Cover story |

Let them eat spuds

They're cheaper, more nutritious and easier to grow than grain. But turning to potatoes does not come without risks, says **Debora MacKenzie**

JAN BANNING/PANOS

FOR some reason, it's always called the "humble" potato. But the tasty tuber from the Andes is poised to take over the world. As the food crisis bites, the land area planted with potatoes is increasing faster than for any other staple crop. Developing countries now grow and eat more of them than the traditional potato-eaters of the rich countries: today, the world's biggest potato producer is China, and India produces twice as much by weight each year as the US.

Yet behind this success story lies a problem. The blight that wiped out Ireland's potato crop in the 1840s is becoming more virulent and is increasingly resistant to the fungicides used to control it. Without a new weapon against blight, we could be setting ourselves up for a replay of the famine wherever the disease strikes. And this time even more people could suffer.

There are good reasons why the world is turning to potatoes. Much of the world's food comes either from grain or animals fed on grain, but rising populations and increasing demand for meat, dairy products and biofuel means that global demand for grain is outstripping supply. Grain yields must ultimately increase to meet this demand but cranking up the global food system will take time, and yields won't increase overnight. In many places potatoes can plug the gap, providing food and income for the people who need them most. "Worldwide we see an overlap between where the poorest live and where people grow potatoes," says Pamela Anderson, head of the International Potato Center (CIP) in Lima, Peru, part of the Consultative Group on International Agricultural Research, which works on crop improvement for poor countries.

Potatoes can squeeze in between grain crops, which means a field yields three harvests a year instead of two. Since there is little international trade in potatoes, their prices tend to be more stable than those of grain. All these things have led the UN to dub 2008 the International Year of the Potato and to hail it as the "food of the future".

In fact, listen to a potato enthusiast, and you may wonder why people bother with grain at all. Potatoes are more nutritious, faster growing, need less land and water and can thrive in worse growing conditions than any other major crop. They provide up to four times as much complex carbohydrate per hectare as grain, better quality protein and several vitamins – a medium-size potato boiled in its skin has half an adult's daily dose of vitamin C, for example. They also contain B vitamins, plus many of the trace elements poor people, and grain, lack. And, unless you douse them with it, potatoes have almost no fat (see table, page 32).

Potatoes do have their downsides, of course. They are more perishable than grain and because they are heavier and bulkier, they are more expensive to transport – one reason why there is little international trade. Their main weakness, though, is disease.

Potatoes are rolling in genetic diversity – there are some 150 species in the potato family and countless varieties. The problem is, almost all potatoes grown outside the Andes are of a single subspecies, *Solanum tuberosum tuberosum*, first cultivated 8000 years ago in the highlands around Lake Titicaca. Keeping all our potatoes in one basket leaves the world's crop vulnerable to being wiped out.

The most likely candidate to do this is late blight, which is what destroyed the potato crops in Ireland and other parts of Europe in the mid-19th century. It is caused by *Phytophthora infestans*, a fungus-like organism called an oomycete, which spreads by producing spores. The disease originated in Mexico, where it infects wild potatoes, and spread north as American agriculture expanded in the 19th century. In 1845, it arrived in Belgium on seed potatoes imported from the US.

The blight quickly spread across Europe, wiping out crops and causing catastrophe in Ireland, where the damp, cool soils and climate, plus the fact that the colonial landowners took the best land to grow grain for export to England, made the Irish poor more reliant on potatoes than other Europeans. Breeders eventually found potatoes that partially resisted the blight, but the crop's future was only secured when fungicides were invented in the 1880s. Now potatoes are more dependent on chemical treatment than any other crop. The potato industry in the European Union is worth €6 billion a year; farmers spend a sixth of that on fungicide.

Farmers in developing countries can rarely afford to buy fungicide, a big reason, along with the pervasive lack of fertiliser and water, why average potato yields in African countries are half those in China or Peru, which are in turn half those of rich countries.

Giving farmers in the developing world access to fungicides would certainly increase yields, but it may not be enough to protect them from blight, as the disease is becoming ever more resistant to fungicides. "Last year I had to spray 12 times, the most ever," says Jim Godfrey, a potato farmer and former head of the Scottish Crop Research Institute in Invergowrie. In the tropics, where both potato and pathogen grow faster, farmers may need to spray every few days.

What's more, the blight is becoming more aggressive – *P. infestans* has two "genders", only one of which came over in 1845, so it was only able to ▶

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reproduce asexually. Though it has spread in this way through Europe and much of the world, the asexual spores can persist only on susceptible plants. Then, in the drought of 1976, Europe's crop failed and it imported tonnes of potatoes from Mexico. With them came the other "gender" of the blight. Now it can breed sexually, which means it can adapt more quickly to both fungicides and resistant potatoes. Sexually produced spores can also survive in soil, making the disease even more difficult to control.

Sexually reproducing blight and increasing fungicide resistance mean more, and worse, outbreaks of the disease around the world. It may not cause starvation on the same scale as the Irish famine – food aid exists now, and few places are as exclusively reliant on potatoes as the Irish were in 1845 – but even so, the potato's potential for disaster is worrying.

That, says Anderson, is why we need to develop new varieties of blight-resistant potatoes. This won't be easy. Potatoes are a notoriously difficult crop to breed, thanks to their unusually complex genetics. The common spud carries four copies of each of its chromosomes where most organisms carry two. That means the potato plant carries a possible four variations for each gene, so when two plants are crossed, thousands of different combinations emerge. That makes it an enormous task to select the best ones.

In other crops that have more than two pairs of chromosomes breeders have found ways around the problem. Most wheat has six copies, but wheat breeders start with plants that are already inbred so that for most genes, all six copies are identical. That way they can predict the outcome of crosses. Attempts to do this with potatoes, and also to engineer potato plants with only two-copy genomes, have been disappointing, says Shelley Jansky of the US Department of Agriculture's potato lab in Madison, Wisconsin. The genetically impoverished potatoes are spindly and weak. "Potatoes just need all that internal genetic diversity to thrive," she says.

That means potato breeders are forced to take a broad approach when looking for useful new varieties. First, they cross genetically diverse parent plants to create up to 100,000 genetically different progeny. Then, they "walk across the field and choose the potatoes they think look promising, and get it down to a manageable number, say a thousand", says Jansky, and examine those plants for the qualities they want.

This kind of classical breeding has given us all the potato varieties we have today, but it is very difficult to use this method to breed a single desired trait into an existing commercial potato variety. Recent efforts to cross commercial varieties with *Solanum bulbocastanum*, a wild Mexican potato which has two genes for resistance to all known strains of blight, did indeed result in blight-resistant potatoes – but they had other, unwanted wild genes as well, and lower yields.

Breeding these hybrids back with the original commercial potato will produce tubers more similar to the original, but they will never be quite the same. This is a problem for the potato industry, says Jansky. Processing companies take a third of the crop in rich countries, and the machines and processes are designed for potatoes of particular shapes, sizes and chemical properties. They know their King Edwards and their Russet Burbanks and they want nothing else – and because potatoes are propagated vegetatively by tuber, they can have exactly the same potato again and again, says Jansky.

Genetic engineering could be the answer to this problem, says Anton Haverkort of Wageningen University in the Netherlands. He is running a 10-year programme to find more genes for resistance to late blight in several wild potato species – and then put

NUTRITIOUS AND DELICIOUS

Nutritional content of potatoes, pasta and rice, per 100g

	Potatoes, baked, including skin	Fresh pasta, boiled	White long grain rice, boiled
Energy (Kcal)	93	130	131
Protein (g)	3.00	5.15	2.69
Fat (g)	0.00	1.05	0.28
Carbohydrate (mg)	21.00	24.93	28.17
Fibre (g)	2.0	0.0	0.4
Sugars (g)	1.20	0.00	0.05
Calcium (mg)	15	6	10
Iron (mg)	1.10	1.14	1.20
Magnesium (mg)	28	18	12
Phosphorus (mg)	70	63	43
Potassium (mg)	535	24	35
Sodium (mg)	10	6	1
Zinc (mg)	0.40	0.56	0.49
Copper (mg)	0.100	0.093	0.069
Manganese (mg)	0.200	0.224	0.472
Selenium (µg)	0.4	0	7.5
Vitamin C (mg)	9.6	0	0
Vitamin B1 – thiamine (mg)	0.100	0.209	0.163
Vitamin B2 – riboflavin (mg)	0	0.150	0.013
Vitamin B3 – niacin (mg)	1.400	0.992	1.476
Vitamin B5 – pantothenic acid (mg)	0.400	0.183	0.390
Vitamin B6 – pyridoxine (mg)	0.300	0.034	0.093
Vitamin B9 – folic acid (µg)	28	64	58

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MARIANA BAZO/REUTERS

them, and nothing else, into three popular varieties of eating potato. Haverkort uses a relatively new method of genetic engineering that doesn't require an antibiotic resistance marker gene – a common tool in creating engineered plants – to be introduced along with the desired genes. So far he has isolated eight genes and the first of his genetically modified plants are now in field trials.

"We call them cisgenic, instead of transgenic," he says. "They contain no genes except what they could have acquired naturally by breeding with other potatoes – except it hasn't taken decades." He hopes EU law will take account of the development and lighten restrictions on such plants, and that Europe's anti-GM public will accept them. "The only genes in there are from potatoes," he says.

Whether consumers accept cisgenic potatoes remains to be seen. Meanwhile, genetically engineered blight-resistant potatoes created by the German chemical giant BASF are already in their third year of field trials. The company has put the two resistance genes from *Solanum bulbocastanum* into commercial potato varieties along with an antibiotic resistance marker. BASF says the plants seem to have durable resistance to blight strains circulating in Europe, and it is hoping to start selling them by the middle of next decade.

The antibiotic resistance gene could be a problem, however. Its presence is central to objections to GM food; opponents say the gene could be taken up by bacteria in the environment, creating superbugs. BASF has another genetically engineered potato that yields more uniform starch for the paper and fabrics industries, which the European Commission declared safe last year, but as countries such as Austria harden their resistance to GM crops, it is holding back on the go-ahead for release. The same fate may await the company's GM food potatoes.

Developing countries, having had the potato for less time, seem to be more open to non-traditional varieties, and in some places GM food is less unpopular. China, for example, is rumoured to have developed varieties similar to BASF's.

In Peru, CIP plans to keep studying how potatoes resist blight, and using its potato gene bank – the world's largest – to find genes that confer resistance. CIP is using GM to develop late-blight-resistant strains for Asia and is also breeding potatoes conventionally. This is partly because CIP has imposed a moratorium on releasing GM potatoes in South America, where most governments are opposed to GM and where most of the potato's wild relatives exist, until more is known about whether introduced genes might escape into wild potatoes. But it is also, she says, because "GM is one tool, it doesn't do everything." Resistance to blight, for instance, might be achievable by implanting one or two genes at a time, but eventually, the blight will adapt to those few genes. And other, more complex traits like nutritional quality and yield depend on many genes, few of which are known, and can only be bred into farmed varieties the old-fashioned way, says Anderson.

However we come by new varieties, as the humble potato spreads around the world, and more and more people depend on it for sustenance, the need to win the battle against disease becomes more urgent. Blight is a disaster waiting to happen, and this time we have no alternative but to fight back. ●

The plant that changed the world

The Spanish brought the potato from South America to Europe in 1536. Most histories say it was then ignored for 200 years, but according to University of Chicago historian William McNeil, peasants knew all about it, and quietly took to growing potatoes as insurance against the frequent loss of their grain stores to marauding armies. When Prussia then other European governments realised in the mid-1700s that potatoes could slash the cost of warfare, they made peasants grow them. Potato-pushers such as nutritionist Antoine Parmentier, whose name still graces French potato dishes, and Austrian empress Maria Theresa, were in fact pushing civil defence. The empress's daughter, French queen Marie Antoinette, is best known for suggesting peasants eat cake, but she wore potato flowers to promote another alternative to bread.

In the 1800s potatoes moved into the mainstream. Before then, half of Europe's farmland lay fallow between grain crops. As the population rose, people planted potatoes on this ground instead. The crop needed weeding, but produced more than enough to feed the labour-force.

Then, in 1845, late blight hit Europe. It is remembered as the Irish potato famine, but hundreds of thousands died in the rest of Europe too. In the early 1850s, yields recovered, and Europe's potato fields continued to feed the population explosion and booming cities of the 19th century. By fuelling the industrial revolution and the economic and military rise of Europeans, says McNeil, potatoes changed the world.

Now history is repeating itself. Asian farmers are feeding a growing population with scarce land and abundant labour by squeezing potatoes between crops of grain. If suitable varieties allow Africans to do the same, the potato may once again be a lifeline for growing, urbanising and war-torn populations. But only if – this time – we can keep blight at bay.