master nature' (Tsing et al. 2020: Introduction to Feral Atlas), this mode of thinking has driven Western instrumentalisation of the potato as a vehicle of national (and later, global) development. By artificially separating 'nature' and 'humanity', this logic allows *P. infestans* to be treated as a malicious externality instead of the potato's natural companion. In contrast to the logic of co-habitation, 'potato modernity' is what supports the bringing into being and keeping alive of *P. infestans* as an invasive species. The same logic continues

to legitimise the entangled scientific-agricultural quest to eliminate this fungus up until today.

We distinguish three phases in the potato's participation in the shaping of an uneven, multispecies transatlantic connection. The potato's journey started in the sixteenth century, when a limited selection of potato varieties found its way from the Andes to European peasant fields. This is the stage of 'pre-invasion' as *P. infestans* did not yet travel along with its companion. After this initial phase, the potato steadily grew into a main global staple food under a monoculture regime in the context of nineteenth-century industrialisation. This came with a new, intensified phase of transatlantic exchange by means of which *P. infestans* could travel along with the potato. Once across the Atlantic, the fungus proliferated rapidly in European fields, causing the 1840s famine. With this traumatic event, we enter a new phase of 'post-invasion'. *P. infestans* finally gained the full attention of scientific research and created new opportunities in agrarian political economy. Through to the present-day intertwined and globalising pursuit of biotechnological control and development goals, *P. infestans* continues to shape a transatlantic connection of precarity between Europe and the Andes.

In our explorations, we use Flanders in Belgium as an illustrative case for the trajectories of the potato and *P. infestans* to, within, and out of Europe.[1] Today still known for their potato agriculture? See 'Flemish farmers and scientists' take central stage in each of the successive phases of transatlantic interaction. Their voices, experiences, agricultural, and scientific practices give evidence of the non-human protagonists of this story which becomes indirectly traceable through archival and secondary sources including diaries, government documents, legal deeds, newspapers, scientific work, and interdisciplinary literature that ranges from agricultural and environmental history to botanical studies, agronomy, phytopathology, environmental science, and bioscience engineering. Our methodology consists of a 'more-than-human' reading against the grain of this diverse set of source materials, extending techniques to uncover the perspectives and experiences of the silenced, illiterate, and dispossessed to other historical participants in processes of social change (O'Gorman & Gaynor 2020: 726). Relying on a rich tradition of historical research on the characteristics and development of Flemish (potato) agriculture (see for example Thoen & Vanhaute 1999), we seek to strengthen the dialogue between historical research and interdisciplinary multispecies studies, contributing to an innovative research agenda around 'more-than-human histories' (O'Gorman & Gaynor 2020).

Pre-invasion: The Potato Crosses the Atlantic

Up to today, scholars continue debating the precise origins of *P. infestans*, as we will discuss further on in more detail. Until its first description as a fungus in the wake of the devastating outbreak of potato late blight in the 1840s, our protagonist stayed under the radar, contained in small populations in Latin American potato-producing areas. By that time, the potato had been cultivated as a food crop for more than two centuries in the European countryside. We label this episode before the nineteenth-century 'discovery' of *P. infestans* as 'pre-invasion'. We explore how, and by whom, the potato was first introduced in Europe.

The well-known dimension of this first phase is the so-called Columbian Exchange, referring to the environmental impact of Columbus' landing in the New World. Coined by Alfred W. Crosby (1972), the concept has largely marked world-historical research on the ecological exchange of species. We can observe that Crosby looked at the exchange rather rigidly as being a disastrous transformation in the 'New World' and an overly successful one in the 'Old World'. In this tradition, scholars have especially paid attention to the dramatic consequences of the enormous ecological exchange of crops and diseases on the American continent. By contrast, the precarious part of the European success story in this multi-species transatlantic world-making still gains less attention. In his book *1493: Uncovering the New World Columbus Created*, Charles C. Mann (2011) makes an important effort to reveal both the benefits and the disasters wrought by protagonist species of the Columbian Exchange such as the potato. Our analysis goes further in questioning the dominant discourse by scrutinising the long-term, yet disruptive effects of the introduction of the potato to the European continent.

To be clear, Columbus did not bring the potato to the European continent. The first European writer to describe the potato was Pedro Cieza de León, who travelled extensively through the Andes in the late 1530s and 1540s.[2] While the potato was of vital importance as a staple food for Andean peoples, Cieza de León made surprisingly scant mention of the potato. After all, the chronicler was mainly interested in emphasising how well the overseas lands were suited to the requirements of Spanish crops and livestock, and not so much in Andean food production systems. Nevertheless, it is quite surprising how little is known about the potato's introduction on the European continent. In comparison, significantly more is known about the development of other crops such as maize (Reader 2009: 69, 85–86).

Part of the explanation for the limited information on the potato's first transatlantic trajectory is that the conquest of the Inca Empire by Francisco Pizarro took place in 1531–1536. In the following decades, European botanical knowledge boomed. Consequently, fifteenth- and early sixteenth-century European botanists could no longer keep track of the newly catalogued plant varieties (Egmond 2010: 11–12). This makes it difficult to know who brought the potato to Europe.

In the dominant narrative about *Solanum tuberosum*'s arrival on European soil, early modern botanists figure as the protagonists. As with many other exotic species, these specialists introduced the potato plant as a curiosity, without aiming for its large-scale production and consumption as a food crop. European landscapes presumably accumulated new species through collecting and cataloguing, a process that was neatly supervised by experts. For example, the famous Flemish botanist Carolus Clusius was a pivotal figure in the diffusion of the potato to gardens of various European botanists at the end of

the sixteenth century. Yet, by the time Clusius learned about the potato, when he received potato tubers in 1588 (resulting in the drawings in **Figure 2**), it had already become a common species in Italy where, apart from eating potatoes themselves, people were also using them as fodder for pigs (McNeill 1999: 73; Salaman & Hawkes 1989 [1949]: 90, 142). Despite extensive networks, reading and travels, Clusius, one of Europe's foremost botanists, came across the potato relatively late. This case proves that elitist botanist intellectuals were not the proclaimed gateways for the European introduction of the potato.

Economic history offers a different perspective. It suggests that the potato was introduced through commercial trade rather than through botanist knowledge exchange, and it equally reveals that potatoes were first cultivated by peasants rather than in botanists' gardens. The research of Earl J. Hamilton into the records of the *Hospital de la Sangre* in Seville allowed later researchers to determine the date of introduction of the potato in Spain as early as 1570, and possibly even earlier (cited in Salaman & Hawkes 1989 [1949]: 143). What is more, researchers revealed that potatoes were introduced on the Canary Islands by the 1560s and were exported from there to continental European ports (Smith 2012: 23). As a result, the potato's arrival in Europe occurred only thirty years after its presumed first sighting when Pizarro conquered the Inca Empire around 1532, and not even ten years after Pedro Cieza de León's writings of 1553 (Reader 2009: 89–91; on the Flemish trade with the Canary Isles see Coornaert 2000). In sum, the potato's relatively sudden appearance in various parts of the North Sea Area in the late sixteenth century must be understood in the context of trade circuits and the shift of the commercial epicentre from the Mediterranean northwards, rather than the knowledge exchange between botanical elites (McNeill 1999: 70–72).

If the potato was originally imported from the Andes via the Canary Isles by Spanish merchants during the second half of the sixteenth century, then why and how did the potato become widely used as the 'bread of the poor' in the eighteenth century? The canonical story praises people like the French military pharmacist Antoine-Augustin Parmentier or Frederick the Great of Prussia as promoters of the potato to support Europe's fast-growing poor population. However, Rebecca Earle (2017: 149) clearly illustrated how seventeenth-century tithe disputes reveal a more structural economic factor at play. At that time, in many European regions, the tithe-able (or taxable) status of a crop depended largely on how long the plant had been cultivated. Therefore, some peasants introduced 'new' crops for household consumption to be exempted from the heavy dues they had to pay to their lords, not in the least on their cereal yields. Based on these tithe disputes we know that potatoes were already sown by peasants in some parts of war-torn Europe from the seventeenth century onwards to escape the surplus extraction by their seigneurial and ecclesiastical lords. William H. McNeill (1999: 72) already pointed to the Thirty Years' War as the last to be fought in Europe before potatoes became widespread enough to prevent rural starvation and thus reduce the human cost of military requisitioning. Hence, such legal records document the spontaneous diffusion of potatoes into small-scale garden plots long before they attracted the attention of agronomists.

These acts of rebellious potato cultivation emerged in several parts of Europe through interactions between local peasants, not monarchs or local lords (Earle 2017: 149). An example of this process has been found in Tielt, another small town in Flanders, where an official writing in 1687 notes that 'for more than thirty-six years potatoes have been planted "buyten de lochtinghen" [outside of the vegetable garden] [and] almost all the inhabitants of the parish [are growing them], each for his [own] consumption and convenience.'[3] In other words, around 1651 the potato had already become a field crop in parts of Flanders. Two centuries later, it was especially the region of Tielt that was severely hit by the late blight potato famine of 1845–1850. By then, this area had become a centre of the Flemish pre-industrial linen industry. As we will see, this development forms another defining feature of the European pre-famine potato landscape.

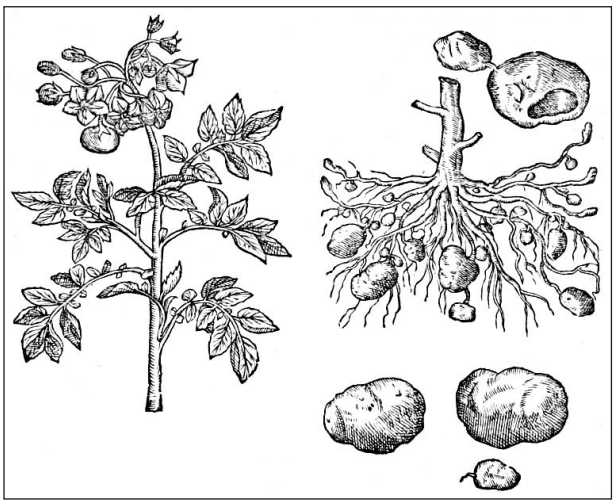

Figure 2: Carolus Clusius' botanical illustration of a potato (Solanum tuberosum). Credit: Clusius 1601: L.IIII, p.lxxix. Wikimedia Commons.

Preparing the Terrain for Invasion: Monoculture and 'Potato Modernity'

The potato's dissemination in European agriculture resulted from a spontaneous encounter between rural inhabitants, their environment, and a new foodstuff. After 1750, however, Europe's potato-producing agricultural landscapes underwent a scaling-up as the potato became a principal food crop for Europe's fast-growing population. In order to cope not only with demographic growth but also with general impoverishment, political elites instrumentalised the potato and its fast-productive potential. However, between 1845 and 1850 potato harvests failed altogether. *Phytophthora infestans* was taking central stage as 'invader' in the history of the potato.

Although a potato consists mostly of water, a medium sized raw potato contains a mere one hundred calories in combination with vitamins C and B6 and minerals such as iron and potassium. Therefore, the most valuable asset of the potato is the balanced nutrition it provides. In addition, cultivating potatoes makes high crop yields possible, even on a limited surface area, or on less fertile land (Smith 2012: 7–9). The shift towards a more popular use from the second half of the eighteenth-century hints at the influence of new ideas about population, health and governance. State power was increasingly understood in terms of a strong, hearty, and active population, managed by a well-organised state apparatus (Earle 2017: 156). As such, political elites aimed to stimulate demographic growth as they strived to build their territories into modern states. The potato, with its high productivity and nutritional value, became essential to this end (Earle 2018: 640–1). Particularly after 1750, the diet of the 'working class' was made dependent on the potato, announcing the age of 'potato modernity' and eventually magnifying the impact of the potato disease in the 1840s.

Up until the middle of the eighteenth century, potatoes were frequently described as unworthy of human consumption. An early edition of the *Encyclopedia Britannica* even called it the 'demoralising esculent' (Reader 2009: 11). The changes in the *Encyclopédie* of Diderot and d'Alembert illustrate the elite-driven expansion of the potato as a popular agricultural crop. In the 1756 edition, an entry on 'Farmers' referred to potatoes as a familiar and miserable food, barely capable of sustaining human life. By contrast, in 1765, an encyclopaedic entry on 'Potatoes' described the potato as highly suitable for working people for providing abundant, healthy nutrition. In ten years, the *Encyclopédie* had shifted from describing the potato as barely a food crop at all, to identifying it as a hearty, nourishing substance whose only defects were its boring taste and windy qualities (Earle 2017: 151–2). In his *The Wealth of Nations,* published in 1776, Adam Smith—just as Arthur Young in his *Tour of Ireland* of 1780—promoted the potato as a food crop suited for the growing European population (Smith 2007 [1776]: 129–30).

However, following Thomas Malthus' pessimistic *Essay on the Principle of Population* published in 1798, more 'reflexive' and even overly gloomy visions gained ground as well. During the first decades of the nineteenth century, two members of the Horticultural Society of London, Thomas Knight and Joseph Sabine, expressed alarm about the rate by which the population was expanding because of the potato, especially in Ireland. Sabine acknowledged the potential of an enormous population increase on account of the potato. Yet, most of all, he underscored the negative implications of the potato's vulnerability to seasonal variations and its limited shelf life. He urged for caution, stating that 'a general failure of the year's crop, whenever it shall have become the chief or sole support of a country, must inevitably lead to all the misery of famine … .' Therefore, he advised the Society to select and import fresh collections of 'varieties of Potatoes, not only with superior qualities in flavour and productiveness, but which shall be less subject to injury by changes of weather when in growth, and which may possess the quality of keeping for a length of time … ' (Reader 2009: 193).

The concerns expressed by the Horticultural Society of London were prophetic. Potato production had grown into a monoculture-like enterprise and started showing evidence of degeneration as its production decreased in quantity and quality. Meanwhile, the rise of new industrialised sectors brought the productiveness of densely populated rural areas in Europe under pressure by the 1840s. Rural production sectors started to lose the commercial battle from mechanised production, making the quickly impoverishing population increasingly dependent on the potato. When *P. infestans* finally arrived, the consequences were devastating. We use the example of Flanders to illustrate how the potato disease got a foothold on the European countryside's potato fields so easily.

In Flanders, we find the potato settling in a region that had been marked by a relatively high population density during the period c. 1200–1400, with thriving medieval cities such as Bruges and Ghent. In the early modern period, population growth stagnated (Devos, Lambrecht & Paping 2011: 157–59). Yet, between 1750 and 1850, a new and unprecedented demographic transition occurred. The population grew 75 per cent, reaching a population density of 233 inhabitants per km² by 1850, which was a high rate at that time (Vanhaute 2007: 125). Especially rural areas, where most of the population had access to only a very small plot of land, saw a rise in population. The potato made the combination of swift population growth and land fragmentation viable. Additionally, the rural linen industry had been mobilized by poor households as a crucial income strategy, next to their agricultural activities. By the early nineteenth century, many rural areas had at least half of the labour force working part-time in the flax and linen industry (Thoen & Vanhaute 1999: 273). Yet, rural flax processing gradually lost ground in favour of cotton-spinning factories in industrial cities like Ghent, often called the 'Manchester of the Continent'. The most important destination for Flemish linen was the foreign market and export levels sharply fell from 4.5 million kg in 1835 to less than 2 million kg in 1848, to decrease further in the following decades. At the same time, the price of linen cloth was halved, and the income of spinners and weavers went into freefall.[4]

The governor of the province of West-Flanders raised awareness about this issue in the Provincial Council in July 1843. Rather than pleading for protectionist measures to safeguard the pre-industrialised linen industry, the governor embraced liberal political-economic measures. Just as the English Horticultural Society had done, he urged the councillors to import fresh stock to foster the productiveness of the potatoes cultivated in Flanders.[5] These imported varieties bore the significant names of *Lima, Péruviennes* and *Cordillières.* Authorities envisioned this as a rational measure to boost productiveness. Unfortunately, the shipments that crossed the Atlantic during the winter of 1843–1844, at the command of the regional government of West-Flanders, included a significant number of tubers infected by *P. infestans*.

Starting in June 1845, the fungus successfully caused an outbreak of potato late blight on these newly imported plants, and quickly spread to other potato plants. As a way of making sense of the strange, new, and contagious plant disease, detailed drawings of affected potatoes like the one in **Figure 3** were made.

Interestingly enough, at the same time as the West-Flemish governor was proposing this measure in the Provincial Council, the East Coast of North America was already afflicted by potato late blight, heavily affecting the harvests of 1843 to 1845. This makes it rather odd that the potato disease had taken all of Europe by surprise in 1845. Moreover, why was 'the West'–both the North American East Coast and north-western Europe–precisely hit at that moment, at the beginning of the 1840s? The sudden appearance of *P. infestans* must be understood in a context of intensified global interactions. The development of steam-powered shipping and the use of ice to prevent the deterioration of perishables facilitated the international trading of potatoes. As part of these interactions, North American and European farmers were also beginning to use *guano* (concentrated sea-bird droppings) imported from Peru as fertilisers (see more on guano trade in Cushman 2013). This new technique was part of a whole series of measures by means of which farmers gradually disconnected their agricultural practices from their natural environment, pressured by high population stress and a general quest for ever higher agricultural yields. The sudden and large-scale outbreak of potato late blight in the 1840s was linked to the monoculture logic that guided potato cultivation in Europe and North America. In regions with intensive agricultural production, such as Flanders and Ireland, the landscape became dotted with numerous homogeneous potato fields. The cultivation of only a limited number of potato species within a single field made these regions much more vulnerable to potato diseases than was the case in the Andes. Thanks to the practice of cultivating a great variety of potato species within the same plot (Zimmerer 1996), the Andes did not experience such large-scale famines as the West did during the 1840s.

Europe especially experienced high levels of excess mortality during the crisis years, albeit with strong regional differences depending on the overall agricultural and nutritional dependence on the potato, peasant property relations and income systems, and the resilience of local poor relief (Beeckaert & Vanhaute 2019). Ireland experienced the highest demographic impact: the potato famine killed about one million people, or one-eighth of the total population. In addition, there was a famine-driven wave of mass-emigration. In 1855, one quarter of native Irish men and women lived abroad (O Grada, Paping & Vanhaute 2007: 26–27). In Flanders, where the imported fungus destroyed almost 90 per cent of the potato harvest, mortality rates of 40 to 50 deaths per thousand inhabitants were registered (outliers go up to 80–100, practically one-tenth of the population) (Vanhaute 2007: 130–35).

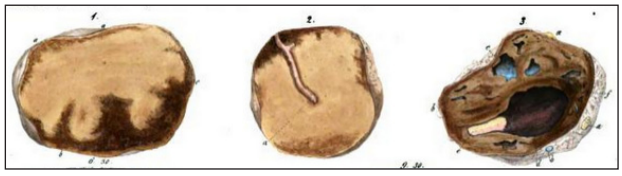

Figure 3: Drawing from 1845 'infected potato'. Credit: Harting 1846.

Whereas the transatlantic exchange of potatoes in 1840 was intended to solve the 'troubles of Flanders'—referring to the structural impoverishment of its rural population—precarious multispecies world-making turned against this seemingly rational solution. In the wake of the food crisis, deprivation, disease and, for many, even death followed. It is not by chance that the well-known expression 'La misère des Flandres' or 'Poor Flanders'—visualised in **Figure 4**—saw the light of day precisely when the decline of the linen industry and the potato crisis simultaneously hit the Flemish countryside.

After Invasion: The Scientific Production of *P. infestans* and Agro-industrial World-making

Up to the present, plant pathologists, relying on historical records and genetic research, conclude that clear evidence on *P. infestans*' whereabouts before the nineteenth-century late blight epidemics is still lacking. Among existing theories about the trajectories of the pathogen, Mexico is accepted as the centre of origin of *P. infestans* (Fry & Goodwin 1997: 363–71). In the late 1920s, Donald Reddick's findings of a wild potato infected with *P. infestans* in Central Mexico first challenged the general assumption that South America constituted the source of the pathogen (Reddick 1939: 410–12). However, this did not necessarily imply that the fungus reached Europe from Central America, as domesticated potatoes were not grown for export in Mexico in the 1840s and tuber blight was not common in the area (Abad & Abad 1997: 682; Andrivon 1996: 1027–35; Bourke 1964: 808; Ristaino 2002: 1371). Indications from historical writings and genetics suggest that the Andes cannot be completely disregarded as a possible departure point for *P. infestans*' transatlantic trajectory. Andrivon has suggested that *P. infestans* first migrated from Central Mexico to South America several centuries ago, then migrated from South America to the USA in 1841–1842, and eventually migrated to Europe from either South America, the USA or both in 1843–1844 (Andrivon 1996). In addition, Abad and Abad have stated that 'the disease has been endemic in the [Andean] area for centuries' (1997: 682). In 1907, the Belgian agronomist Georges Vanderghem, working in Peru, noted that *P. Infestans* 'exists since times immemorial in the Andes' (Abad & Abad 1997: 686). Adding to this theory is the role of the nineteenth-century Peruvian guano economy and the intense trade and transport links between the Andean region, the USA, and Europe; an element that was already mentioned in the 1840s by M. J. Berkeley who researched potato late blight in England (Berkeley 1846: 9–34). The fact that precisely *Lima*, *Peruviennes* and *Cordilières* were among the first potato varieties to be affected by the disease in Europe also suggests the fungus' Atlantic crossing from the Andes (Bourke 1964: 808).

When late blight was reaching epidemic proportions in the USA and Europe, *P. infestans* did not yet exist as a scientific fact. Nor did the specific disciplines exist that would dedicate their attention to this newly identified organism's whereabouts, its behaviour, and its effects. Until the full development of the natural sciences in the second half of the nineteenth century, *P. infestans* remained undetected. At the time of the disease, the cause of the potato plague was mainly attributed to climatic and meteorological factors such as wet and cool weather conditions. Farmers and agronomists tended to insist on the fungus being a symptom and not the cause of the disease (Turner 2005: 344). Some theoreticians, such as the Brussels-born pharmacist Léon Peeters, linked the disease to emerging industry and the associated air pollution. To target the polluting industry as the main culprit was an idea that also circulated within political circles. For example, the municipal council of Aaigem in Flanders noted 'that the contaminated rain, which is covered with coal, coal-laden clouds, must cause the disease of the potatoes.'[6]

The most common theories explained the cause of the disease by pointing to the degeneration of the plant itself. However, the phytopathological explanation—in other words the idea that the cause was a new inhabitant of the potato fields, a parasitic fungus—already circulated at that time, but remained overlooked. On 31 July 1845, about a week after Felicitas Rommel's diary observations, an article by Abbé Edouard van den Hecke (published in the Ghent newspaper *l'Organe des Flandres*) suggested that a fungus was causing the plague (Bourke 1964: 806). One year earlier, amateur botanist James E. Teschemacher, in Boston, USA, had come up with a fungal theory to explain the potato rot as well (Peterson, Campbell & Griffith 1992: 754). Speculations about fungi being responsible for plant diseases, that had circulated since the eighteenth century and were continuously dismissed, would only start to consolidate with the work of Charles Morren of Liege, Belgium. The Ghent-born medical doctor formulated his hypothesis in an open letter published on 20 August 1845 in the Brussels newspaper *l'Indépendence Belge* (Morren 1845). The letter was first distributed across Europe and was subsequently published in the USA, gaining support from several European and US scientists (Bourke 1964: 806; Wheeler 1981: 321). Yet the fungal theory would only become generally accepted after the scientific revolution in evolutionary microbiology instigated by the work of Pasteur during the 1850s and the German mycologist (fungal expert) Heinrich Anton de Bary during the 1860s (De Bary 1876). Borrowing Latour and Woolgar's argumentation (1986), we could say that de Bary constructed—rather than 'discovered'—*Phytophthora*

Figure 4: Misère des Flandres, 1848. Etching by Vandekerkhove. Credit: Collection Central Library KU Leuven, CAG 00001861. Also on www.hetvirtueleland.be, Centrum Agrarische Geschiedenis (CAG).

infestans as a scientific fact, confirming its existence by giving it its scientific Latin name in 1876 (Turner 2005: 345). The multispecies relations and controversies between scientists, farmers, potatoes, and microorganisms eventually produced not only a new species, *P. infestans*, but also a new discipline, phytopathology.

Since the famine of the 1840s, late blight had become one of the greatest threats to potato agriculture and remains a hugely feared disease. Once its carrier, *P. infestans*, had conquered Europe and the USA, it started to cause severe problems of late blight across the globe. In that context, *P. infestans* returned to Latin America. First scientific reports on late blight in South America appeared in the late nineteenth century, linked to the introduction of potatoes from Europe or the USA. The disease was reported in Argentina in 1887 and Brazil in 1898. In both cases, its presence was attributed to introduced potato species from Europe in the 1880s. In the early 1930s, Abbott reported on the presence of late blight in coastal Peru, nearby Lima, the same area where seed potatoes from Europe and the US had been introduced. Already by the late 1940s, the impact of late blight became severe, and started to appear in the higher areas, as well as in other Andean countries such as Bolivia and Chile (Niederhauser 1991: 25–29).

In response to the pathogen's spread, phytopathology developed not only the tools to explain, but also to solve the causes of the potato disease, using bioscientific applications, including the breeding of disease resistant potato varieties, and, as the hopes in the former faded, the production of chemical pesticides (Turner 2005: 347–52, 366). Chemical disease control, along with crop improvement and intensified fertilizer use, really started to develop from the 1940s on, shaping a global Green Revolution. Before this, farmers had used inorganic chemical products, usually prepared by themselves. In the following decades, research and development of a multiplicity of chemicals and related patents boosted a growing global fungicide market, dominated by scientists and companies in the North (Russell 2005).

Phytophthora infestans was no longer an invisible companion but a destructive invasive species. Its global spread fuelled the emergence of an agro-industrial complex, supported by new agricultural inputs, international marketing strategies, and (supra)national government policies that embraced potato agriculture as a stronghold for development. Global potato agriculture was backed by institutions such as the Rockefeller Foundation and the International Potato Centre (CIP by its Spanish initials), founded in 1971 and housed at the National Agrarian University 'La Molina' in Lima, Peru, where it preserves more than 4.500 edible species in an ex-situ gene bank. The potato grew into a key food staple in the developing world, driven by a form of 'potato evangelism' that pledged to tackle poverty (Turner 2005: 367). But already in the 1950s, the development of fungicide resistance and the appearance of new genotypes of the pathogen started to undermine this complex. In the 1980s–1990s, potato late blight resurged internationally in epidemic proportions, prompting the CIP to make late blight a global research priority (Turner 2005: 367). The return of *P. infestans* also fostered an interest in historical research among plant pathologists who tried to find out the origin and trajectory of the pathogen populations that arrived in Europe in the early nineteenth century (Andrivon 1996; Abad & Abad 1997; Fry & Goodwin 1997; Ristaino 2002; Ristaino, Groves & Parra 2001: 695–97).

Global potato policies made farmers worldwide vulnerable not just to the potato's hypersensitivity, but also to a market-dependent agro-industrial model, while often displacing native root vegetables. Papua New Guinea underwent this precarious historical process towards entangled potato cultivation, technoscientific infrastructure and development policies within a matter of decades. While the potato was only introduced in the island country in the 1970s, *P. infestans* invaded Papua New Guinea's potato fields merely 30 years later, in 2003 (Reader 2009: 261). This led to an intervention by the CIP which, after introducing newly created seed tubers, continued to play an important supervising role that kept the Papuan farmers in a dependent position, justified by science. The Papuan potato story holds an important lesson about the limits of contemporary development politics. The FAO's International Year of the Potato and the—now reformulated—Millennium Development Goals assigned a star role to the potato in the global fight against poverty (FAO 2008). Yet, for Papuan peasant villages, accepting the promises of the potato implied accepting the terms of a global potato business, with longer-term consequences reflected in deepening regional inequalities (Reader 2009: 261). On the losing side of this business, potato peasants were confronted with the financial costs and the environmentally damaging impact of fungicide spraying (Zubrod et al. 2019).

At every step of the scientific quest towards a post-late blight world, the potato crisis continues to be explicitly invoked as the *raison d'être* of scientists' work and development policies. Headlines about potato agriculture's adoption of genetically modified organisms (GMO) 'That Could Have Prevented the Irish Potato Famine' raise hopes that what fungicides are unable to do may be achieved through new biotechnological solutions (Schultz 2014). Growing evidence on hazardous and expensive fungicide excesses now serve to create an opening for biotechnological applications. With the development of a GMO that is resistant to the potato tuber moth (*Phthorimaea operculella*)—symbolically named *revolución*—in 2007, the CIP has joined the bio-technological turn. In the years since, several research centres, including some of CIP's branches, have developed GM potatoes resistant to *P. infestans*. Peruvian potato producers, however, received the news about genetically modified developments as a threat, and mobilised. 'Yes, they may pay more for the seed,' confesses one scientist working on late blight resistant GM potatoes in response to objections to GMOs, 'but they will spend an awful lot less on fungicide' (McGrath 2014).

While GM potatoes bank on the promise of fungicide-free agriculture, their embeddedness in an expanding agro-industrial production system that relies on private

property and free market mechanisms, carries the seeds of deepening dependence and conflict. In 2011, when Peru decided to open the market for genetically modified products, peasants, in coalition with academics, activists and Peru's booming gastronomy sector, managed to pressure the government to adopt a ten-year moratorium on the import of genetically modified seeds (Hernández & Cavero 2013; Efe 2011). Invoking Andean, collective, ways of world-making through potato cultivation that counter Western individualism and profit-seeking, small-scale potato farmers' resistance is not a naïve refusal of technology and improvement as such, but an awareness of the limits of technoscience 'solutions' (GRAIN 2007; Dondanville & Dougherty 2020). Like other anti-GMO protests around the globe, Peruvian potato communities highlight and resist the imposition and normalisation of an agro-industrial production model that undermines Andean agro-biodiversity, communal autonomy and food sovereignty (Van Dyck et al 2021).

Moving from agrochemicals to biotechnology, a powerful agro-industrial complex thrives on ecological and social exhaustion. The continuous spectre of the late blight serves to push the frontiers of biotechnology, deepening the human/nature divide ever more, on a planetary and even on an extra-planetary scale. To illustrate, in 2015, CIP launched a programme in a collaboration with NASA to grow potatoes under Martian conditions. The 'Potatoes on Mars' programme is justified by its objective 'to raise awareness of the incredible resilience of potatoes, and fund further research and farming in devastated areas across the globe where malnutrition and poverty are rife and climbing' (CIP 2015). Similar to biotechnological interventions to combat the plague, the space experiment seeks to appropriate the ruins of monocrop harvest failures. Spurred by the promises of the potato and the spectre of invading spores, we seem to be nearing a phase of multispecies galaxy-making.

Living with Invasion: Enclosure versus Co-habitation

Human intervention in the form of genetic modification seems to disregard that multispecies world-making is not a rational, linear process. By adding new varieties to the rich diversity of existing potato varieties, genetic modification overlooks how 'in multispecies landscapes, social persons of many species interact, variously shaping each other's' lives' (Tsing 2014: 223–4). Even when driven by sincere altruism, this modernist intervention is steeped in a form of hubris. This is exemplified by the nineteenth-century European famine, as well as by contemporary processes that contribute to the erasure of the agro-ecological worldview, knowledge, and 'polyculture' practices of Andean communities (Cuvi 2018: 81). Based on an intimate relation with their complex and diverse natural environment, these rural communities kept the thriving of *P. infestans* in check over centuries. The gradual loss of polycultural practices can be perceived as a multispecies landscape enclosure. This process goes beyond the mere physical enclosure of peasant communities, at the brink of losing land and water access when entering in competition with big GM players. More broadly, at the level of nature-humanity interactions and knowledge production, the expansive drive of 'potato modernity' not simply ignores, but actively destabilises inter-generationally transmitted and locally embedded (multispecies) knowledge regimes.

In the Andes, the plague that Europeans scientifically 'discovered' and categorised with an appropriate Latin name, is approached with a local terminology. A peasant wisdom, collected by Peruvian potato specialist Vidal Villagómez, explains: 'Many diseases affect the potato, those known as when there is excessive rain and low clouds cover the crop. This is how it appears—the 'rancha' arrives when the plant acquires a leaden colour. Then it blackens and then dries' (authors' translation, Villagómez 2004: 42). Another poem, composed by Vidal in quechua on the basis of oral Andean peasant traditions, indicates the 'pinku-pinkuta' (quechua for the herb horsetail or *Equisetum Bogetense*, which is applied as an organic fungicide) as the standard remedy for 'la rancha.' These are indications of how Andean agrarian practices—and even cultural heritage—have integrated the presence of late blight and its potential social and economic damage. Accepting rather than criminalising its invasive characteristic, Andean peasant societies have developed a form of negotiation with *P. Infestans*, safeguarding the possibility of co-habitation.

The *Parque de la Papa*, an association of six indigenous potato-producing communities in the highlands of Peru, presents itself as a viable and concrete response to the need to preserve and reproduce this kind of Andean knowledge. Supported by a local NGO, these communities joined forces in 2002 with the aim of securing sustainable livelihoods and stewarding the incredible levels of potato bio-cultural diversity in the face of mounting climatic challenges in the cradle of potato domestication (Hernández & Cavero 2013: 11–16). The everyday reproduction of this community-managed landscape is guided by a novel perspective on the conservation of Andean biogenetic patrimony *in situ*, which Olivia Angé—informed by ethnographic research on the 'affective encounters' between people and tubers in the *Parque de la Papa*—describes as 'interspecies respect' (2018: 30–40). In advancing a workable dialogue between different forms of knowledge (Cuvi 2018: 86), these kinds of initiatives actively seek to re-balance forms of multispecies world-making on a damaged planet (Tsing et al. 2017).

Our Face Turned Towards the Past: Historians in a More-Than-Human World

By approaching the potato and its companion's transatlantic voyages in a more-than-human and historical perspective, we unveil the nineteenth-century famine as an instance of what Tsing describes as unintended world-making through multispecies encounters (2014: 223). State- and market-driven interventions to boost potato productivity sought to reorganise rural landscapes into controllable, plantation-like structures. These human designs were constantly undermined by unexpected multispecies responses, in which peasants, fungi and potato varieties collaborated. As a result, the way in which

the potato was incorporated within European agricultural practices shaped a 'patchy' (Tsing, Mathew & Bubandt 2019) and 'intricate but unintended' (Tsing 2014: 223) world that partially exceeds human control.

Through transatlantic mobility and exchange, people, potatoes, and fungi entangled in a way that could not be grasped by human planning and management. Rather than being the result of planned knowledge exchange between botanist elites, the introduction of the potato in Europe is exposed as a spontaneous bottom-up trajectory through commercial trade and fiscal wartime survival strategies, leading to co-habitation between European peasants and potatoes. Only after circa 1750, potato production entered a new phase as competing political elites on the European continent instrumentalised the potato to enable a productivity growth to feed a fast growing and impoverishing population. It gave rise to the age of 'potato modernity', characterised by an unsustainable potato monoculture.

European elites' response to the limits of potato cultivation relied on intensified transatlantic exchange, facilitating the adoption of new varieties from the Andes, which led to the introduction of *P. infestans* in North America and Europa. Between 1845 and 1850, European potato harvests failed, leading to widespread devastation. In response to late blight, novel scientific branches and sophisticated theories on new species and their behaviour saw the light, constructing *P. infestans* as a scientific fact and framing its presence and performance as a hazardous invasive species.

Sustained by a modernist and Cartesian worldview, these responses are marked by the lack of consideration of the possibilities for co-habitation. Approaching the natural world as separated from—and hence manageable by—humanity, this perspective essentially ignores the reality of precarious multispecies coexistence. By contrast, multispecies 'polycultures' in the Andes propagate the cultivation of a wide variety of potato species, a form of affective multispecies co-habitation that seems to have prevented the occurrence of large-scale harvest failures in the Andes for centuries. All this time, a fungus that later came to be known as *P. Infestans* remained unnoticed, organizing its life outside human designs.

From the early-modern introduction of a selected set of potato varieties in European soils to the current globalised potato economy, people's understanding of how worlds are made according to 'unintended designs' that guided the contact, negotiation and collaboration between different species has been erased. The inattentiveness to unintended design not only caused the famine of the 1840s, but it also guided the responses to this crisis and keeps on powering the development of an agro-industrial complex to which a damaged planet offers fresh terrain for modernisation and economic growth. Today, genetically modified potatoes seek their entrance in South America, backed by a Cartesian approach to human-nature relations in and around potato fields. Far from resolving precarious multispecies entanglement, biotechnology's claims only announce a new phase in a longer contentious history of 'potato modernity'.

Notes

[1] A short entry on the link between Flanders and the European potato late blight crisis of 1845 has been published in Dutch in the compilation *World History of Flanders* (Bruneel, Beeckaert & Cottyn 2018).

[2] Pedro de Cieza de León, 1553 (translation by C.R. Markham (1864). *The Travels of Pedro Cieza de Leon.* 1st series, vol. 33. London: Hakluyt Society, 68), cited in Reader (2009: 69).

[3] Authors' translation. Chris Vandenbroeke, 'Aardappelteelt En Aardappelverbruik in de 17e En 18e Eeuw', *Tijdschrift Voor Geschiedenis* 82, no. 1 (1969): 51.

[4] Guillaume Jacquemyns, *Histoire de La Crise Économique Des Flandres (1845–1850)* (Bruxelles: Maurice Lamertin, 1929), 163.; cited in Vanhaute, 'So Worthy an Example to Ireland', 133.

[5] Provinciaal Archief West-Vlaanderen, BE PAWV A/G.A., *Procès-verbaux des Séances du Conseil provincial de la Flandre Occidentale. Session de 1843*, 8–9.

[6] Authors' translation. Vanhaute, Database 'Arm Vlaanderen', Aaigem (Correspondence 15 Septembre 1853), Ghent University.

Competing Interests

The authors have no competing interests to declare.

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