CIP
INTERNATIONAL POTATO CENTER

RESEARCH BRIEF 01

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Bioengineered potato: Resistance to late blight disease and higher crop yields

CIP Research Assistant compares the yields of the bioengineered late blight resistant Victoria variety (left) and its conventional version (right) at the NARO research station, Uganda (CIP/NARO).

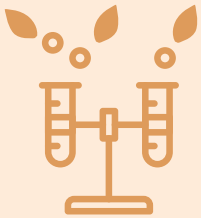
Average potato yields in sub-Saharan Africa are four times lower than those in industrialized nations, mostly due to the effects of diseases, particularly late blight. This research demonstrates that the transfer from wild potato relatives of three resistance-conferring genes into a cultivated potato variety provides complete resistance to late blight for several seasons. Initial findings suggest this resistance will be long lasting. Cultivation of this late blight resistant potato would increase family farm incomes by 40% and ensure the supply of fungicide-free potatoes to consumers.

The challenge: Spraying with fungicides

Unless protected by expensive and toxic fungicides—up to 15 times a season—late blight disease devastates potato crops throughout the world. Considered responsible for one million deaths in Ireland and widespread famine in Europe during the 1840s, late blight, caused by *Phytophthora infestans*, remains the most devastating potato disease triggering annual yield losses of 15–30% globally. Costs in terms of disease control and reduced yields due to late blight amount roughly to USD 10 billion a year in developing countries.

Estimated yield losses in Uganda range from 13–57% of the total potato production. A 2004 survey of 227 farmers in Kenya revealed that 54% of them put late blight losses at 30–60%. Many farmers in Ethiopia have shifted potato production from the long to the short rainy season to avoid the worst effects of the disease which is triggered by excess moisture. Resource-poor small-scale farmers are the most exposed, suffering the highest losses, up to 100%.

Bioengineering



Bioengineering is the modification of the genetic information in a crop using direct gene transfer and other biotechnology methods. The new genetic information can be a new gene from another species, or a change in the DNA sequence which will give a new desirable property to the bioengineered crop. The resulting organisms are also referred to as genetically modified or transgenic organisms.

The rows in the front plot are empty as all the potatoes have been destroyed by late blight disease. The bioengineered Victoria potato has survived unaffected, NARO research station, Uganda (CIP/NARO).

> Wild potato relatives have co-existed with the late blight pathogen for centuries.

The most popular potato varieties are susceptible to late blight which is exclusively controlled by costly and toxic fungicides. Even organic production relies on less effective, but highly toxic copper-based fungicides.

Research solution: adding three resistance conferring genes into local varieties

Wild potato relatives have co-existed with the late blight pathogen for centuries in Central and South America. Traditional farmers have long valued wild relatives for the exceptional diversity they have added to breeding activities in the Andes region. Over the last 100 years, breeders have crossbred small numbers of wild relatives with potatoes to successfully enhance their resistance to many diseases. However, combining all the desirable traits into one potato variety would be impossible using traditional breeding practices. It took 46 years of conventional breeding and selection to obtain the late blight resistant varieties, Bionica and Toluca, which only contain one resistance-conferring gene, rather than the three genes transferred through bioengineering.

Moreover, new pathogen strains quickly overcome the resistance of the newly released varieties based on a single resistance gene. That so many popular potato varieties need to be treated with expensive chemicals frustrates potato farmers worldwide. Adding a few resistance-conferring genes to the potato offers the potential to resolve many of these challenges.

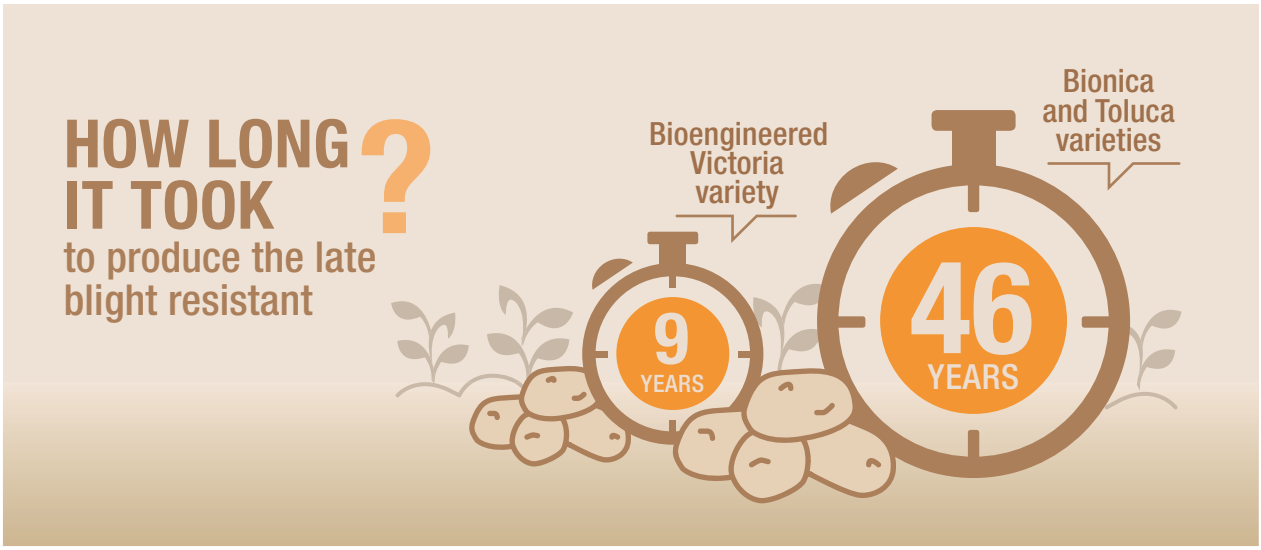
Bioengineered crops resistant to some of the world's most devastating pests have been cultivated for the last 22 years in 24 countries on 190 million hectares of land. The use of chemical pesticides for these crops has dropped by 37%, yields have risen by 22% and farmer profits increased by 68%. These benefits have been comparably greater for developing nations. The biodiversity of agricultural landscapes has been enhanced, while the pressure of pests, including for organic producers, has fallen. All these additional benefits have come at no additional costs or risks than those of conventional farming. There is no scientific evidence of harm caused to human health or ecosystems. Reputable academic institutions, such as the World Health Organization, concur that the bioengineered crops currently grown are as safe and nutritious as their non-bioengineered equivalents.

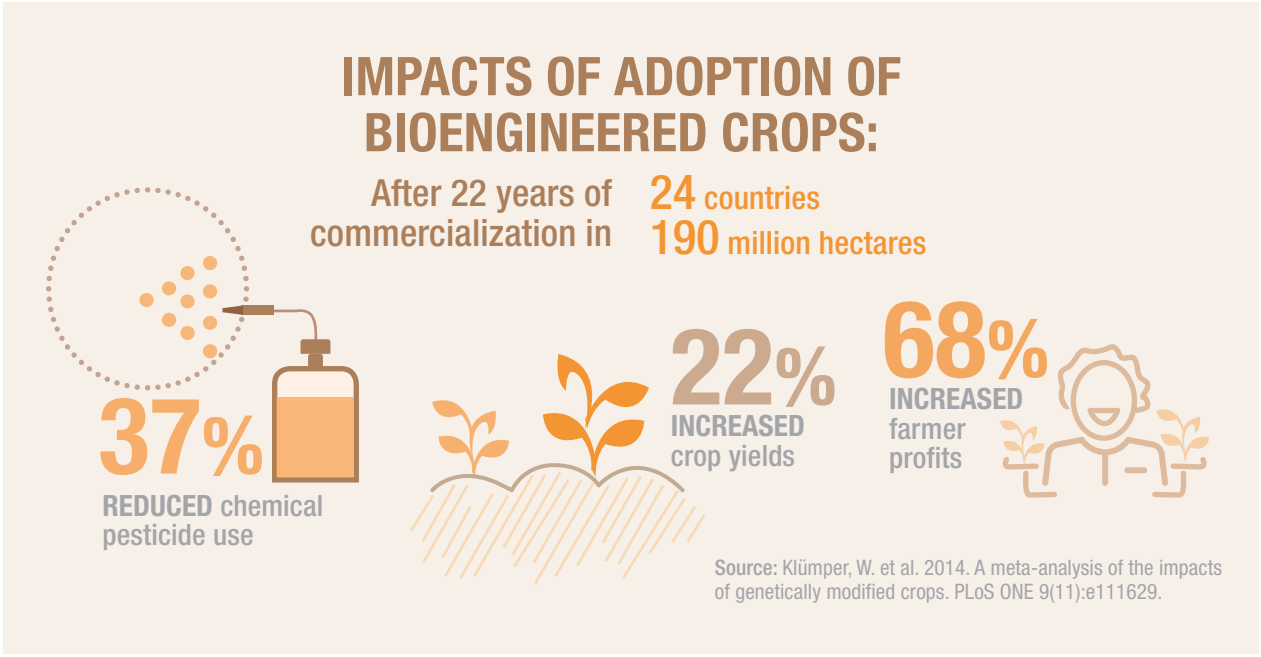
Findings

In 2008, scientists at the International Potato Center (CIP) laboratory in Peru transferred three resistance-conferring genes from Mexican and Argentinean wild species into the variety Victoria, a farmer-preferred potato in Uganda. Over the next four years, numerous greenhouse tests were conducted to identify the most productive and disease resistant varieties. The bioengineered potatoes were then transferred to the facilities of the Biosciences eastern and central Africa-International Livestock Research Institute Hub in Kenya where more laboratory and greenhouse tests were conducted by CIP scientists.

In 2015, the bioengineered potatoes were transferred to Uganda and planted in experimental trials by the National Agricultural Research Organization (NARO) for five seasons. Phytosanitary and biosafety regulatory agencies in Kenya and in Uganda played an important role in securing full compliance with national regulations. In all cases, the bioengineered potatoes were cultivated without fungicides, while non-bioengineered potatoes were rapidly killed by late blight disease. The yields from the bioengineered potatoes were four times higher than the national average. Farmers who were given the opportunity to visit the fields were impressed by the ability of their well-known Victoria potato to withstand late blight disease without chemicals.

Testing continues in 2019 to demonstrate that the bioengineered potato is substantially equivalent to the non-bioengineered variety, apart from resistance of the former to late blight disease. The tests will examine molecular changes in the potato genome, confirm that all the genes respond as expected, and undertake a comparison between the bioengineered and non-





bioengineered potato attributes, such as sprouting, flowering, maturity, tuber appearance, nutritional qualities and yields. Researchers will also examine the behavior of other organisms which come into contact with the bioengineered potato during the field trials. These comprehensive tests are designed to ensure that the bioengineered potato does not negatively impact human health or the environment.

Conclusions

While scientists are eager to reclaim the Victoria potato from late blight disease, research is ongoing to evaluate how long this new resistance will last. But researchers believe it is likely to be long-lasting. A new set of bioengineered varieties are being prepared and a new set of disease resistance genes are being tested, including for resistance to viruses and bacterial wilt. Perhaps more important at this stage is the need to enhance engagement with potato partners in Uganda and in neighboring countries to explain the benefits of adopting this new variety.

The late blight resistant bioengineered potato eliminates the costs associated with the use of fungicides (chemicals, sprayers) and offers farmers increased yields, which CIP scientists estimate could represent a 40% increase in profits for small scale-farmers. For African farmers, the costs associated with potato production, the losses caused by the disease, and their exposure to harmful chemicals would be greatly reduced. In addition to benefiting from increased crop yields, seeds multipliers would save money otherwise spent on fungicide sprays during field production of seed tubers. And finally, consumers would be able to purchase fungicide-free potatoes.

Tubers of the bioengineered late blight resistant Victoria, Uganda (CIP/NARO).

Scientists have successfully developed late blight resistant potato. It is now up to the national authorities of Uganda to decide if bioengineered potatoes can be released, cultivated and consumed in the country. This process should be evidence-based, focusing on the benefits to local producers and businesses of higher productivity and incomes, to consumers of healthy potatoes and to the environment of chemical-free farming. This would give farmers the choice to grow bioengineered late blight resistant potatoes and consumers a choice to eat potatoes free of fungicide residues.

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