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The Hidden "*Hot Zone*"

An Epidemic in Two Parts

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The Hidden "*Hot Zone*"
An Epidemic in Two Parts

Phytophthora infestans is a "Hot Zone" disease that has been vastly more deadly than the *Ebola* virus recently made famous in books and cinema. It attacks the species *Homo sapiens* by cutting off its food supply.

P. infestans, also known as "late potato blight", is the fungus that caused the Great Potato Famine of 1845-49, resulting in starvation and death for millions. One hundred and fifty years after the fungus decimated food production around the world, the blight is back again in new and deadlier forms. Mutating rapidly, the disease is outwitting known chemical agents. Flamethrowers are now used to burn off *P. infestans'* most virulent strains.

The new epidemic threatens not only a (US) $160,000 million commercial potato crop in western industrialized countries. The threat is far greater in many parts of Africa, Asia and Eastern Europe where potatoes have become a major subsistence crop for the poor. If the harvest of 1995-96 fails, the lives and livelihoods of millions of poor people will be imperiled.

P. infestans--and the issue of food security--will be discussed by NGOs and governments around the world at the FAO's 50th Anniversary Food Security Conference in Quebec City, 15-19 October. As with the epidemic of 1845, the threatened epidemic of the mid-1990s may kill because of two blights: The disease itself, and the unwillingness of governments to wage a true war against hunger.

Part One - Epidemics of the *Phytophthora* Disease

The First Epidemic (1845-1860)

Although we can never be completely certain, analysis of both nuclear and mitochondrial DNA fingerprints and of *Phytophthora infestans'* allozyme, argues strongly that the disease lived undisturbed in the shadow of the Toluca Volcano, for perhaps thousands of years.[1] As a fungus, it propagated clonally and gradually mutated in the cool humid forests that dominated the valleys of Mexico's central highlands. Then in 1530, the Spaniards pushed into the region and the Cortez family turned the Toluca valley into its personal fiefdom - burning the forest into farmland. Sometime, possibly early in the 19th century, the relatively benign fungus expanded from its forest hosts to other species.[2] What havoc it may have wrought among the Otomi, Huastec, and other agriculturalists is not recorded.[3] The Huastec however, practiced, as they do to this day, a highly-sophisticated form of forest management known as *te'lom* which allowed them to utilize as many as 300 different forest species including 81 species directly for food.[4] Such a diversified production strategy would have kept *P. infestans* in check at least up until the time the Spanish introduced crop monoculture.

Researcher William Fry at Cornell University theorizes that an American biologist may have accidentally brought *P. infestans* home with him from an expedition to the volcano in the early 1840's,[5] not long before American soldiers occupied the region during the Mexican-American War. What is known is that sometime in the autumn of 1843, the outbreak of a devastating new disease was reported in Philadelphia. Somewhere in the city's outskirts an epidemic was boiling, and no antidote was available. Whether it was a change in the weather - which had grown unseasonably cool and rainy - or some other factor, the disease did not advance further. Worries subsided until the following year - again in the autumn - when the disease seems to have hopped to the maritime provinces of Canada and the American mid-west.[6] It killed wherever it landed. The disease appeared to have been airborne - capable of moving as much as three or four miles a day. Wherever it landed, destruction occurred within 24 hours.[7] But, once again, as quickly as it came, the disease faded into the background. Although it never truly disappeared, and indeed, returned from time to time to repeat its destruction, it never reaped the ruin in North America that it was about to visit upon Europe.

In June of 1845, *Phytophthora infestans* struck again. Belgian newspapers reported the first signs of the disease, and the country braced itself for disaster. Throughout the summer, *P. Infestans* surfaced in the Netherlands and then Germany. Not long thereafter, it appeared on the fringes of Moscow, ravaging Spain out to the Canary Islands, and searing the Balkans.

On August 17, 1845, newspapers announced the arrival of the deadly fungus in Ireland. On October 15th, the British Prime Minister declared Ireland to be a disaster. The disease swept from one shore to the other almost overnight and, for almost four years, held sway over the lives of millions. Before it faded - but, as in America, never vanished - more than a million (perhaps as many as 1.5 million) Irish were dead, and a quarter of the population had fled.[8]

There were sporadic rumours of the fungus's continuing devastation... stories from Spain and the Balkans, tales of destruction as far away as China, and in parts of Africa hardly known to Europeans. Modern DNA probes now show these rumours to have been true. The disease even doubled back from Europe into Brazil where its impact was the same as everywhere else. By the 1860s, however, the rumours petered out and the world gradually forgot. All that was left were the unmarked mass graves and the continuing devastation to the psyche of the nations and the families who survived.

The Second Epidemic (1981- ?)

The fungus remained a muted force among the poor for more than a century - but it never again reached the heights of destruction felt in the 1840s. Far away in the Toluca valley, towns and cities grew, and farmlands spread. The forest was slowly swallowed up - where the dairy herds did not wander, mines were bored into the sides of the volcano.

Then, in the mid-1970s, the disease broke free of the volcano's shadow once again. Epidemiologists know for a certainty that a more aggressive strain (dubbed genotype *A2*) of *P. infestans* was found in Switzerland in 1981, and that scientific evidence traces the pathogen back to the central highlands of Mexico. The disease may have come to Europe as a byproduct of the extensive agricultural trade between the two regions in the 1970s. The "new" *P. infestans* also struck The Netherlands and Germany in 1981. The UK was hit in 1984, and the disease materialized in Poland in 1988[9] and Ireland in 1989.

According to Dutch and American investigators pursuing the fungus, European traders - likely Belgian and Dutch - inadvertently carried the disease with them to Egypt in '84, Japan in '85, and then to points as diverse as Rwanda, Israel, and Brazil in the late 1980s. By the beginning of the 1990s, Korea, The Philippines, Taiwan, and Bolivia all reported outbreaks of the new *A2* strain. In every encounter, the disease mysteriously presented itself only to fade, reappear, and fade again, causing limited but recurring destruction. Some claimed it was the cool, humid weather that brought it on. Others simply counted their blessings.

The disease also continued to invade other hosts. As best as can be surmised, it infected tomato seedlings, shipped from either the Toluca Valley or, possibly, northern Mexico, destined for Florida and California. When rot was discovered, the infected tomatoes were probably composted. Somehow *P. infestans* survived. Somehow, the new disease strain in its new host slipped back into Pennsylvania, New York, and Washington.

In 1992, epidemiologists noticed that *P. infestans* had changed. Evidence suggests that the two strains of the disease, types *A1* and *A2*, converged sometime that year in a field in British Colombia on Canada's Pacific coast. Not only were there two distinct types of the same Mexican disease together, they were mutating rapidly and multiplying differently. Where the fungus had previously evolved ponderously through clonal reproduction, the convergence in Canada's far west meant the disease could now propagate, much more aggressively, sexually.

In 1994, like a tropical depression, *P. infestans* gained hurricane force and leapt through the United States and Canada. The old variations of Type *A1* such as *US-1* were pushed aside - not by the aggressive *US-7* and *US-8* strains of a year earlier, but by sexually-reproducing *BC-1* and then *US-11* and on to *US-14*.[10] Scientific sleuths tracking *P. infestans* counted numerous different strains of the fungus - each more vicious than the last - and the newest forms were resistant to every available chemical remedy.

In 1994 or perhaps earlier, as it had 149 years before, the new strains appear to have bridged the Atlantic and begun another march through Europe. Whether via the United States, or through a separate pathogenic migration, the disease is also spreading from cargo shipments originating in Belgium and the Netherlands to Rwanda and other parts

Chronology of a Pandemic *Phytophthora Infestans*

First Epidemic

1840 U.S. biologist returns from Toluca Valley (Mexico) with disease;
1843 Disease breaks out in Pennsylvania (USA);
1844 Disease spreads throughout eastern North America;
1845 *P. infestans* reaches Belgium - spreads throughout Europe;
1845+ Disease appears in Asia, Africa, and Brazil;
1860 *P. infestans* loses some of its virulence, slips into background, but remains a recurring problem in many parts of the world.

Second Epidemic

1981 New, more virulent, strain of *P. infestans* arrives in Switzerland from Toluca Valley;
1981+ Type *A2* strain appears in various parts of Europe, Asia, and Latin America;
1992 Sexual reproduction between Types *A1* and *A2* discovered in Canada;
1992+ New strains multiply and spread throughout North America.

of central Africa - and again to Latin America via Bolivia and Ecuador. In the closing quarter of 1995, investigators know they are dealing with one of the most dangerous pandemics the world has ever seen - deadly and, so far, utterly unstoppable. They can only hope that the weather - or whatever controls its progress - will put an end to it before the blight kills as it did one hundred and fifty years ago.

Phytophthora infestans

P. infestans is a "Hot Zone" disease that has been vastly more deadly than the *Ebola* virus made famous recently. It attacks the species *Homo sapiens* by cutting off its food supply. *P. infestans* is the fungus that raged through Ireland causing the great potato famine of 1845-49. At least a million died, and millions more risked treacherous ocean crossings to begin new lives on the farthest shores of the Baltic Sea and North America. While the destruction of Ireland was the most horrific example of the fungus's effect, it caused death and starvation wherever it went. In La Laguna, Canary Islands, the "late potato blight" began a series of human and natural disasters that plagued the region for the remainder of the century. Locusts, drought, and storms followed on the heels of repressive taxation and the collapse of the cochineal industry. In the Balkan Duchy of Carniola, the fungus's blight lingered on into the 1860s, smashing the population year after year with the same ferocity as their Hapsburg rulers. If the death rate was lower in the Netherlands, the social and economic impact remained enormous. Dutch Corn Laws were repealed as they had been in the UK, and tax laws were restructured - for once to support those afflicted by *P. infestans* - as they had not been in the UK.

With such a history, it is understandable that even the hint of a new potato famine has doubled potato prices in some parts of the United Kingdom. [12] Last year, farmers in New York State hit by the blight, had $100 million in crop losses added to another $100 million in extraordinary expenses trying to contain the disease. With more virulent forms of the disease cropping up in Idaho's Treasure Valley region, farmers are bracing for an assault on their $587 million potato harvest, and the State is alarmed that their $2.6 billion potato-processing industry is in jeopardy.[12] This pales in comparison to the worldwide implications of a new pandemic. When RAFI first began tracking the path of *P. infestans* in 1992, the farmgate value of the global potato market was $40 billion and the world potato industry - including processing - was valued at $160 billion. [13]

Food Security

The real threat, however, lies neither in western Europe nor in North America. From a crop originally domesticated in the Andes, and later cultivated in Central America, the potato has risen to become - after rice and wheat - one of the world's most critical sources of carbohydrates and a farm product for 129 countries. Since the 1970s, international agricultural research programmes have evangelized the undoubted merits of the bountiful tuber throughout Africa and Asia. The "biological (nutritional) value" of the potato ranks second only to eggs, and is well-ahead of wheat or beans. A strong case was made that the potato produces more food - of higher dietary value - per hectare than any other crop.

Yet, in retrospect, the evangelism seems a little overblown. Even as the *A2* strain began its latest march across Europe, the International Potato Centre (CIP) in Lima, Peru, released an epistle from one of its economists arguing that policy-makers in the South "grossly underestimate" the economic and nutritional merits of the potato. Decrying the fact that farmers in the South "account for only 15%" of the world's cultivated potatoes, CIP identified the

barriers to increasing potato production as unfounded historic biases and astronomic, unjustifiable production costs (commercial tuber seed in the late seventies could cost as much as U.S. $1,000 per hectare).[14] There was not a word from CIP about *P. infestans* and the ongoing ravages of even the original *A1* strain.

Belgian and Dutch seed potato companies were quick to follow public research programmes selling their own varieties throughout the Third World. Seed companies created markets in the Middle East and East Asia. The trade also looped back from the Benelux countries to the crop's centre of genetic diversity in the Andes. The fungus tagged along. Outbreaks of the more aggressive disease genotype have been identified in Bolivia, Ecuador, Colombia, and Brazil.

Seed company interest in the Third World market grew as the potato acreage in the North declined. Between 1961 and 1991, land sown to the crop in industrialized countries was almost halved. During the same period, acreage doubled in Asia and almost tripled in Africa, making the South the growth market for commercial potato varieties.[15]

The New Irish

As it was 150 years ago, potatoes continue to be the crop of the poor. Some of the world's poorest countries have been encouraged to plant potatoes as a new staple. Researchers now speculate that the original strain of *P. infestans* spread accidentally from Belgian missionaries into east and central Africa (Rwanda, Zaire, Burundi, Uganda) decades ago.

Today, about 110,000 hectares of this highland area - on both sides of the Zaire-Nile Divide, are seeded by small farmers with half-hectare plots, with the new crop. Three-quarters of their harvest goes for home consumption.[16] (Ironically, the Zaire-Nile Divide is thought by many medical researchers to be the original home of that other global scourge - AIDS, and also of the *Ebola* virus.) In this troubled region, potatoes can mean the difference between survival and starvation.

The "new Irish," the Europeans who are likely to suffer most from a new blight, are the Poles, Russians, Ukrainians and (east) Germans, who eat as much as two or three times the quantity of potatoes consumed in Ireland.[17] Russia is the world's number one potato producer.[18] A crop failure in eastern Europe or the republics of the former USSR could have disastrous human consequences.

Late Potato Blight *Phytophthora Infestans*

The fungus, *P. Infestans* is indigenous to the central highlands of Mexico. In some respects, the disease acts more like an algae than it does its closer relatives. Late Potato Blight actually afflicts both potatoes and tomatoes (and their related species). It strikes under cool humid conditions just before harvest, and can turn a 300 hectare field into mush within 24 hours, causing lesions and dry rot in the tubers. The first evidence of the infestation is usually grey spots on the foliage which quickly turn into a cottony film that envelopes the plant.

Propagating clonally, the 1840s epidemic included several strains of genotype *A1*. The much more aggressive genotype *A2* first appeared in the 1980s. The fungus can abandon its clonal form of reproduction for sexual reproduction when types *A1* and *A2* occur in the same field. This was discovered in Canada in 1992. Since then, the two types - with numerous new strains - have been found in several other U.S. States. *P. infestans* travels by air in two respects: air currents can carry it 3-4 miles a day, and with today's aircraft, cargoes of diseased potatoes and tomatoes can reach any corner of the globe within 24 hours. It is often difficult to detect the disease on seed potatoes until it is too late.

Despite the alarm for the African highlands and eastern Europe, perhaps the greatest danger lies back in the Andes. If the sexually-mutating strains of *P. infestans*, a disease that started on the slopes of the Toluca volcano, reach the shores of Lake Titicaca - where potatoes have been grown for almost 6,000 years,[19] then the genetic diversity of the world crop could be wiped out. The entire world depends upon the unique Aymara and Quechua-bred cultivars (and their associated species) sown throughout the region. There is a real risk that the fungus could eat away the genetic resources we will need to defeat it.

If potato breeders were unduly complacent about late potato blight in the sixties and seventies, they were properly alarmed by the mid-eighties. By 1992, CIP estimated that the disease was cutting Third World yields by 30% and that fungicide control campaigns related to late potato blight were costing the Third World $600 million each year. (Global fungicide costs are estimated to be $1.8 billion - making potatoes the most chemically-intensive food crop in the world.)[20] In a frantic effort to outbreed the fast-mutating fungus, CIP released more than 250 new potato clones to 27 countries around the world. Among the hardest hit locations are Rubengeri in Rwanda and Rio Negro in Colombia.[21] Scientists recognize, however, that nothing offers farmers or consumers true security. The lives of millions - and the livelihoods of hundreds of millions - depend on the weather at harvest time this year.

Blight Blunders

Herein resides a mystery. The only widely-used fungicide effective against the disease was, like the new strain itself, from Switzerland. Metalaxyl, developed by Swiss giant Ciba-Geigy, had proven effective against the original 1840s strain that had reappeared in Switzerland in 1981.[22] Sold under the trade names *Ridomil*, *Apron*, *Subdue*, and *Acylon*, metalaxyl was impotent in the face of later forms of the *A1* fungus as well as *A2* strains. Some researchers maintain that metalaxyl, accidentally but inevitably, created the more aggressive disease by forcing the fungus to mutate around the chemical for its own survival. The worry now is that fear of the new strains will push governments to accept even more potent chemicals, contributing to a toxic cycle and disease that will only threaten humanity further.

There are also grounds for questioning the breeding strategies of both public and private institutions. Starting years ago, in order to fend off the *A1* strain, breeders opted for a strategy of single-gene vertical disease resistance, creating a series of short-lived fungus resistant potatoes. Heroically - but (in retrospect) rather absurdly - sacrificing one resistant gene ("*R-genes*") after another until a series of 16 *R-genes* had been thrown into commercial potatoes. The *A1* resistance conferred by each of the "new" genes was quickly overcome by a fungus that grew leaner and meaner with each fight. The first *R-gene* worked for six years. By the time breeders released the sixth *R-gene*, the crop could barely survive a season. Breeders now agree that single-gene resistance was a bad idea. The only real beneficiary was Ciba-Geigy - still selling metalaxyl to ever more desperate farmers.

At least in part, the present threat is the product of over-enthusiastic potato evangelism - backstopped by aggressive company marketing; foolish breeding strategies; and reliance on a single commercial fungicide.

Part Two - The Part of the Political Disease

Wakes and Anniversaries

The potato harvest in eastern Canada and the United States this year will be taking place under auspicious circumstances. It was on the 15th of October exactly 150 years ago that the British Government acknowledged that the potato crop in Ireland had failed. Over the following years, tens of thousands of Irish refugees washed up on a little island in the St. Lawrence River near Quebec City known as Grosse Isle. The largest mass graves in Canada are still to be seen on that island. One hundred years - plus a day - after the British recognized the Irish famine, government delegates from an independent Ireland joined their British counterparts and delegations from 42 other countries in Quebec City to establish the first United Nations agency - the UN Food and Agriculture Organization - dedicated (in the altruistic postwar glow of atomic radiation) to end famine. On October 16th this year, Agriculture Ministers from 165 nations will convene at the Chateau Frontenac in Quebec City to mark FAO's fiftieth anniversary with a special conference on world food security.

FAO Focus: Investment Security?

As every politician knows, you can't hold a conference on food security without a clarion call for a war against hunger. This was said in 1945 when conference chair, Lester Pearson (later Canadian Prime Minister) called for "Welfare not Warfare."[23] (Rather more cynically, U.S. State Secretary Dean Acheson said that FAO's task was to bring "hot meals to Hottentots").[24]

One of the 1995 conference's major tasks will be to approve a draft declaration that will be signed by Heads of State at a Food Summit next year. To date, the draft being considered reads more like a stockholders' report than a campaign to vanquish starvation. The word "farmer" arises only once in the brief document. "Investment" or "investor," on the other hand, appears 22 times - more often than FAO refers to "government." Exchange or interest rates and discussion of GATT's Uruguay Round are more common than the word "hunger." There are more references to the economic or investment "environment" than to the ecological "environment." On the only occasion in the draft Declaration where the word "sanctity" arises, it is in the context of the "sanctity of contracts." The solution to world hunger, it would seem, lies in private investment and the marketplace. This is the language of the IMF, the World Bank and the World Trade Organization - not of a United Nations agency dedicated to a war against hunger.

It is also, however, the language of the potato famine. Responding to criticism that the British were not buying enough food to feed the starving Irish, the government's famine coordinator replied, "Our purchases, as I have more than once informed you, have been carried out to the utmost limit short of seriously raising the price in the London market."[25]

Historians could well argue that the havoc wrecked in the 1840s was not caused so much by *P. infestans* as by private investment and the marketplace. Historians concur that there was never a food shortage in Ireland. For every shipload of usually indigestible food aid that reached Irish docks, six or more shiploads of cereal crops left the same ports for markets in England and Europe. The hungry had no control over this hemorrhaging of food stocks abroad.

The land tenure system, taxation, and the mercantile theories of the time were what killed people. As it was in Ireland,

so it was in La Laguna where Spanish tyranny and the replacement of cochineal with aniline dyes threw the unemployed and landless onto the vicissitudes of a devastated potato crop. Thus, it was also in the little Duchy of Carniola where Hapsburg rule exacerbated the crisis. In every case, *P. infestans* brought to a crisis a blight already imposed by *P. investments*.

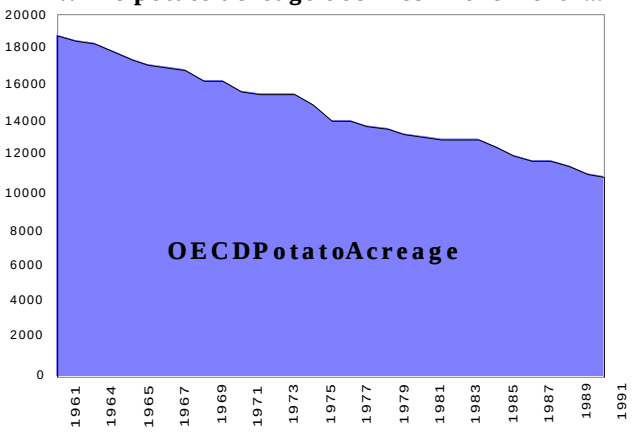
We seem to be turning full circle. One hundred and fifty years ago, a fungus slipped out of the Toluca Valley through the USA and Canada to decimate Ireland and terrorize Europe. Today, more virulent forms of the same fungus have again escaped the eroded forests of Toluca to sweep across North America into Europe and, propelled by international trade, to the Third World. In 1845, the solution to hunger was a free market. In 1995, the answer is said to be the same. As Canadians celebrate their Thanksgiving in mid-October, they might better place their faith in the weather.

Genetic Diversity/Vulnerability
Potato

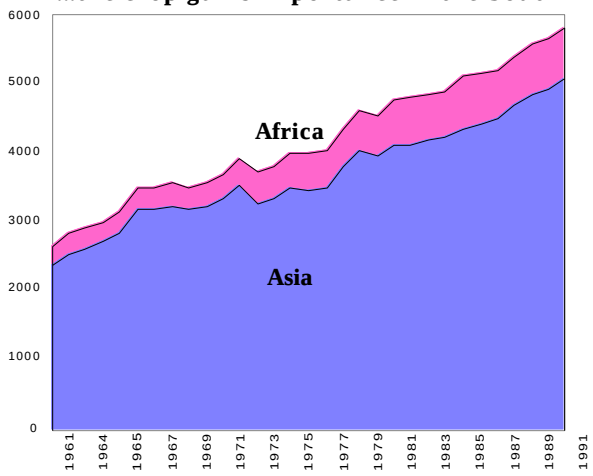
The centre of origin for the cultivated potato lies in the Andes of South America. European invaders brought the tuber home where it spread gradually throughout Europe. In many parts - but nowhere more than Ireland - it became the staple food of poor people. Imported from the Andes, the European potato had none of the genetic diversity of the South American crop. Thus, it was highly susceptible to diseases. In Ireland, the "Lumper" potato of the peasants was high-yielding, but highly-vulnerable to late blight.

The world potato crop (outside of the Andes) continues to be genetically highly-uniform and highly-vulnerable to disease. This is in part because potatoes propagate clonally, and partly because the risk of diseased tubers imposes special constraints for breeders and traders. Following a 1970 blight in the U.S. maize crop, a study of the American potato crop revealed that farmers and consumers were at high risk, and that the crop could easily be destroyed by a fast-changing infestation. Two potato varieties accounted for almost half of the entire U.S. crop at the time. Nothing has ch

While potato acreage declines in the North...



...the crop gains importance in the South



Reference: **DD3-pot.318/p486 14 August 1995**

What Can Be Done?

1. Support must be given to indigenous agricultural communities in Mexico, Central America, and the Andes, who are already breeding genetically-diverse potatoes. If there will ever be a sustainable non-toxic solution to late potato blight, it will be developed with these farmers from their breeding materials.

2. National and international farming systems and disease research initiatives - such as those developed by Mexico and CIP - should be supported by the international community. However, these initiatives should emphasize national collaboration with farmers directed toward sustainable (non-chemical) farming systems and breeding strategies.

3. Governments and NGOs attending the food security symposium and FAO 50th anniversary conference in Quebec City in October, 1995 should discuss the threat to the potato crop, the threat to food security posed by the genetic vulnerability of crops, and should consider steps to address the new potato famine.

4. Governments and NGOs participating in the **FAO Fourth International Technical Conference on Plant Genetic Resources** (Leipzig, Germany, June, 1996) should discuss the problem of the genetic vulnerability of the potato crop as a case example concerning the conservation, control, and management of germplasm, and should consider steps that might be taken by the plant genetic resources community in the event of a new potato famine.

5. The circumstances surrounding the promotion of potatoes in the Third World; the orientation toward single-gene disease-resistance breeding strategies; the use of fungicides; and the promotion and marketing of seed potatoes should be fully investigated by FAO, together with governments, the potato seed industry, and NGOs in order to control future problems for potatoes and other crops.

6. Recommendations leading to a **Code of Conduct on Germplasm Introduction** should be tabled at the Leipzig meeting discussed above.

7. Governmental and NGO aid agencies, in addition to reviewing their own seed distribution procedures, should consider steps they might take in the event of a new famine.

Acknowledgements

RAFI has been monitoring scientific developments in potato breeding, germplasm conservation, and product processing, since a *RAFI Communique* researched and written by Hope Shand in September/October, 1992. We must recognize, however, the pioneering and remarkable contribution of Dr. William E. Fry, Professor of Plant Pathology at Cornell University along with a number of his colleagues at Cornell, and at the U.S. Department of Agriculture (USDA). A number of persons within the USDA were helpful to RAFI in preparing this report who cannot be acknowledged individually.

This preliminary update on the late potato blight has been prepared by RAFI staffers Pat Mooney, Hope Shand, and Edward Hammond with assistance from Beverly Cross and Jean Christie.

***Reference:* DD3-pot.318/p486 14 August 1995**

Endnotes

1. Fry, William E. et. al., "Historical and Recent Migrations of Phytophthora Infestans: Chronology, Pathways, and Implications", Plant Diseases, July, 1993, p.653.

2. The fungus now attacks two major crops - potato and tomato - as well as their related undomesticated species. It is believed that it affects still other uncultivated species, but no list is available.

3. According to Cultural Survival Canada, among the other indigenous nations in the region are the Huichol, Zacatec, Tepehuan, Acaxee, Lacandon, and Tarahumara, who, along with the Otomi and Huastec, have been shifting (and shifted) cultivators for many centuries.

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15. Data derived from FAO Agrostat series covering 1960-90.

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17. CIP, *Potato Atlas* (as taken from the CIP CD-ROM as document CIPPO117).

18. Personal communication from Dr. William Fry, Professor of Plant Pathology at Cornell University to Pat Roy Mooney of RAFI, on 9 August, 1995.

19. French, E.R., P. Jatala, and J.L. Turkensteen, "Potato (Solanum Spp.) Fungi, Bacteria and Nematodes" in Plant Health and Quarantine in International Transfer of Plant Genetic Resources, (ed. William B. Gewitt and Luigi Chiarappa), CRC Press (Cleveland), Chapter 16, p.226. There is no publication date but it is believed to be circa 1980.

20. Niederhauser, John S., "Pictipapa", Phytopathology News, May, 1995, p.86 quoting a speech by the same author made at the Second International Agribusiness Seminar held in Monterrey, Mexico, July 20-22, 1994. Hope Shand of RAFI was also a guest speaker at this conference.

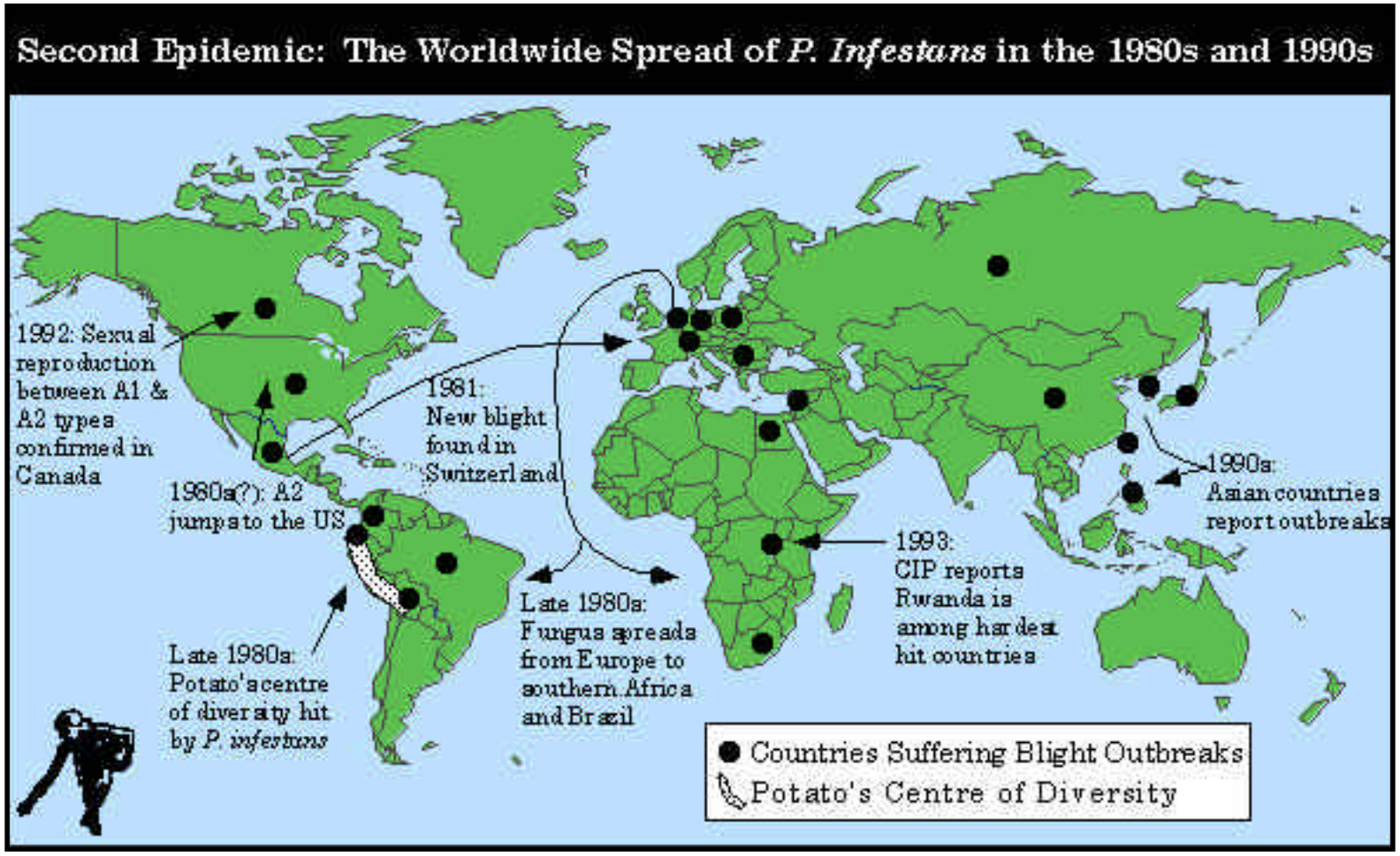
21. "CIP in 1992 - Programme Report", CIP, 1993, p.46.

22. For an examination of this issue, see Matuszak, J.M. et. al., "Sensitivity of Phytophthora infestans to Metalazyl in Mexico: Distribution and Dynamics" Plant Disease, Vol.78, No.9, September, 1994, p.911-916.

23. The First FAO Conference - Quebec, Canada, 1945, page 1 and pages 46-48 (as made available by the FAO Archives).

24. The quote is attributed to Dean Acheson following the Hot Springs Conference of 1943 as cited in English, John, Shadow of Heaven The Life of Lester Pearson, Volume One: 1897-1948, Lester & Orpen Dennys, 1989, p.278.

25. Cecil Woodham-Smith, The Great Hunger, Harper and Row Publishers, New York and Evanston, 1962.


Second Epidemic: The Worldwide Spread of P. Infestans in the 1980s and 1990s
1992: Sexual reproduction between A1 & A2 types confirmed in Canada
1980s(?): A2 jumps to the US
1981: New blight found in Switzerland
Late 1980s: Potato's centre of diversity hit by P. infestans
Late 1980s: Fungus spreads from Europe to southern Africa and Brazil
1993: CIP reports Rwanda is among hardest hit countries
1990s: Asian countries report outbreaks
Countries Suffering Blight Outbreaks
Potato's Centre of Diversity