



## ToBRFV: The Global Tomato Crisis

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In the spring of 2015, tomato growers in Jordan noticed something alarming: nearly every plant in their greenhouses was diseased, fruits were rough, brown, and unsaleable — and the usual arsenal of genetic resistance had done nothing to stop it. The culprit turned out to be a previously unknown virus, now called Tomato Brown Rugose Fruit Virus (ToBRFV). Within a decade of its discovery, it had spread to more than 35 countries across four continents. Today it is considered the single gravest viral threat to global tomato production a crop worth billions, feeding hundreds of millions of people worldwide.

### What is ToBRFV?

ToBRFV is a member of the genus *Tobamovirus*, the same family that includes the infamous Tobacco Mosaic Virus (TMV) and Tomato Mosaic Virus (ToMV). Like its relatives, it is a rod-shaped RNA virus tiny, exceptionally stable and ruthlessly efficient at spreading.

### A brief history

The first recorded outbreak occurred in October–November 2014 in net houses in southern Israel, where tomato cultivars carrying tobamovirus resistance genes showed unexpected mosaic symptoms on leaves and yellow spotting on fruit. At roughly the same time, Jordanian growers reported nearly 100% disease incidence in greenhouse tomatoes.

The virus was formally identified and described in 2016 by researchers led by Salem and colleagues, who sequenced its genome and confirmed it as a new species of tobamovirus. By 2018, ToBRFV had been detected in Germany, Italy, Mexico and the United States. By 2019, it had reached Turkey, China, the United Kingdom, the Netherlands, Greece and Spain. By 2020–21, it had extended its reach to France, Egypt, Norway, Switzerland, Saudi Arabia and Syria. In India, ToBRFV was detected in open fields of tomato crop in May 2023 in Karnataka and Maharashtra states. Affected plants showed symptoms of mosaic patterns, mottling, yellowing, chlorosis, deformed leaves and necrotic spots or brown rugose patches on the fruits. Laboratory analysis (DAS-ELISA, RT-PCR, sequencing) confirmed the presence of ToBRFV in 11 fruit samples which had been collected from symptomatic plants (Kavya *et al.*, 2024).

The speed of this geographic expansion is telling: the virus almost certainly hitchhiked across borders not through insect flight, but inside tomato and pepper seeds traded internationally.

### Why is this so concerning?

Three factors combine to make ToBRFV uniquely alarming to the global horticulture industry.

First, it defeated a resistance gene *Tm-22* that had worked reliably for over 50 years. Molecular research has revealed that the viral movement protein (MP) is the key: six specific amino acid residues in ToBRFV's MP allow it to evade the immune recognition system that *Tm-22* normally activates. No previously known tobamovirus had this capability.

Second, While breeding companies are developing resistant cultivars, widespread commercial availability is still emerging. Breeding companies are racing to develop resistance, and some resistant germplasm has been identified in wild relatives such as *Solanum peruvianum* and *Solanum ochrantum*, but none has reached growers' hands in commercial form.

Third, its extreme stability and multiple transmission routes make complete eradication nearly impossible once a greenhouse or field becomes infected.

## Symptoms

### In tomato

**On leaves:** Early infection produces a mild-to-severe chlorotic (yellowing) mosaic, often with dark green bulges and leaf deformation. In severe cases, leaves narrow to a shoestring shape, wither and the plant may collapse entirely. Necrotic (dark, dead) lesions can appear on leaf stalks, stems and sepals.

**On fruit:** Infected fruits develop distinctive brown, rugose (rough, wrinkled) patches. Yellow spots often appear around the calyx (the green crown of the fruit), along with marbling, deformation and irregular ripening.

**In pepper:** ToBRFV causes mosaic and mottling on leaves and small yellow to brown rugose dots and necrotic blotches on pepper fruits. Young infected plants become stunted and in some cases stem necrosis causes partial or total plant collapse.

### How does it spread?

ToBRFV is transmitted through mechanical means it needs physical contact, not an insect, to move from plant to plant. This makes it simultaneously easier and harder to control than insect-vectored viruses. There is no spray that kills a vector; instead, every human touch, every tool, every drop of water is a potential vehicle of transmission.

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**ToBRFV**  
(Tobacco brown rugose fruit virus)

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Human touch



Tools



Water



Any contact can transmit the virus

**THE KEY ROUTES OF SPREAD INCLUDE:**

**1 Contaminated seeds**



Seeds extracted from ToBRFV-infected fruits are essentially 100% contaminated on their coat surfaces. Although the virus does not penetrate the embryo itself, when contaminated seeds germinate, the virus can infect cotyledons through micro-lesions.

The seed-to-seedling transmission rate is low – roughly 0.08% to 2.8% – but this is deceptive. Just two infected seedlings transplanted into a greenhouse can generate nearly 100% infection across all plants within months.

**2 Mechanical contact**



Pruning knives, harvesting tools, workers' hands, gloves, clothing, footwear, trays, and irrigation pipes can all carry the virus.

Tobamovirus particles are extraordinarily stable – they survive for weeks to months on bench surfaces and for as long as infected plant debris remains intact in the soil.

**3 Irrigation and drainage water**



ToBRFV persists in recirculating water systems common in hydroponic greenhouses, which can rapidly distribute the virus to all connected plants.

**4 Bumblebees**



In greenhouse tomato production, bumblebees are widely used for pollination. Research has shown that bumblebees can mechanically carry ToBRFV particles on their bodies and mandibles during buzz pollination, transferring infectious sap from diseased to healthy plants.

This is not true vector transmission (the virus is not replicated in the bee) but it can accelerate intra-greenhouse spread significantly.

**5** The virus almost certainly hitchhiked across borders inside tomato and pepper seeds – and its global journey may be far from over.



### Which plants are at risk?

Tomato (*Solanum lycopersicum*) is the primary crop host. Pepper (*Capsicum annuum*) is a secondary but significant natural host and ToBRFV has also been detected in pepper grown in Jordan, Italy, Turkey, Syria and Lebanon.

Beyond commercial crops, ToBRFV infects more than 40 plant species across four families including various *Nicotiana* (tobacco) species, *Chenopodium* species, several *Solanum* weeds and ornamental plants such as petunias. Weeds growing near tomato fields are a genuine risk: they can act as reservoirs, harbouring the virus without obvious symptoms and releasing it back into the crop through mechanical contact or pollinator activity.

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## Advice to Farmers: Prevention Is Everything

### Hygiene Best Practice Checklist for Growers

- **Use certified, ToBRFV-tested seed** from reputable suppliers. Treat seeds with 2.5% sodium hypochlorite for 15 minutes before sowing.
- **Disinfect all tools daily** - pruning knives, clips, stakes, trays
- **Wash hands thoroughly** on entering and leaving each greenhouse unit. Use disposable gloves and discard them correctly peel from wrist upward so the outer surface folds inward.
- **Change or sanitise clothing** between different greenhouse blocks. Never carry plant material (tomatoes, peppers) between greenhouses.
- **Restrict access** to essential workers only. Visitors, inspectors, and contractors are a meaningful biosecurity risk.
- **Monitor bumblebee hives** regularly; hives can harbour primary inoculum. Replace hives if infection is detected.
- **Remove and destroy infected plants** immediately. Bag plant material do not compost it.
- **Practise crop rotation** with non-host crops between tomato and pepper seasons.
- **Test irrigation water** in recirculating hydroponic systems; ToBRFV survives in water and can infect entire systems.

There are currently no curative chemical treatments for ToBRFV. Once a plant is infected, it cannot be cured only removed. This makes prevention the only practical strategy available to farmers today.

### Cross-Protection: A Promising Short-Term Tool

One strategy with real promise is cross protection a technique with a century of history. The idea is straightforward, infect plants with an attenuated (weakened) strain of the same virus before exposure to the aggressive form. The mild strain occupies the plant's infection sites and activates its defences, leaving little room for the severe strain to gain a foothold.

Cross-protection has been used successfully against several tobamoviruses, including TMV and Cucumber Green Mottle Mosaic Virus (CGMMV). For ToBRFV, scientists are working to engineer attenuated variants using infectious clones synthetic copies of the viral genome with strategic mutations that reduce pathogenicity while preserving the ability to stimulate immunity (Rohde *et al.*, 2025). The approach is technically feasible and could offer a faster solution than breeding, though regulatory pathways for deliberate inoculation of crops with viral agents are complex.

### The Long Game: Genetic Resistance

The most durable and economical long-term solution is the development of new resistance genes. Resistance breeding against tobamoviruses has succeeded before: *Tm-22* delivered 50 years of reliable protection (Ishibashi *et al.*, 2023). The challenge is to find new resistance sources that ToBRFV cannot overcome.

Several approaches are being pursued simultaneously. Screening of wild tomato relatives has identified promising resistance in three accessions of *Solanum ochrantum* and tolerant genotypes in *Solanum pimpinellifolium* (Jewehan *et al.*, 2021). These traits are being characterised genetically and DNA markers are being developed to speed their introduction into commercial cultivars through conventional breeding.

A breakthrough from Japan demonstrated that knocking out four copies of the host gene *TOM1* (which tobamoviruses require for replication) using CRISPR/Cas9 technology produced tomato plants highly resistant to ToBRFV and three related tobamoviruses, with no visible effect on normal growth or development (Ishikawa *et al.*, 2022). If regulatory approval pathways allow, this approach could significantly accelerate the development of durable resistance without traditional introgression timelines.

Pathogen derived resistance (using the virus's own sequences, expressed as RNA hairpins in transgenic plants) and artificial microRNA strategies are also under active

investigation, as are CRISPR based diagnostics that can detect ToBRFV specifically in the field within 90 minutes (Zhao *et al.*, 2023) crucial for rapid response when outbreaks occur.

### Looking Ahead

ToBRFV represents a new chapter in the long evolutionary arms race between tomato breeders and plant viruses. Its emergence forced a rethink of resistance strategies that had been trusted for half a century. It has shown that even the most durable genetic defences can be overcome when a new virus evolves or is inadvertently moved into a new environment.

The international seed trade, which is indispensable for global food security, also creates highways for seedborne viruses to travel faster than any regulatory system can respond. Countries with strong phytosanitary infrastructure like those in the European Union have managed to limit ToBRFV's impact through rigorous monitoring and quarantine measures. In many other regions, the virus has spread unchecked.

The message for growers, seed companies, researchers, and regulators is unified: complacency is not an option. Vigilant hygiene, rapid diagnosis, investment in resistance breeding and international cooperation in seed health standards are the collective tools that stand between this silent invader and a sustained crisis in one of the world's most important vegetable crops.

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