



Photo 1: Healthy 3R-gene Shangii (left plot) and devastated non-biotech Shangii (right plot) by late blight disease in the confined field trial in Njabini in Kenya.

Unlocking the Potential of 3R-Gene Potato in Kenya: Why timely release of 3R-gene Shangii matters for food security and farmer incomes

Key messages

- Potato is Kenya's second most important food staple after maize and contributes about KES 50 billion annually, supporting around 3.5 million actors along the value chain. Yet average yields have fallen by about 51% since 2005, from about 20 t/ha in 2005 to 9.8 t/ha in 2021.
- Late blight (LB) disease accounts for an estimated 23% of national potato production losses, while fungicides used to control LB represent about 12% of production costs, raising economic, health, and environmental concerns.
- Releasing 3R-gene Shangii, a late blight-resistant biotech variety, is projected to generate KES 845.9 million (US\$ 8.2 million) in net benefits annually and could allow about 3,063 people to escape poverty each year under the baseline scenario.
- A five-year delay in releasing 3R-gene Shangii would reduce expected net annual benefits by 36%, to about KES 539 million (US\$ 5.2 million).
- A strategy of consecutive releases—starting with 3R-gene Shangii and later adding a second 3R-gene variety with higher adoption potential—can raise net annual benefits to about KES 1.216 billion, reinforcing the case for timely and well-planned deployment.

1. The challenge: late blight and declining potato performance

Agriculture remains the backbone of Kenya's economy, directly contributing about 22% of GDP and employing more than 70% of the rural workforce. Potato is central to this system: it contributes around 8% of agricultural value added, generates about KES 50 billion annually, and supports roughly 3.5 million actors along the value chain. Food balance sheet data place po-

tato as Kenya's second most important food staple after maize in gross production.

Despite this importance, potato productivity has been declining. Yields fell from about 20 t/ha in 2005 to 9.8 t/ha in 2021, well below the attainable 30–40 t/ha, indicating a widening yield gap. Key constraints include limited access to quality seed, adverse weather, and pests and diseases—especially late blight caused by *Phytophthora infestans*.

Based on expert elicitation, production losses due to LB are estimated at 23% nationally, while fungicide use to control LB accounts for about 12% of production costs. Many smallholder farmers face high fungicide costs, inefficient spraying practices (including timing and number of sprays), and late management, which can contribute to fungicide resistance. Overuse and misuse of fungicides also raise food safety, public health, and environmental concerns.

2. A biotech solution: 3R-gene late blight-resistant potato

To address persistent LB-related losses, the International Potato Center (CIP) and the Kenya Agriculture and Livestock Research Organization (KALRO), together with partners, developed and field-tested biotech potato varieties resistant to LB. These “3R-gene” potatoes stack three LB resistance genes from wild potato relatives into farmer- and consumer-preferred varieties—Asante, Shangji, and Tigoni—so that the transformed varieties retain their desirable traits while gaining resistance to late blight.



Figure 1: Healthy 3R-gene Shangji (left plot) and devastated non-biotech Shangji (right plot) by late blight disease in the confined field trial in Njabini in Kenya.

3. What Kenya stands to gain: economic and social impacts

Using a multi-region Economic Surplus Model (ESM) implemented through the IFPRI DREAMpy tool, the study assessed the potential benefits of adopting 3R-gene potato in Kenya’s three main production regions (North Rift, South Rift, Eastern and Central). The analysis incorporated four common late blight management regimes: no fungicide use, and triweekly, biweekly, and weekly fungicide applications.

Incremental economic returns and distribution

Over a 30-year simulation period, the model shows sizeable incremental welfare gains from 3R-gene potatoes, with strong differences across varieties.

Under the “most likely” adoption scenario:

- **3R-gene Shangji** delivers by far the largest gains, with net benefits of about KES 25.38 billion

The technology is built around a strategy for durable resistance. The R genes were selected to provide broad-spectrum resistance; they are introduced together, making it more difficult for *P. infestans* to overcome all three genes at once; and defeated 3R-gene varieties can be replaced with new 3R-gene varieties carrying different resistance genes. This multi-pronged approach is expected to give resistance that remains stable over a long period.

Adoption of 3R-gene varieties would eliminate the costs of LB fungicide applications. Among farmers who currently spray fungicides, production cost changes range from –7% to –30% per hectare across regions and spray regimes, with an average saving of about 12% per ha in production costs relative to non-3R-gene varieties.

- **3R-gene Asante** generates modest but positive net benefits of about KES 0.22 billion
 - **3R-gene Tigoni** yields slightly negative net benefits of about –KES 0.04 billion, mainly because of low expected adoption.
- On an annual basis, these results correspond to average net economic surplus gains of:
- **Shangji:** KES 845.9 million (US\$ 8.2 million) per year
 - **Asante:** KES 7.3 million (US\$ 0.07 million) per year
 - **Tigoni:** –KES 1.26 million (US\$ –0.01 million) per year

Given that 3R-gene Shangji is based on a widely grown, farmer-preferred variety and is the only 3R-gene option with large positive net benefits under the baseline, the detailed distributional and scenario analysis focuses on this variety.

Table: Distribution of potential annual economic benefits of 3R-gene Shangji across regions (million KES)

	Region	Δ Farmer surplus	Δ Consumer surplus	Δ Net benefits	IRR
No spraying	North Rift	11.1	8.8	19.7	78
	South Rift	25.2	6.9	32.0	76
	Eastern and Central	15.2	9.8	24.9	83
	Total	51.5	25.4	76.5	79
Triweekly Fungicide Application	North Rift	5.6	10.2	15.6	69
	South Rift	148.8	39.3	187.5	83
	Eastern and Central	23.6	41.8	64.9	74
	Total	178.0	91.4	268.0	78
Biweekly Fungicide Application	North Rift	(11.2)	29.7	18.2	64
	South Rift	328.9	64.6	392.9	98
	Eastern and Central	(8.2)	66.4	57.6	73
	Total	309.5	160.7	468.7	86
Weekly Fungicide Application	North Rift	(0.0)	5.6	5.5	74
	South Rift	21.8	5.3	27.1	97
	Eastern and Central				
	Total	21.8	10.9	32.6	88
	Overall total	560.8	288.4	845.9	

The South Rift region records the largest benefits for 3R-gene Shangji, reflecting its higher expected adoption area. Across regions and spray regimes, producers capture the largest share of total benefits—about KES 560.8 million (US\$ 5.4 million) annually—highlighting the importance of the technology for small-holder farmers who dominate the sector.

Poverty impacts as an alternative metric

As an alternative way of expressing these welfare gains, the economic surplus estimates were translated into poverty impacts using an established approach. The study estimates that adoption of 3R-gene Shangji under the baseline scenario could allow about 3,063 people to escape poverty each year, and about 91,884 people over the full life of the technology.

The cost of delay and other adoption scenarios

The study also explores several “what if” scenarios, showing how benefits vary with different adoption patterns and management practices:

- A five-year lag in the release of 3R-gene Shangji, due to delays in research or regulatory processes, reduces expected net annual benefits by 36%, from KES 845.9 million to KES 539 million (US\$ 5.2 million).
- If some farmers continue spraying fungicides at about three sprays per season after adopting 3R-gene Shangji, net benefits are 26% lower than in the baseline.
- Releasing a version of 3R-gene Shangji that only halves the expected yield loss compared to expert estimates (i.e., a lower-yielding transformed variety) would reduce net benefits by 31% relative to the baseline.
- Doubling research and development costs, for example due to

higher regulatory and monitoring requirements, reduces net benefits by only about 0.4%, indicating that the investment remains attractive even under higher cost assumptions.

An additional scenario assumes that 3R-gene Shangji is followed by a “new” 3R-gene variety with higher adoption potential, reflecting emerging farmer-preferred varieties. When the two 3R-gene varieties are released consecutively, total net benefits increase: net annual benefits reach about KES 1.216 billion, compared with the single-release baseline.

4. Policy priorities and opportunities for future work

• Fast-track regulatory approval and release of 3R-gene Shangji

The study finds sizeable economic and poverty-reduction benefits from 3R-gene Shangji, and shows that a five-year delay substantially reduces net benefits while leaving the overall case for adoption positive. The authors highlight that regulatory efficiency and effectiveness are important to realize the maximum benefits of the technology for producers and consumers in Kenya.

• Prioritize farmer-preferred varieties in deployment strategies

Expert adoption estimates point to 3R-gene Shangji as the priority variety, with the highest potential adoption and net benefits compared with 3R-gene Asante and Tigoni. The analysis also shows that a second 3R-gene variety, reflecting newer farmer-preferred varieties, can further raise national welfare when released after Shangji. This supports a gradual, sequential release of 3R-gene potatoes aligned with farmers’ varietal preferences.

• Invest in outreach and farmer awareness to realize full benefits

Model results indicate that continued fungicide use after adopting 3R-gene Shangi would significantly reduce net benefits. At the same time, Kenyan experts expect that outreach, communication, and awareness programs on the potential benefits of 3R-gene potato are likely to stimulate higher adoption. Clear extension messages on appropriate management of 3R-gene potato, including changes in fungicide use, will be important for farmers to capture the expected gains.

• Strengthen evidence on real-world impacts and costs

The paper also identifies areas where more evidence will be useful as 3R-gene potatoes move toward release and dissemination:

- o The economic surplus model is sensitive to assumptions on yield changes, cost changes, and elasticities, and uses regional averages that do not account for heterogeneity among farmers. This implies that actual on-farm yield and cost responses across farmer types and regions will be important to document once the technology is in farmers' fields.
- o Transaction costs related to dissemination, promotion, and adoption of 3R-gene potato are not included in the current analysis, and would reduce realized benefits once they are incurred.
- o Current estimates focus on direct producer and consumer surplus. The authors note that ignoring indirect benefits—such as potential reductions in food safety, public health, and environmental risks from lower fungicide use—may lead to underestimation of the full benefits of 3R-gene potato.

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