



**Photo 1:** Healthy 3R-gene potatoes (green plots) and devastated non-biotech potatoes (empty plots) by late blight disease in Kuru in Nigeria.

# Harnessing Biotech Potato for Food Security and Profitability in Nigeria

## Key messages

- Agriculture provides over 75% of rural employment in Nigeria, yet productivity constraints keep the country dependent on food imports.
- Potato is a nutritious staple and commercial crop, with about 95% of national production concentrated in Plateau State; production has grown but still falls short of demand.
- Late blight (LB) disease, especially in the wet season (which accounts for 82% of production), causes yield losses of 20–50%, driving high input costs and income instability.
- The biotech 3R-gene potato varieties (Desiree, Diamant, and Shangi) were developed to provide complete resistance to LB, offering a way to stabilize yields and reduce fungicide dependence.
- Under the most likely adoption scenario, each 3R-gene variety is projected to generate a total net benefit of about NGN 345 billion (≈US\$ 810 million) over 30 years, with annual net benefits of NGN 11.4–11.6 billion (US\$ 26.8–27.3 million). Consumers capture about 65% of these gains, farmers about 35%.
- As an alternative expression of these welfare gains, baseline projections suggest that each variety could lift around 16,300–16,700 people out of poverty over its lifetime (around 16,000–17,000 per year when expressed at the margin).
- Sensitivity analysis shows that benefits remain positive under lower adoption, halved yield gains, and higher research costs, but are notably reduced by delayed release—highlighting the importance of timely approval and strong diffusion.
- Simultaneous release of all three 3R-gene varieties yields the highest annual net benefits (about NGN 13.807 billion (US\$ 32.41 million)), making it the preferred strategy.

## 1. The challenge: wet-season vulnerability and high input costs

Agriculture is central to Nigeria's economy, providing employment for most rural households and contributing significantly to poverty reduction. Yet the sector faces many constraints, including land pressure, climate variability, land degradation, limited technological adoption, high production costs, and pervasive pest and disease problems. These factors depress productivity and reinforce dependence on food imports.

Potato (*Solanum tuberosum* L.) is an important food and commercial crop, grown mainly at high altitudes (1,200–1,400 m) in Plateau State, with smaller areas in Kaduna, Taraba, Cross River, and Kano. It is a nutritious staple—rich in carbohydrates, vitamins, and minerals—and is affordable for low-income consumers. Production increased from about 1.09 million tons in 2012 to 1.22 million tons in 2022, but remains below domestic demand due to constraints such as poor seed quality, limited storage, and disease pressure.

Late blight (LB), caused by *Phytophthora infestans*, has affected potatoes (and tomatoes) in Nigeria since at least the early 1970s. It thrives under wet-season conditions, with high humidity and suitable temperatures, and is particularly damaging because the wet season accounts for around 82% of annual potato production. LB can cause 20–50% yield losses and, in severe cases, leads to extensive foliage damage, plant death, and tuber rot.

The pathogen can complete several infection cycles within a single season, producing large amounts of inoculum depending on strain virulence, host susceptibility, and environmental conditions. Farmers

often resort to fungicides, but many smallholders find them costly, lack protective equipment, and may not have adequate information on correct use. As a result, control is often incomplete, yields remain unstable, and there are concerns about environmental pollution and health risks.

## 2. The solution: 3R-gene potatoes for more resilient production

To address the persistent burden of LB and the limits of fungicide-based control, the International Potato Center (CIP) and Michigan State University developed late blight-resistant (LBR) biotech potatoes by transferring three resistance genes (3R-gene) from wild potato species into high-performing varieties grown in Africa.

The 3R-gene varieties—Desiree, Diamant, and Shangji—are designed to confer complete resistance to LB, while maintaining agronomic and consumer traits valued in Nigeria. Over the past decade, these varieties have been tested in field conditions in several countries, including Uganda, Kenya, Nigeria, Bangladesh, Indonesia, the United States, and multiple European countries.

Nigeria's policy environment is relatively conducive for field trials and the potential release of these varieties. However, the adoption of genetically modified (GM) crops in Africa remains contested, and limited knowledge about the socio-economic benefits of GM crops is often cited as a barrier. An ex ante economic impact assessment is therefore essential to quantify the potential benefits of 3R-gene potatoes, inform regulatory review, and guide decisions by government, seed producers, and farmers on deployment and adoption.



**Figure 1:** Healthy 3R-gene potatoes (green plots) and devastated non-biotech potatoes (empty plots) by late blight disease in Kuru in Nigeria.

### 3. Economic and social impact assessment

The study applies the economic surplus model in DREAMpy to estimate the potential welfare impacts of adopting 3R-gene Desiree, Diamant, and Shangi in Nigeria's irrigated and rainfed systems. It also translates these welfare gains into poverty impacts as an alternative metric.

#### Incremental economic returns and distribution

The ESM confirms that adopting 3R-gene potatoes would generate substantial net welfare gains for farmers and consumers. Over a 30-year simulation period, each 3R-gene variety is projected to deliver total net benefits (present value) of roughly NGN 343–349 billion, equivalent to about US\$ 804–820 million:

- 3R-gene Desiree: NGN 342,502 million (US\$ 804 million)
- 3R-gene Diamant: NGN 347,084 million (US\$ 815 million)
- 3R-gene Shangi: NGN 349,249 million (US\$ 820 million)

3R-gene	Total benefits in USD (millions)			Total benefits in NGN (millions)		
	Δ Farmer surplus	Δ Consumer surplus	Δ Net benefits	Δ Farmer surplus	Δ Consumer surplus	Δ Net benefits
Desiree	288	517	804	122,643	220,236	342,502
Diamant	288	527	815	122,791	224,375	347,084
Shangi	288	532	820	122,893	226,446	349,249

**Figure 2:** Incremental economic benefits of the 3R-gene potato (present value)

This translates into annual net social welfare gains in the range of:

- NGN 11.417–11.642 billion per year (US\$ 26.80–27.33 million).

The distribution between producers and consumers is skewed towards consumers, who receive about 65% of the gains, compared with 35% for farmers. For example, in the case of 3R-gene Shangi, the annual net benefit of NGN 11.642 billion (US\$ 27.33 million) is split between:

Consumers benefit mainly through lower prices or more stable supply, while farmers gain from higher yields and reduced losses, particularly in the wet season.

Poverty impacts as an alternative metric

As an alternative way of presenting the welfare gains, the economic surplus estimates are translated into poverty impacts using an established method. Under the baseline scenario, the number of poor people escaping poverty over the lifetime of each variety is:

- 3R-gene Desiree: about 490,113 individuals (**≈16,337 per year**)
- 3R-gene Diamant: about 496,670 individuals (**≈16,556 per year**)
- 3R-gene Shangi: about 499,768 individuals (**≈16,659 per year**)

Scenario	Total net ES (billion NGN)	Average benefit per year (billion NGN)	Gains from R&D as % of agricultural production (annual basis)	Poverty elasticity	Poverty reduction as % of the poor (all years)	Poverty reduction as % of the poor (yearly basis)	Number of poor escaping poverty (all years)	Number of poor escaping poverty (annual basis)
Baseline	343	11.417	0.0238	1.1	0.0079	0.0003	490,113	16,337
Doubling of the R&D costs	342	11.404	0.0238	1.1	0.0078	0.0003	489,575	16,319
A five-year lag in the variety release	212	7.079	0.0148	1.1	0.0049	0.0002	303,910	10,130
Yield loss was abated by half	175	5.831	0.0122	1.1	0.0040	0.0001	250,309	8,344
Maximum adoption rates	492	16.407	0.0342	1.1	0.0113	0.0004	704,358	23,479
Minimum adoption rates	202	6.722	0.0140	1.1	0.0046	0.0002	288,572	9,619

3R-gene Diamant	Baseline	347	11.569	0.0241	1.1	0.0080	0.0003	496,670	16,556
		347	11.567	0.0241	1.1	0.0080	0.0003	496,553	16,552
	A five-year lag in the variety release	215	7.179	0.0150	1.1	0.0049	0.0002	308,185	10,273
	Yield loss was abated by half	178	5.926	0.0124	1.1	0.0041	0.0001	254,390	8,480
	Maximum adoption rates	495	16.516	0.0344	1.1	0.0114	0.0004	709,005	23,634
	Minimum adoption rates	204	6.810	0.0142	1.1	0.0047	0.0002	292,332	9,744
3R-gene Shangi	Baseline	349	11.642	0.0243	1.1	0.0080	0.0003	499,768	16,659
	Doubling of the R&D costs	349	11.639	0.0243	1.1	0.0080	0.0003	499,639	16,655
	A five-year lag in the variety release	217	7.224	0.0151	1.1	0.0050	0.0002	310,125	10,338
	Yield loss was abated by half	179	5.968	0.0124	1.1	0.0041	0.0001	256,221	8,541
	Maximum adoption rates	498	16.615	0.0347	1.1	0.0114	0.0004	713,282	23,776
	Minimum adoption rates	205	6.848	0.0143	1.1	0.0047	0.0002	294,000	9,800
	Third season for Shangi—irrigation	368	12.254	0.0256	1.1	0.0084	0.0003	526,048	17,535
Simultaneous release of the three 3R-gene LBR varieties	Third season for Shangi—irrigation	13.807	0.0288	1.1	0.0095	0.0003	592,738	19,758	

**Figure 3** : Estimated poverty effects of the different 3R-gene LBR potato varieties.

Across alternative scenarios, annual poverty reduction ranges from about 8,344 to 23,776 individuals, depending on the variety and the assumptions made about adoption, yield impact, and timing of release. Under the simultaneous release scenario, the combined impact across the three varieties is estimated at 592,738 people escaping poverty over the technology's lifetime (about 19,758 per year).

### How adoption, timing, and yield assumptions shape the gains

Because ex ante assessments rely on key assumptions, the study examines how sensitive the projected benefits are to changes in adoption rates, yield improvements, research costs, release timing, and potential extra production seasons.

- **Adoption rates:** Benefits are highly sensitive to adoption. Compared with the baseline, expected net benefits can increase by up to 46% or decline by up to 43%, depending on whether adoption reaches maximum or minimum levels. Even under minimum adoption, benefits remain positive, though smaller.
- **Yield gains:** Halving the expected yield gains leads to about a 49% reduction in net benefits relative to the baseline, highlighting how central yield improvements are to the total welfare effects.
- **Delayed release:** A five-year delay in the release of the 3R-gene varieties reduces net benefits by around 38% compared with baseline, underscoring the cost of regulatory or implementation delays.
- **Higher R&D costs:** Doubling research and development costs has only a small effect on the projected net benefits,

indicating that the economic case remains strong even under higher upfront investment.

- **Third season for Shangi:** For 3R-gene Shangi, adding a third production season under irrigation (reflecting its early maturity and existing dry-season irrigation) increases annual net benefits to NGN 12.254 billion (US\$ 28.77 million)—about 5% higher than the baseline.
- **Simultaneous release:** If 3R-gene Desiree, Diamant, and Shangi are released simultaneously, adoption could cover about 59% of the rainfed and 54% of the irrigated potato area. In this case, annual net benefits are projected at NGN 13.807 billion (US\$ 32.41 million)—an increase of about 18–21% relative to single-variety releases.

Overall, the sensitivity analysis shows that 3R-gene potatoes remain economically attractive under a wide range of plausible conditions, with the strongest gains realized when release is timely, adoption is high, and yield benefits are fully expressed.

## 4. Policy priorities and opportunities for future research

### Policy priorities

1. **Prioritize simultaneous release of all three 3R-gene varieties:** Given the strong economic case for simultaneous release, policymakers should prioritize a strategy that brings Desiree, Diamant, and Shangi to market together. This approach maximizes adoption potential and yields the highest annual net benefits. Clear coordination between regulatory bodies, research institutions, and seed stakeholders is essential to achieve this.

2. Strengthen seed systems and value chain integration: Realizing the projected gains depends on delivering 3R-gene seed to farmers at scale and at an affordable cost. Priority actions include:

- Scaling up certified seed production and distribution for the three varieties.
- Ensuring robust quality control along the seed value chain.
- Supporting integration of 3R-gene Shangi into domestic processing value chains, given its favorable processing traits and short dormancy, which are attractive to processors.

3. Ensure that farmers capture full cost savings: For the technology's benefits to materialize, farmers need to adjust their practices, particularly fungicide use. Without clear guidance, risk-averse farmers may continue routine spraying even when it is no longer needed for LB control. Targeted extension and training should:

- Emphasize that 3R-gene potatoes are specifically resistant to LB, while other pests and diseases still require management.
- Support farmers in safely reducing unnecessary fungicide use, with attention to health and environmental benefits.

4. Maintain efficient and transparent regulatory pathways: A five-year delay in release significantly reduces net benefits. Regulatory bodies should therefore strive for efficient, predictable review processes, while maintaining high safety standards. Transparent communication on risk assessment and expected benefits can help build public trust and support informed policy decisions.

### Opportunities for future research

As with other ex ante economic surplus assessments, the Nigeria study faces limitations related to data and modelling assumptions:

- The analysis is constrained by limited national statistics on potato production and consumption disaggregated

by variety and region. Some parameters rely on secondary global databases and expert judgment, which, while standard in ex ante work, highlight the need for better national data.

- The economic surplus model focuses on direct, immediate benefits and does not incorporate indirect health and environmental externalities from reduced fungicide use. For example, lower fungicide demand could reduce exposure risks among smallholders (who often lack protective equipment) and decrease emissions from fungicide production and transport.
- Broader economy-wide impacts—such as effects on employment, income distribution, and nutrition—are not captured and would require more complex modelling frameworks and richer datasets.

Future research priorities include:

- Conducting ex post impact evaluations once 3R-gene potatoes are released, using observed adoption, yield, cost, and price data to validate and refine the ex ante estimates.
- Quantifying health and environmental co-benefits of reduced fungicide use, including occupational health outcomes and environmental footprints.
- Improving national data systems for potatoes (production, consumption, prices, and varietal shares) to support more granular analysis.
- Exploring economy-wide impacts through more advanced modelling when adequate data become available.

By acting on these policy and research priorities, Nigeria can better harness the potential of 3R-gene potatoes to strengthen food security, enhance farmer incomes, and reduce losses from late blight in a sustainable way.

#### Authors:

Evelyne Kihiu<sup>1\*</sup>, Jack Malit<sup>1</sup>, Daniel Lenka<sup>2</sup>, David Douches<sup>3</sup>, Eric Magembe<sup>1</sup>, Marc Ghislain<sup>1</sup>, Marcel Gatto<sup>1</sup>, Jose B. Falck-Zepeda<sup>4</sup>, Charles Amadi<sup>5</sup>.

<sup>1</sup> International Potato Center (CIP), Nairobi, Kenya.; <sup>2</sup> University of Jos- Plateau State, Nigeria.; <sup>3</sup> Department of Plant, Soil and Microbial Sciences, Michigan State University, U.S.; <sup>4</sup> International Food Policy Research Institute (IFPRI), Washington, D.C., United States of America.; <sup>5</sup> National Root Crops Research Institute, Umudike, Nigeria.

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