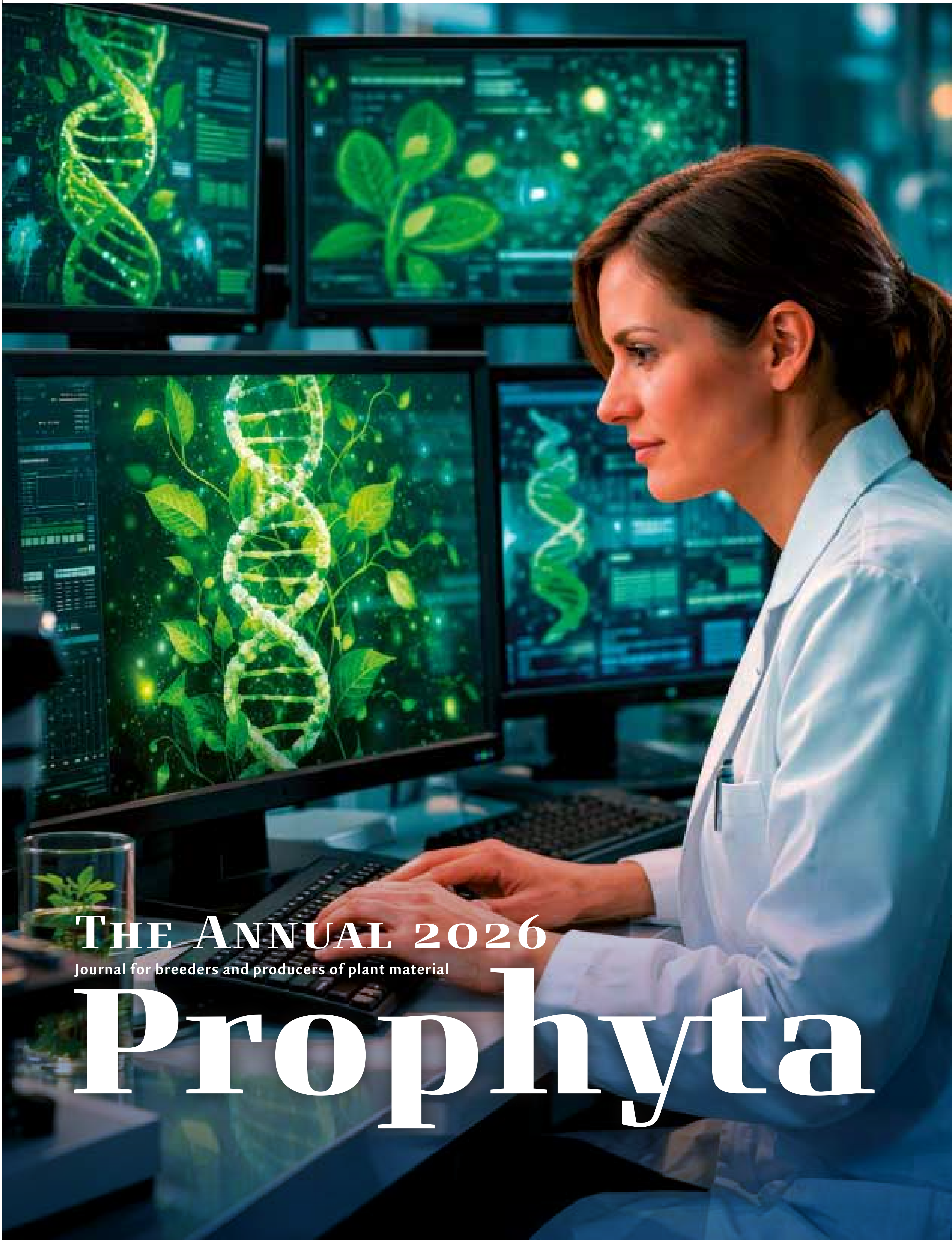

THE ANNUAL 2026

Journal for breeders and producers of plant material

# Prophyta

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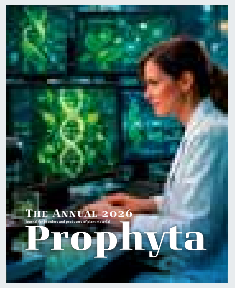


ON THE COVER: Digitalization of our research and work processes is unstoppable. Data, images, machine learning, and AI are now decisive for our future. Like this AI generated illustration.

# THE ANNUAL 2026

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## More organic varieties

Thirty years ago Bejo started to breed organic vegetable varieties. At the time, this market was still in its infancy. There were significant challenges, such as limited market demand, scepticism regarding seed quality, and complicated regulations for the cultivation of organic seeds. The company, however, recognized the long-term societal and sustainable importance of organic farming and subsequently made the strategic decision to invest in the production of organic seed. Today, Bejo's organic range now includes more than 30 crops and over 150 varieties, each selected for its performance under organic growing conditions.
The global organic food and beverages market size is projected to reach nearly 500 billion euro by 2030, growing at a Compound Annual Growth Rate of 13.6% from 2024 to 2030. The number one country for organics is Denmark, as the country has the most well-developed organic market. According to Statistics Denmark, the organic market share of retail trade in 2023 was 11.8 % measured by value. On average, 65.5% of Danish consumers put organic food in their shopping basket every week. The unique and governmentally certified Danish organic label 'The Red Ø' (Ø-mærket) has been very important to the widespread success that organic food products have achieved in Denmark. It is Denmark's official, state-controlled organic label, introduced in 1990 as the world's first national organic certification.

# Fleuroselect Gold Medal winners 2027

Verbena breeding has made significant steps in recent years, culminating in the innovative *Verbena bonariensis* 'Flair' from Benary - the most genetical compact variety on the market. The bright violet, round-shaped flowers have an eye-catching effect from a distance

The latest Helianthus variety from PanAmerican Seed, 'Always Sunny Gold', received a Gold Medal for its stunning golden yellow colour, longer field performance and the multitude of bees it attracted

A new era of Bacopa begins with 'Galactic Mist', the first *Sutera cordata* from seed to deliver flower sizes comparable to vegetative varieties. Developed by PanAmerican Seed, this breakthrough variety combines impressive, pure white blooms with outstanding uniformity and performance

'Heucherette Pink' redefines expectations of seed-raised Heuchera. This *Heuchera sanguinea* from PanAmerican Seed stands out as the first from seed with exceptionally strong flowering, producing large pink blooms that mature into rich rose tones, carried on bold yet compact flower spikes

The latest addition to Sakata's Zinnia series Profusion is 'Double White Imp'. Sakata's breeding efforts have resulted in significantly larger flowers, based on an even more compact plant and an enhanced flower longevity

## British scientists breed high-energy barley

Rothamsted Research has developed the first crop in the UK to receive a Precision Bred Organism (PBO) marketing notice confirmation through the new British regulatory pathway for precision breeding. Using CRISPR, the scientists succeeded in breeding a high-energy barley variety. The edits reduce the breakdown process of plant oils, causing the plants to accumulate higher levels of lipids in their vegetative tissues. The result is a forage crop with increased metabolisable energy.
The genetic changes introduced into the barley are small edits that could also occur naturally or through conventional breeding, which was also approved following a scientific review by the Advisory Committee on Releases to the Environment. The Genetic Technology (Precision Breeding) Act 2023 and the Genetic Technology (Precision Breeding) Regulations 2025, allowing the crop to progress towards wider evaluation (research and analysis) and eventual commercial deployment of the trait.
The barley is being evaluated through the PROBITY (Platform to Rate Organisms Bred for Improved Trait and Yield) initiative, a collaboration between researchers, farmers, and supply chain partners designed to test precision-bred crops in real farming environments.
Alongside the high-lipid barley, the project is also assessing precision-bred wheat varieties with traits aimed at improving grain quality and yield, led by Rothamsted Research and John Innes Centre, respectively.

## Olives saved in Svalbard

The 'Svalbard globale frøhvelv' has been the emergency stock of seeds since 2008

For the first time, olive seeds are being stored in the Svalbard Global Seed Vault. They were collected by the Olive Genebank of the University of Córdoba. The deposit included wild olive seeds from Spain and seeds representing the fifty most important cultivated olive varieties worldwide.
Earlier this year, two new countries deposited their seeds in Norway's Arctic facility: Guatemala and Niger. Together, they added 8,880 seed samples to the already well-filled vault. In total, there are 1,387,038 seed samples stored under permafrost deep inside a rocky mountain on the island of Spitsbergen. Among the new samples is an ancestor of maize preserved by local indigenous farmers in Guatemala.
The Svalbard Global Seed Vault is an initiative of the Norwegian government to ensure the world's future food supply. It serves as a back-up in case of emergencies caused by natural disasters, human conflicts, changing policies, mismanagement, or even a global catastrophe.

## AI-based nematode identification

A newly developed AI system can independently recognize the root-knot nematode *Meloidogyne chitwoodi* through a microscope (Nemascope) with 96% accuracy. Its performance matched that of an experienced taxonomic nematologist. *M. chitwoodi* is one of the most difficult nematodes to identify. It is therefore assumed that it would also work for species that are easier to distinguish. The breakthrough was achieved by researchers at Wageningen University & Research together with Veridi Technologies, a Dutch company developing solutions for monitoring plant diseases.
Harmful nematodes are reported to cause dozens of billions of euros in damages yearly to growers all over the world. Accurate identification is crucial, but identifying nematodes is costly and requires a great deal of expertise. Providing farmers all over the world with access to an affordable identification system could lead to better yields and less reliance on nematicides.







# Practical questions about collaboration

**Our worldview is under sustained pressure.**
Geopolitical developments, shifting economic interests, contested facts, armed conflict and climate (planetary) boundaries are changing rapidly. This directly influences political decision-making and, in turn, the work of advocacy bodies such as ISF, Euroseeds and national organizations. Their role in safeguarding a predictable regulatory and trade environment is therefore more critical than ever.
These dynamics also affect our day-to-day work as researchers and breeders, as well as seed producers and traders. They raise practical questions about collaboration: with whom can we share data and materials, where can we operate reliably and how do costs and risks change under new constraints? I remain confident that our sector has the resilience to maintain responsible partnerships and to keep contributing to global food security. The challenges are substantial and the technical options are expanding in parallel.
A key driver is the digitalization of research and operational workflows. Data analytics, imaging, machine learning and AI are increasingly central to how we design experiments, interpret phenotypes and accelerate decision-making. Several contributions in this edition of Prophyta connect directly to these developments. Personally, I find it reassuring to see how quickly and rigorously teams are building new research lines and tools. At the same time, I keep asking myself what a mature, responsible endpoint looks like and how we ensure transparency, reproducibility and appropriate governance along the way.

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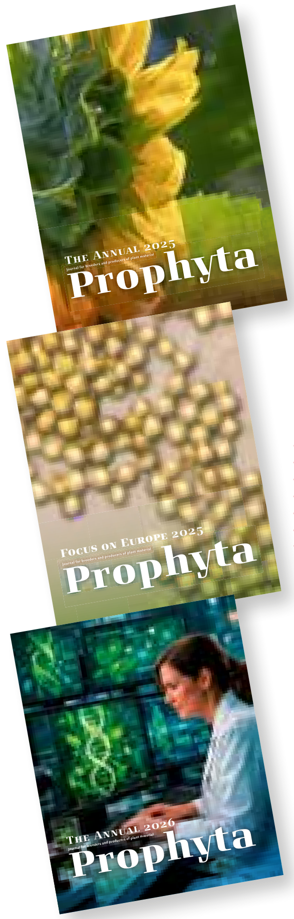
Steven van Paassen, editor-in-chief




# Become a Friend to continue Prophyta!

**For many years**, our magazine has been offering a broad spectrum of background articles, innovation and technology information, interviews, regulatory explanations, breeding developments and much more. Articles written by and photographs supplied by enthusiastic professionals who work in our seed and plant material sector. They contribute free of charge, and the magazine is a non-profit publication.

We are very thankful to our advertisers, many of them have been involved for more than 25 years already. With their financial support, we can largely cover the costs incurred in offering you a beautifully printed magazine twice a year. It is sent to you and 2,000 other professional readers, and many of you are enthusiastic about receiving it.

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Thanks for your support,
Prophyta magazine







Oncidium is also known as the Dancing Lady orchid because the plants have so many fluttering blooms on each spike that they have been said to resemble the full skirt of a ball gown

## CPVO and Taiwan strengthen cooperation

Early this year, the European Community Plant Variety Office (CPVO) and Taiwan agreed to strengthen the cooperation on the protection of *Oncidium* and *Phalaenopsis* orchids. The accord updates the bilateral framework by adding *Oncidium* to the list of species eligible for streamlined procedures.
The agreement focuses on the mutual recognition of Distinctness, Uniformity and Stability (DUS) testing. The CPVO will accept DUS test reports issued by Taiwanese authorities for Oncidium orchids. This allows breeders to bypass duplicate technical trials in the European Union, saving time and reducing export procedures.

## Coping with climate change

Scientists at the Innovative Genomics Institute, Berkeley, USA, have conducted a large-scale experiment to establish how probable and predictable a quick evolution of plants will be under changing climate conditions. They studied *Arabidopsis thaliana* in over thirty locations, each with twelve plots, in Europe, the Middle East and North America. Using whole-genome sequencing of over 70,000 surviving plants, a team of 70 scientists uncovered both known and novel adaptive genetic variants in the plants that survived. These genes were largely ones involved in handling environmental stress, like high heat, as well as genes that influence the timing of growth and reproduction - crucial parts of the plant lifecycle influenced by temperature, and therefore sensitive to climate change. The team explored the evolutionary dynamics that led some groups to survive while others perished, identifying genomic patterns that predicted survival or demise. The study 'Rapid adaptation and extinction in synchronized outdoor evolution experiments of Arabidopsis', was published in Science on 26 March 2026.

## Breeding hybrids through paternal leakage

According to scientists from the University of Hong Kong, Max Planck Institute and Wageningen University & Research, plant mitochondria can also be inherited via the paternal line. This can result in a potential new tool for plant breeders developing hybrids. Normally, mitochondria are inherited maternally, but occasional transmission of paternal mitochondria (paternal leakage) can lead to a recombination between maternal and paternal mitochondrial genomes. This can result in a genetically controlled difference in the timing, rate or duration of the developmental process. So far, the extent of paternal leakage and the cellular processes governing mitochondrial inheritance remain largely unknown. The scientists used *Nicotiana tabacum* to detect paternal mitochondrial inheritance. They discovered that the paternal transmission frequency was 0.18%, which increased markedly to 7.34% when the organellar exonuclease DPD1 was disrupted and pollen development occurred at low temperature. While still in a fundamental phase, this research highlights the potential of biparental transmission to rescue mitochondrial function and generate novel mitochondrial genotypes through recombination.

The unicameral parliament of Ukraine consists of 450 deputies and meets in the Verkhovna Rada building in Ukraine's capital, Kyiv

## Ukraine joins international treaty

The Ukraine parliament - Verkhovna Rada - has ratified the International Treaty on Plant Genetic Resources for Food and Agriculture. This step will provide Ukraine with access to global plant genetic resources and participation in the international benefit-sharing system, including a streamlined mechanism for exchanging genetic resources between gene banks worldwide. Joining the International Treaty is critically important to Ukraine for breeding and restoring the agricultural sector. In the context of war and the loss of some genetic resources, this will strengthen food security and the long-term resilience of the agricultural sector.
Globally, there are around 64 key agricultural crops (including wheat, rice, maize, barley, potato and soybean) that provide approximately 80% of plant-based food and calories. The international system focuses on these crops, as access to their genetic resources is critically important for food security.

Interview Michael Keller

# 'Multilateral cooperation matters **more, not less**'

Steven van Paassen

**In this troubled geo-political time, the ISF World Seed Congress is being held in Lisbon. ISF Secretary General, Michael Keller, thinks the world has something to learn from Portugal and the Iberian region in confronting challenges and building resilience. "In our view, it is precisely because the world is becoming more fragmented that multilateral cooperation matters more, not less." The congress can add to that.**

**Hosting the Congress in Lisbon** is both symbolic and strategic for Southern Europe, Iberia and Portugal. It puts the region at the centre of a global conversation on trade, innovation, collaboration and resilience, in line with this year's theme - "Joint Actions, Resilient Futures."

Michael Keller: "Southern Europe is living with many of the pressures shaping agriculture today, from climate stress to shifting market dynamics, evolving consumer demands and uneven access to innovation. This makes the Portuguese capital a relevant venue for discussing the current state of play, challenges and practical solutions."
According to Keller, the ISF Congress this year is also an opportunity to highlight Portugal's role as a connector between regions, markets and perspectives. It is notable that *The Economist* magazine named Portugal the Economy of the Year in 2025, after naming Spain the previous year. The publication also ranked the country first in its Food Systems Resilience Index released early this year. "Therefore, I think the world has something to learn from Portugal and the Iberian region in confronting challenges and building resilience."

### Create spaces

One of ISF's missions is to foster a collective sense of responsibility to engage in multilateral cooperation. How does ISF want to achieve this in a world of conflicts and de-globalization, with the resurgence of protectionism and non-scientific barriers?
Keller: "The fact is, no country is completely independent in providing farmers with all the seeds they need to sustain their populations. The seed supply chain is global by design. Our role as ISF is to keep the seed sector anchored in science-based, rules-driven dialogue and to create spaces where companies, policymakers, researchers and other stakeholders can align on common interests, led by ensuring global food security and supporting resilient agri-food systems."
Keller states that we may not control geopolitics, but we can help ensure that seed systems remain resilient, that seeds move and that farmers have access to the latest innovations and the seed of their choice.

ISF Secretary General Michael Keller: "Innovation only matters when it reaches the people"

### Fundamental

"However," Keller explains, "Seeds are rarely in the headlines because they are the beginning of the story, not the final visible product. Yet, as any farmer would know, seeds are absolutely fundamental. Every harvest, every food system and every strategy for climate resilience starts with seeds. In that sense, seeds may be less visible in the daily news, but they are nonetheless central to some of the most important issues facing the world today: food security, sustainability, productivity, biodiversity and adaptation to climate change. The global seed sector is therefore stronger and more relevant than ever, not only because of its scientific and innovative capacity, but because it helps translate that innovation into real solutions for farmers and society."

This is where ISF has a critical role to play. "One of our responsibilities is to make seeds more visible: to show that seed is not a niche issue, but a foundational one for food security and resilience. This means engaging in various global forums to reach policymakers and key decision-makers, but also reaching out directly to journalists and storytellers, and increasing our reach on our social media channels. In fact, our communications efforts have shown us that we have a story worth telling and that people are interested in it. Growing influence and increasing visibility take time, and the results so far show we are going in the right direction," Keller says.

> 'Innovation only matters if it reaches the people who can use it and benefit from it'



"Second, ISF's influence comes from our ability to bring the global seed sector together, to speak with a collective voice and to engage constructively with governments, international institutions and other stakeholders. We work to ensure that the movement of seeds, plant material and innovation remains as open, consistent and science based as possible. In a world marked by geopolitical tension, protectionism and non-scientific barriers, that voice matters more than ever."
Keller is optimistic about this. "The world does listen. It listens when we bring evidence, a global perspective and practical solutions to the table. ISF's effectiveness is evident in the way the seed sector is increasingly recognized in international discussions on trade, access to genetic resources, innovation and resilient food systems. Our role is to keep demonstrating that seed is a strategic topic. If we want to build resilient futures, seed must be part of the global conversation."

### Shared interests

In practice, the interests of agriculture, horticulture and ornamental sectors have distinct realities within the ISF organization. "But they also have shared interests. All depend on access to innovation, science-based and predictable regulation, the movement of seed and plant material and resilient, inclusive systems. ISF's role is to create alignment around those common foundations, while making room for sector-specific priorities and expertise," according to Keller.
Current politics is making trade more volatile. Tariffs and non-tariff barriers, strategic competition



'The world listens when we bring evidence, a global perspective and practical solutions to the table'

and shifting alliances create uncertainty for seed movement, business planning and farmer access to innovation. Keller: "But volatility does not have to mean vulnerability. ISF contributes by advocating for science-based, rules-driven trade and by helping the sector stay nimble, as new agreements and new market realities emerge. The ISF Trade Rules are a concrete example, because they have withstood all kinds of volatility and historical changes over the last 100 years!"

### Three examples

Besides politics, successful public-private partnerships are critical to shaping the future of the seed sector. Keller shares three important examples of this. "First is ISF's partnership with CGIAR, formalized through a five-year Memorandum of Understanding to improve farmers' access to quality seed and innovation from the private and public sectors. The partnership focuses on building stronger seed systems, encouraging greater adoption of improved varieties and closer collaboration between public research and the private seed sector, especially in countries where access to quality seed remains a major challenge."

"Another important example is the G7-OECD initiative, launched in 2024, to strengthen Africa's participation in the OECD Seed Schemes, in which ISF is a strategic partner. That matters because the OECD Schemes provide a harmonized international framework for varietal certification of seed, helping countries trade certified seed more effectively and with greater trust. Expanding African participation is a concrete way to connect policy cooperation, seed quality assurance and market access."

"Third, but not least, is the World Trade Organization's (WTO) Standards and Trade Development Facility (STDF) funded project in the Asia-Pacific region, led by APAARI and involving partners, including ISF and APSA. This initiative focuses on strengthening phytosanitary compliance and public-private partnerships to boost seed trade. What makes it especially relevant is that it brings regulators and the seed industry into a more structured dialogue, while also building capacity around SPS implementation and practical tools, such as ePhyto. That is exactly the kind of cooperation the sector needs to make seed movement safer, more efficient and more predictable."

### Practical mechanism

For Keller, these examples show that public-private partnership is no longer a side topic. It is becoming a practical mechanism for improving seed systems, enabling innovation, and making quality seed more accessible across regions. That is exactly the kind of cooperation the sector needs more of.

### Inclusive seed systems

The future of seeds will undoubtedly be shaped by a combination of existing, emerging and yet-unknown innovations. New breeding techniques, AI and stronger data-driven systems can accelerate productivity and resilience. Keller: "Innovation only matters if it reaches the people who can use it and benefit from it – i.e., the breeders and the farmers. In fact, this is a reality for many companies of all sizes: breeders working alongside the farmers to develop breeding programmes, test varieties and deliver the final product. This is also why inclusive seed systems are so important: systems where farmers of all sizes can access high-quality seed of their choice, where local markets are supported and where innovation reaches those who need it most."
Keller: "But the question is not only what is technically possible; it is also how innovation is deployed responsibly, at scale and with public trust, transparency and real value for farmers and society. At ISF, we are very conscious that tools are only valuable if the public accepts them and if regulations and policies governing their use are supportive."

### Toward solutions

Keller hopes participants leave Lisbon with a stronger sense of shared purpose and pride in being part of this sector, along with a practical momentum for joint action. "This is a moment to move beyond diagnosis and toward solutions: more resilient seed systems, open markets, science-based rules and innovations that deliver measurable impact for farmers. My message to participants is simple: none of these challenges can be solved alone, but together we can shape resilient futures."

Reading the signals

# Repositioning for a **volatile** world

Maria Lawrence

**As geopolitical tensions, climate pressure and trade disruptions reshape global agriculture, the vegetable seed industry is adapting with strategic precision. Maria Lawrence, Senior Market Intelligence Analyst at A-INSIGHTS (becoming Valona), maps the shifts redefining competitive positioning across the sector.**

For decades, the vegetable seed sector has been a relatively quiet outperformer, characterized by steady growth and comparably resilient margins. That stability now appears to be under more pressure, with growth moderating in parts of the market and earnings showing greater year-to-year variability (Graphic 1).

A closer reading of patent filings, variety registrations, financial data and M&A activity reveals why: the strategies underpinning that growth are decisively shifting. Vegetable seed players are, in fact, not only pursuing growth: they are increasingly defending core positions through innovation, expanding into new geographies and adapting portfolios to changing production realities.

One clear response is the growing focus on trait-based innovation. Patent activity around Tomato Brown Rugose Fruit Virus (ToBRFV) illustrates both the speed and direction of this shift. Filings increased sharply from 2020 and peaked in 2022–2023 (Graphic 2). During those peak years, 65–80% of filings were still variety-led, reflecting a more traditional breeding approach. More recent filings, however, show increasing attention to trait- and mechanism-level protection, pointing to a shift beyond the finished variety towards the underlying biology of resistance.

This direction is also visible in the market. Axia Vegetable Seeds expanded XR-resistant tomato registrations rapidly in the Netherlands, with the share of resistant varieties rising from 0% to 80% within 24 months from 2022, illustrating how quickly resistance traits are becoming central to competitive positioning.

Patent activity is concentrated among a small number of players. Rijk Zwaan led ToBRFV-related filings with 38 publications, followed by Nunhems with 25, highlighting the focus on securing positions around key resistance traits.

Rijk Zwaan reinvests nearly 30% of revenues into R&D, reflecting the priority placed on innovation.

## From yield to resilience

Breeding priorities are also shifting towards more risk-adjusted performance. In a more volatile growing environment, companies are placing greater emphasis on consistency under stress rather than yield under ideal conditions alone. This is reflected in how companies position their capabilities. Syngenta Vegetable Seeds has highlighted the use of AI to improve environment-specific variety placement, while East-West Seed emphasises varieties that perform across diverse conditions with relatively low input requirements.

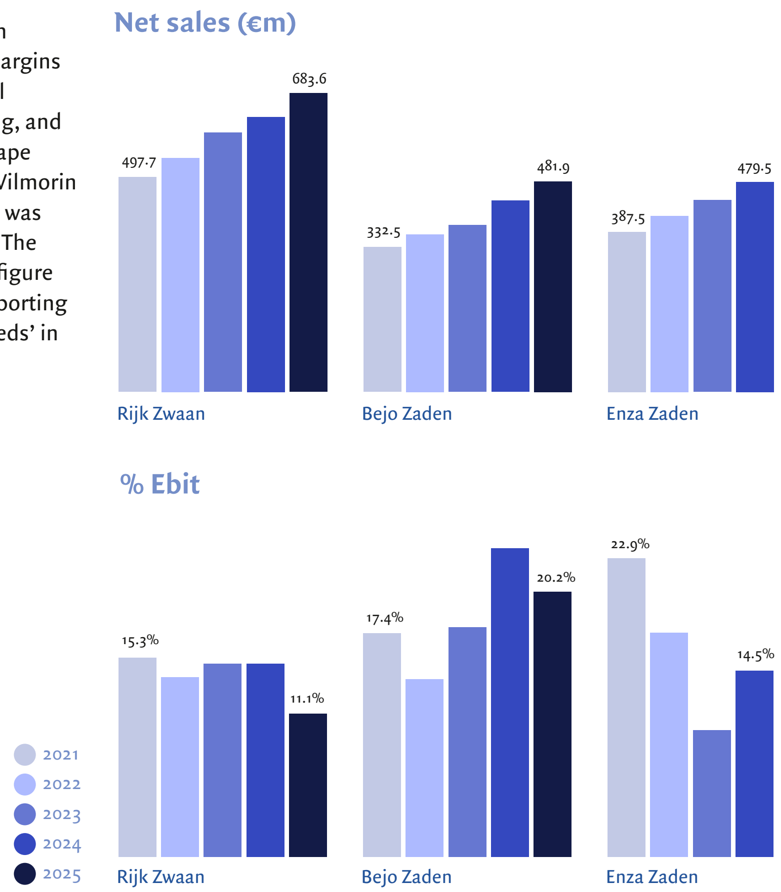
It is also evident that companies are actively reshaping their geographic footprint. Revenue data shows that leading European players are increasing their exposure beyond domestic markets (Graphic 3), with a growing presence in Asia and emerging regions.

This is visible in company performance. Rijk Zwaan increased revenue from €592.9m in 2023 to €683.6m in 2025, with growth driven largely by 'Rest of Europe' and 'Rest of World' markets.

M&A is also supporting this shift. Sakata, for example, strengthened its position through acquisitions including Agritu Sementes (Brazil) and Allium Seeds (UK), expanding both regional presence and onion market share.

## To strategic action

While the external environment remains uncertain, the strategic response is becoming clearer and increasingly visible in the data. Systematic competitor tracking across patents, registrations and M&A activity is now a competitive advantage.

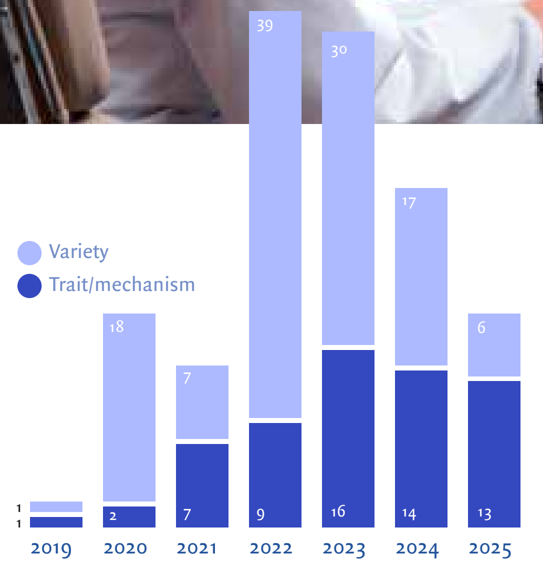



**Graphic 1** Growth continues, but margins diverge as capital focus, trait pricing, and climate risk reshape performance. 1) Vilmorin & Cie Vegetables was delisted in 2023. The rounded €836m figure is Limagrain's reporting for 'vegetable seeds' in 2025.

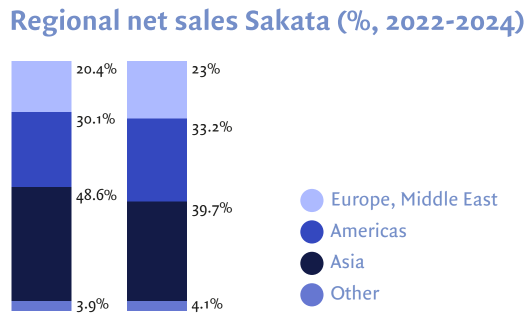




Professional scientist is working in a modern scientific research laboratory




**Graphic 2** Patent filings with "tomato" and "ToBRFV" (2019-2025). Source; Espacenet, 2019-2025.




**Graphic 3** Regional net sales Sakata (%, 2022-2024). Source: A-INSIGHTS, Sakata Annual Report

Maria Lawrence is a Senior Market Intelligence Analyst at A-INSIGHTS, a market intelligence solution specialising in the agri-food sector, currently merging with Valona.
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Pedro Pereira Dias, president of ANSEME

# Meeting point to build **trust**

Steven van Paassen

**According to Dr. Pedro Pereira Dias, President of the Portuguese Seed Association Anseme and directly involved in the organisation of the ISF Congress, the congress in Lisbon is particularly significant for the seed industry in Southern Europe and especially for Portugal. It represents recognition of the growing role that the Mediterranean region plays in the European agricultural context, not only as a production area, but also as a territory for testing, technical quality, adaptation and innovation in response to climate challenges.**

Steven van Paassen, chief editor Prophyta. stevenvanpaassen@prophyta.org

**For Portugal, hosting the ISF Congress** is a unique opportunity to showcase its companies, research centres and farmers, strengthening their integration into European and international value chains. It is also a strategic moment to position the country as a platform for dialogue between Northern and Southern Europe, between different agricultural models and production realities, at a time when agroclimatic diversity is increasingly valued.
Dias: “In my opinion, the Portuguese seed industry is relatively small in scale, but it is characterised by strong specialisation, technical knowledge and proximity to farmers. We have a resilient business fabric, with companies that combine tradition, local knowledge and the ability to adapt to demanding markets. My experience in African markets has also given me a broader global perspective on the sector.”

### Climate and predictability

Among the main opportunities, Dias highlights the appreciation of Portugal’s unique soil and climate conditions, the growing demand for varieties adapted to water and heat stress, and the country’s potential as a platform for seed testing and multiplication.

The close link between companies, producers and research centres is also, in his opinion, a key added value.
“At the same time,” Dias states, “the threats and challenges are significant: increased regulatory pressure, high R&D costs, a shortage of skilled labour and the need for scale to compete in a globalised market. I believe that adaptation to climate change and regulatory predictability will be key factors for the sector’s future.”

### Strengthen plant breeders

“In this future, we will see seeds developed based on models that integrate climatic, genetic and agronomic data, allowing for better adaptation to local conditions. New breeding techniques, once authorised in Europe, can make a decisive contribution to the resilience of European agricultural systems.
Rather than replacing human expertise, these technologies will strengthen the role of plant breeders, making innovation faster, more targeted and better aligned with the real challenges faced by agriculture,” Dias says.

Trial field in Portugal

### Widening gap

Technological innovation in the seed sector is unstoppable and transformative. Artificial intelligence, data-driven approaches and new breeding techniques are accelerating processes that once took decades, enabling more precise, efficient and sustainable selection.
It seems that the fast pace of technological innovation can increase the risk of a widening gap between large multinational companies, small enterprises and small-scale farmers. However, in the opinion of Dias, this is neither inevitable nor desirable.
“In the Portuguese context, the close relationship between seed companies, distributors and farmers is a clear competitive advantage. The challenge lies in ensuring that innovation reaches the field in an accessible way, through adapted varieties, technical support and inclusive business models. Technology only fulfils its purpose when it creates value for those who produce food. Therefore, it is essential that the sector works collaboratively, ensuring that Portuguese and European farmers, regardless of their size, benefit from innovation and remain an active part of the value chain.”



Seeds are a key element in building a more sustainable, resilient and productive agricultural future

Pedro Pereira Dias, President of ANSEME

### More than debate

Above all, the ISF Congress is expected to foster dialogue, alignment and strategic vision. The central message is clear: seeds are at the very beginning of the food chain and are a key element in building a more sustainable, resilient and productive agricultural future. Investing in innovation, science and collaboration is not an option, it is a necessity.
Dias: “I believe that the future of agriculture will not be built in isolation. It will be built through networks, cooperation, science and long-term vision. Lisbon will therefore be more than a stage for debate; it will be a meeting point to build trust, share solutions and reinforce collective commitment to the future of European and global agriculture.”

**New professor and chair of plant breeding at WUR Agnieszka Golicz**

# A new era in **plant breeding** research

Steven van Paassen

**As of 1 March 2026, Agnieszka Golicz has been appointed Professor and Chair of the Plant Breeding group at Wageningen University & Research (WUR) in the Netherlands. With an academic background spanning bioinformatics, genomics and explainable artificial intelligence, she brings a strong data-driven perspective to plant breeding - one that closely aligns with WUR's ambition to strengthen breeding research through cutting-edge technology. This article introduces Prof. Agnieszka Golicz and explores her vision of artificial intelligence as a powerful tool for advancing basic research.**

**Born in Poland, educated in Australia** and most recently working as Professor of Agrobio-informatics at Justus Liebig University Giessen in Germany, Prof. Golicz chose to continue her international career in the Netherlands. Wageningen, she says, had long been on her radar. "I heard a lot about Wageningen, especially about how breeding research is organised here. The level of collaboration between WUR and the agro-industry is something you rarely see anywhere else in the world."

She is particularly drawn to the integration of university-based education with fundamental and applied research. "For me, breeding is about searching for biotechnological breakthroughs, together with students, and translating those insights into real-world applications. Working in this kind of environment is incredibly inspiring."
Those breakthroughs increasingly involve artificial intelligence. But Prof. Golicz is quick to emphasise that AI itself is not the subject of her research. "We don't study AI for its own sake, and using AI is not a goal in itself. We use it as a tool, mainly within specific research projects."
This tool, however, opens unprecedented possibilities. AI enables researchers to combine large datasets - from the genetic code to observable plant traits - on a scale that was unimaginable just a few years ago. It can model complex interactions between genes and environment and even help unravel the molecular machinery inside living organisms.
"This approach is also rapidly being adopted in the agro-industry," Prof. Golicz explains. "It saves time, money and resources. But in academic research, it also enables us to ask deeper questions."
Prof. Golicz is not interested in just describing a phenomenon. She wants to understand how something works, what drives it. "What mechanisms underlie the specific interaction between genotype and environment? What processes govern the way biomolecular systems operate? With AI, we can explore these mechanistic questions in entirely new ways."
By weaving together predictions, large-scale datasets and visualizations, researchers can begin to see patterns that were previously invisible. Hidden relationships emerge, opening new avenues for crop improvement.
"We can generate new knowledge about underlying biological principles. I believe we are at the start of a new era in research."



'We can combine all kinds of predictions and use phenotype and genotype data on a scale which has never happened before'

"Students entering plant breeding programmes need a new set of skills"

Agnieszka Golicz:"We are exploring an unknown territory"

## The black box challenge

This new era does not come without its challenges: AI-driven research often strays from traditional scientific playbooks, and many of its models still function as mysterious 'black boxes', revealing results without clearly showing how they got there.
"We are exploring an unknown territory. That means a lot of trial and error," Golicz says. "We don't always know exactly how the tool reaches its conclusions."
All of this makes careful validation more important than ever: findings need to be tested again and again, and on a large scale. Researchers must learn to work effectively with AI - how to choose the right method for the right application. At the same time, biology itself remains unpredictable. "We are dealing with living plants, their genetics and their interactions with the environment. These systems are not easy to capture in models. That's why fieldwork and direct observation remain essential."

## Next generation

The rapid development of AI also has major implications for education. According to Prof. Golicz, students entering plant breeding programmes need a new set of skills.
"Curiosity and a willingness to explore are more important than ever. Students have to find a balance between working on the computer, in the lab and in the field."
At the same time, she warns against neglecting existing knowledge. "That would be the biggest mistake. It's like relying solely on a navigation system - you risk losing your sense of direction, the landscape and the broader context."
This is why Prof. Golicz values working in diverse teams. "There is so much valuable expertise already available. I like to bring together researchers across generations and disciplines. That's how you create real innovation."

## From research to application

Prof. Golicz appreciates that WUR gives her and her team the freedom to experiment. If new approaches prove successful, they can be adopted by researchers in the agro-industry to accelerate breeding processes.
"If we understand why a gene behaves the way it does, we can translate that knowledge into action," she explains. "That allows for more targeted breeding, shorter breeding cycles and more efficient use of resources."
Such insights can help develop crop varieties that are better suited to specific conditions, such as biotic stress, or improve understanding of crop interactions; opening the door to robust mixed cropping systems, instead of vulnerable monocultures.

## Working at the frontier

Looking ahead, Prof. Golicz sees her work firmly rooted in fundamental research, but always with a focus on broader societal questions. "Researchers at WUR are working at the frontier, and that will continue to be the case. The need for knowledge is constantly changing." She points to long-term challenges: the future of food production, labour availability, economic shifts and sustainability. "How do we balance technology, efficiency and sustainability? I'm excited to develop systems that help us address these questions in a meaningful way."

**The four famous pillars of Portuguese agriculture:**

# Port, cork, olive oil and rice

Ripe olives for the production of oil

John van Ruiten

**Portugal is a net importer of food and faces persistent structural challenges in its agricultural sector. The country has approximately 250,000 farms, around 80% of which are familyowned. Together, they cover 3.6 million hectares and contribute about 2.6% to gross national product.**

**Climate change, rural depopulation** and an increasing reliance on seasonal migrant labour place additional pressure on agricultural production. Nevertheless, agriculture remains economically significant, providing the primary source of income for roughly 11% of the labour force.
Historically, Portugal played an important role in the global dissemination of rice. During the maritime expansion of the 15th and 16th centuries, Asian rice varieties were introduced to West Africa, South America and Portugal itself. Within Portugal, varieties, such as *arroz carolino* and *arroz agulha*, were developed. With an average annual consumption exceeding 15 kilograms per capita, Portugal has the highest rice consumption in Europe. The main ricegrowing areas are Ribatejo and Alentejo.

Portugal is the world's leading producer of cork. More than 730,000 hectares are planted with cork oak (*Quercus suber*), predominantly in the Alentejo region. Cork can be harvested for the first time approximately 25 years after planting and subsequently every nine to ten years, with trees remaining productive for more than two centuries. Over 60% of global cork production originates in Portugal and is used not only for wine stoppers, but also for construction materials, furniture, flooring and fashion products. The protection of cork oak forests has deep historical roots, with legal safeguards dating back to 1209.
Olive oil production has expanded rapidly over the past 15 years, with the cultivated area now exceeding 360,000 hectares. Traditional varieties, particularly *Galega*, remain dominant. Portugal has become the world's sixthlargest olive oil producer, with an average annual output of around 150 million litres, largely of extravirgin quality.
In northern Portugal, the Douro Valley is internationally renowned for port wine production. Approximately 26,000 hectares of terraced vineyards are planted with more than 100 grape varieties. Although winemaking in the region dates back to Roman times, port wine gained prominence in the late 17th century, influenced by English merchants and facilitated by the Methuen Treaty of 1703. Port is produced using the *mutage* method, whereby fermentation is halted through the addition of grape spirit, resulting in a wine with an alcohol content of around 20%. Different ageing processes give rise to styles, such as Ruby, Tawny and Vintage, the latter noted for its exceptional longevity and capacity for longterm maturation.

Cellars full of port in Porto, Portugal

Ir. J.E.M. van Ruiten is the treasurer of the Prophyta Foundation, Leiden, the Netherlands.
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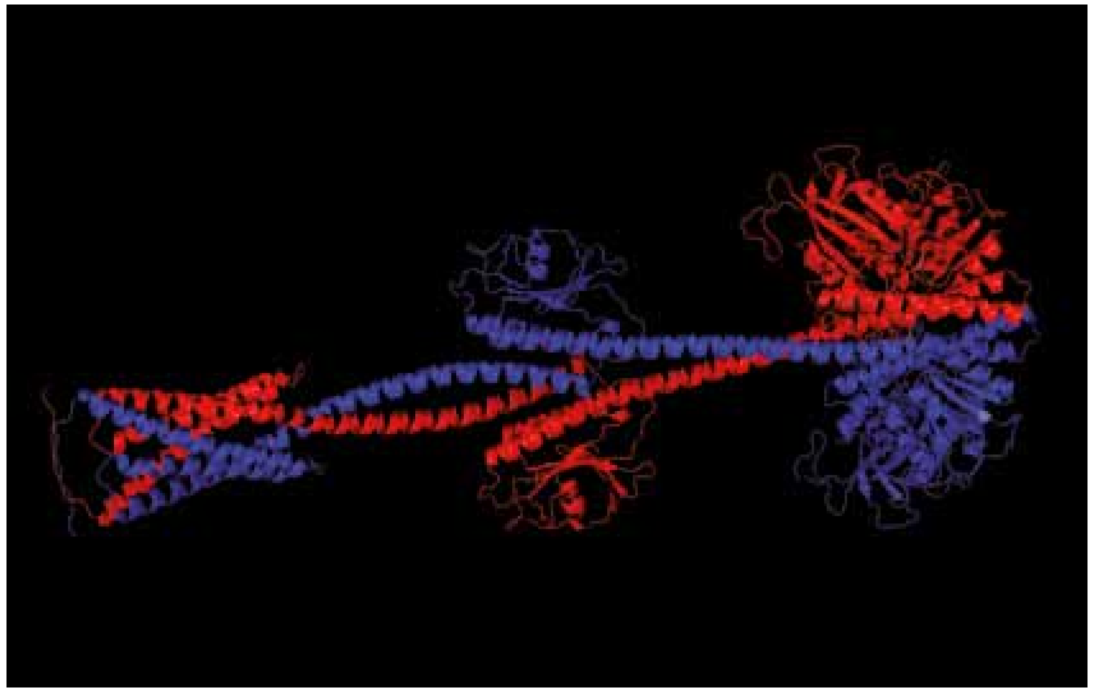
**Artificial Intelligence in plant breeding**

# From promise to practical **insight**

Steven van Paassen

**Artificial intelligence is frequently portrayed as a revolutionary force, capable of transforming industries at unprecedented speed. In plant breeding, expectations are similarly high. AI is expected to accelerate discovery, shorten breeding cycles, and unlock biological complexity that has long remained out of reach. According to Geo Velikkakam James, Research Leader Computational Biology at Rijk Zwaan, the key question is not *whether* AI works - but *where* it truly adds value in breeding practice.**



AI-generated protein structure

**At international breeding company** Rijk Zwaan, AI is neither a miracle solution nor a distant future vision. It is a developing set of tools - always dependent on data quality, biological understanding and human expertise. James finds it useful to distinguish between two broad categories of AI: generative AI and analytical AI.
Generative AI creates new content, such as pictures, text or summaries. In breeding companies, it can support internal reporting by summarising trial results, compiling regional climate information, or assisting with documentation. These applications can improve efficiency in daily workflows.
"Generative AI helps us work faster and more consistently," James explains, "but it does not directly influence breeding decisions."

Analytical AI, by contrast, plays a more strategic role. It focuses on recognising complex patterns and making predictions about biological systems. Examples include predicting protein structures, analysing the effects of mutations, or modelling interactions between plant resistance genes and pathogen effectors. This is where AI begins to influence how biological questions are formulated and explored.

### The 'language of biology'

Recent developments in AI research have focused on models trained on DNA and protein sequences - often described as learning the *language of biology*. Similar to how large language models learn patterns from human text, these biological models are trained on vast genomic datasets. The ambition is substantial: given a DNA or protein sequence, can AI predict its potential function? Such predictions can offer insight into protein structure, biological mechanisms and trait expression. They allow researchers to explore interactions at a molecular level that would be extremely difficult or time-consuming to test experimentally. However, these analyses are computationally intensive. Depending on the complexity of a protein and the number of variants tested, calculations can take days, weeks or even months, and require specialised hardware.

Geo Velikkakam James is Research Leader Computational Biology at breeding company Rijk Zwaan, located in Fijnaart, the Netherlands. He works in a multidisciplinary team with researchers and non-researchers, looking for new applications.

> 'AI is not a shortcut. It's a new lens through which we can understand biology'



Geo Velikkakam James: "suggests opportunities, highlights patterns and supports decision-making"

Human expertise, biological intuition and breeding experience remain central

As a result, these tools are currently used mainly for deep, targeted research questions - such as investigating disease resistance mechanisms - rather than for routine selection decisions across breeding programmes. "These models are fantastic for gaining detailed insight," says James, "but they are not yet something you run for every trait or every cross."

From random screening to smart prioritisation

One of the clearest practical benefits of AI lies in prioritisation. Gene banks contain thousands of accessions, making random screening costly and inefficient. AI models can analyse genomic patterns to predict which accessions are most likely to carry a desired trait.

This allows breeders to focus phenotyping capacity where the probability of success is highest. "Instead of screening everything," James explains, "AI helps us decide where to look first."

Once a resistant or promising line has been identified, AI can then help address the next key question: *why* does this line perform the way it does? Understanding the underlying mechanism enables more targeted followup research and better-informed breeding decisions.

At this stage, AI primarily expands the range of hypotheses and directions available to researchers. It suggests opportunities, highlights patterns and supports decision-making - but it does not replace experimental validation.

A question often raised is whether AI significantly reduces the total time required to develop new varieties. According to James, it is still too early to draw firm conclusions - and the answer is nuanced.

AI can clearly save time in areas such as data exploration, prioritisation and hypothesis generation. At the same time, it also creates more possibilities to explore, more scenarios to test and more questions to ask. "AI can save time," James says, "but it can also generate more work. That's why you need to be strategic."

At Rijk Zwaan, AI is not used by default in every project. Each application starts with a deliberate consideration: *is AI really needed here - and if so, which type?*

And, James adds with a smile: "We also have a lot of very good people." Human expertise, biological intuition and breeding experience remain central.

No AI system performs better than the data it is trained on. That makes data quality a critical issue in breeding applications. Breeding programmes integrate a wide range of data sources: crossing schemes, phenotypic observations, genotypic data, marker information, and environmental and weather data.

To prepare for effective AI use, many companies are investing heavily in making their data FAIR: Findable, Accessible, Interoperable and Reusable.

This is not merely an IT standard - it is a prerequisite for AI readiness.

"Without highquality, wellstructured data," James states, "even the most advanced AI models will underperform." At Rijk Zwaan, data improvement runs in parallel with AI development. The two are inseparable.

> 'Instead of screening everything, AI helps us decide where to look first'

### One crop is not another

Another challenge lies in applying AI across different crops. Models that perform well in one species do not automatically translate to another. A system optimised for tomato, for example, may not work equally well for spinach. Understanding where models are robust, where they need adaptation, and where they currently fall short is part of the ongoing learning phase. "We are not at full maturity yet," says James. "This is still a phase of testing, benchmarking and understanding strengths and limitations."

Plants contain roughly 30,000 genes, yet the function of many of them remains unknown. Much of plant biology is still a black box. AI, combined with phenotyping, markers, sensors and breeder expertise, offers new ways to explore that complexity. Not by replacing existing methods, but by adding another powerful analytical layer.

Looking ahead, AI is expected to improve understanding of trait mechanisms, support knowledge transfer across crops, enable more strategic breeding decisions and facilitate integration of increasingly complex datasets.

The speed of progress, however, will depend not only on data and models, but also on computational infrastructure, crossdisciplinary collaboration and thoughtful implementation.

"The opportunities are clear," James concludes, "but so is the responsibility. AI must be applied carefully and critically. It doesn't replace biology - it helps us understand it better."



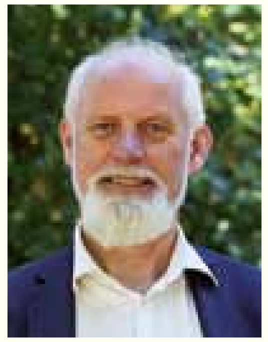


Column

# Celebrating NGTs in Europe

Niels Louwaars





**The dragging discussions about GMOs in Europe yield an outcome that make NGTs useable. A sigh of relief is heard in large parts of the seed and biotech sectors. ISF steered towards global harmonization, but some rules were not on the wish list of the sector. Sticky issues may still arise with the implementing acts, but as said in some cultures when something excellent happens – it could be worse.**

**The elephant is still in the room though: the European Parliament (EP) demanded that NGT-products would not be patented. Currently, there are some 5,000 CRISPR patent families on plants worldwide (SCTB-Centredoc, August 2025), and who knows what other patents (on cells, viruses, etc.) could affect breeders. That demand has been watered down with the consent of that same EP. The EU wants to balance rights and access through transparency - a declaration of patents resting on an NGT and willingness to provide FRAND licenses through licensing platforms – and a Code of Conduct. An NGT patent expert group will assess the impact on innovation, access, seed prices, litigation, competition and transparency, initially after one year (sic!). The Commission may take "appropriate actions including, if appropriate, proposing legislative measures." That last part is certainly welcomed. So, let's celebrate; but with the brakes on.**

Niels Louwaars, Seed Systems Specialist, the Netherlands.
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# Unlocking the **full potential** plant

Rick van de Zedde



**The generation of novel genotypes - those exhibiting distinctness, uniformity and stability - underpins the registration of new plant varieties for agricultural and horticultural use. Advances in novel breeding techniques present considerable potential for accelerating this process; however, the systematic evaluation of genotypic performance remains a significant bottleneck due to its labour- and time-intensive nature.**

To address labour- and time-consuming systematic evaluation of genotypic performance, automation, robots and other digital phenotyping technologies are increasingly being integrated into plant breeding pipelines for task-specific applications. Complementing these high-end solutions, cost-effective phenotyping tools, including smartphone-based imaging applications with dedicated analytical software, are becoming widely available and are broadening access to semi-automated plant performance evaluation.

Nevertheless, the full potential of these technologies remains unrealized. Accelerating their effective integration into routine breeding practice is essential to advancing a truly data-driven approach to plant science. This ambition is rendered increasingly urgent by the rapid pace of climate change, which is intensifying the demand for robust, (a)biotic stress-tolerant crop varieties.

This urgency provided the incentive for Wageningen University & Research and Utrecht University to establish the Netherlands Plant Eco-phenotyping Centre (NPEC) - a state-of-the-art national research infrastructure designed to enable the high-throughput phenotypic screening of large plant populations across controlled growth room environments, greenhouse conditions and open fields. To date, NPEC has supported over 300 indoor experiments and several hundred UAV-based flights, collectively contributing to more than 100 scientific publications. With a mature and operational technological infrastructure now in place, the primary bottleneck has shifted from data acquisition to data interpretation - specifically, the extraction of actionable insights from the substantial volumes of data generated. In response, NPEC has articulated a strategic ambition to position itself as a cornerstone of artificial intelligence research within the plant sciences, with a commitment to disseminating datasets in accordance with FAIR principles - ensuring they are Findable, Accessible, Interoperable and Reusable by the broader research community.

Central to the implementation of FAIR principles is the generation and curation of high-quality data and extracted traits, comprehensively documented with all relevant metadata in formats that are both human- and machine-readable. In practice, FAIR-compliant data management requires rigorous data labelling, accurate reference data and thorough metadata documentation encompassing technical specifications of equipment, software configurations, analytical parameters and operational protocols. Only through this level of systematic documentation can datasets be rendered truly reusable and interpretable by independent researchers across disciplines and institutions.

An early example of this approach is provided by the Leaf Segmentation Challenge, initiated by the Imaging Working Group of the International Plant Phenotyping Network (IPPN), which invited researchers to compete in generating optimal leaf segmentation and leaf count results using a publicly released dataset. This dataset retains considerable relevance within the community, with download rates continuing to rise. Notably, analysis of usage patterns reveals that a substantial proportion of current users originate from the artificial intelligence domain, rather than the plant sciences - demonstrating that well-curated, open datasets are an effective mechanism for engaging researchers beyond traditional disciplinary boundaries.

A compelling recent illustration is provided by the work of Bart van Marrewijk, a PhD researcher specialized in automated 3D plant architecture reconstruction, whose work formed a central component of the Virtual Tomato Crop project. Both 2D and 3D image segmentation pipelines were developed and applied, enabling the quantification of key morphological traits - including leaf number, plant height, digital biomass and internode length - through deep learning-based analysis. This research generated several peer-reviewed outputs, most notably *TomatoWUR*: an annotated dataset developed to facilitate the quantitative benchmarking of segmentation, skeletonization and plant trait extraction algorithms. Its release triggered an international collaboration with researchers from UC Berkeley, who demonstrated a markedly improved approach to 3D plant model reconstruction through the application of Gaussian Splatting, an advanced AI-based rendering technique, substantially enhancing 3D models acquired within the NPEC greenhouse.

Drs. Rick van de Zedde is programme manager at the Netherlands Plant Eco-phenotyping Centre (www.npec.nl) at Wageningen University & Research.

Bart M. van Marrewijk, Tim van Daalen, Katarína Smoleňová, Bolai Xin, Gerrit Polder, Gert Kootstra (2025). TomatoWUR: an annotated dataset of tomato plants to quantitatively evaluate segmentation, skeletonisation and plant-trait extraction algorithms for 3D plant phenotyping.

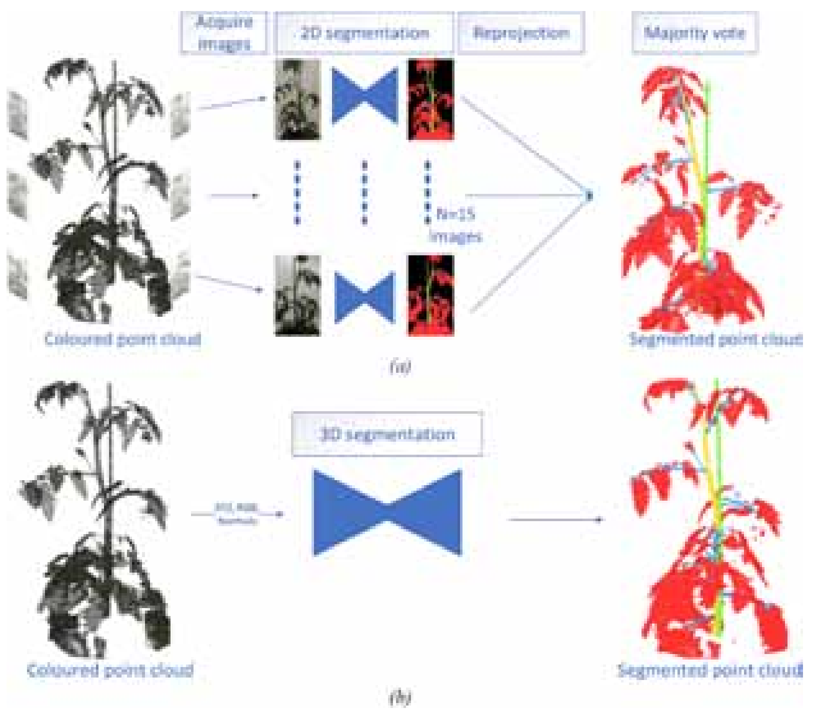


Impression from a soy bean flooding tolerance experiment in the NPEC greenhouse. Below the table the air inlet sock is visible, on the right the blue outgoing air pipes and above the tables the 3D/ multi spectral camera on a gantry. More details at www.npec.nl



The AI domain is characterized by a rapid succession of methodological advances; however, agriculture consistently lags behind other sectors in terms of labelled data availability and the translation of these advances into applied development. The proactive publication of well-curated, FAIR-compliant datasets represents a critical lever for addressing this deficit, with the potential to catalyze the methodological advances urgently required for sustainable crop production. NPEC is strategically positioned to support the development of foundation models capable of enabling researchers to extract richer and more generalizable insights from the vast image repositories accumulating across the plant sciences globally.

Looking further ahead, the next frontier lies in the generation of integrated, multi-modal datasets that fuse genomic, metabolomic and phenomic data into unified, thoroughly documented resources - encompassing reference data, metadata, and standardized protocols - disseminated openly in the public domain. The construction of such resources demands a coordinated, multi-disciplinary team effort across the plant sciences and, when coupled with advances in artificial intelligence, holds the capacity to yield discoveries that fundamentally transform our understanding of plant biology and accelerate the development of resilient, climate-adaptive crops capable of withstanding the intensifying pressures of a changing climate.




Schematic visualisation to segment plants in 3D using 2D-to-3D reprojection (a) or a 3D segmentation algorithm (b), input is a coloured point cloud and output is a segmented point cloud. The blue triangles represent a deep neural network.

**How well managed and accessible is your data today?**

# Is AI changing the rules of **Plant Breeding**?

Lisa Brandt and Jan Willem Kruize

**The breeder's intuition is no longer the only source of insight, it is now surrounded by data. Artificial Intelligence (AI) is often mentioned as the next step in this development. Yet AI itself is not the solution. The real challenge lies in connecting data, knowledge, technology and breeding processes in a way that strengthens the breeder's expertise.**

Reliable phenotypic data forms the basis for modern breeding approaches.

**A breeder can often recognize** a promising plant at a glance. Years of experience, intuition and practical knowledge make it possible to spot potential in seconds. This human expertise has been the foundation of successful breeding programmes for decades. At the same time, the breeding landscape is evolving rapidly. Where field observations once formed the primary basis for decisions, they are now increasingly complemented by genetic data, digital plant measurements and environmental information collected through sensors. Cameras capture plant development. Laboratories generate genetic profiles. Environmental data flows in from weather stations and greenhouse systems.

### Objectify observations

Digital phenotyping plays an increasingly important role. With sensors and image analysis, traits such as plant vigour, leaf area or disease symptoms can be measured consistently and at scale. This helps objectify phenotypic observations and makes results easier to compare across locations, years and trials.
Reliable phenotypic data also forms the basis for modern breeding approaches, such as genomic selection. By linking genotype and phenotype, breeders can predict the future performance of plants earlier in the breeding cycle.
AI can help identify patterns in these large datasets, strengthening the predictive power of breeding programmes. But even the most advanced algorithms depend on one crucial factor: data quality.

### Data as the real foundation

As breeding programmes generate more types of data, a well-structured and reliable data foundation becomes increasingly important. Field data, laboratory results, genomic information and images are often stored in separate systems or files. When these datasets are connected, they provide a more complete view.
However, in many organizations data remains fragmented across departments or software platforms. These data silos make it difficult to combine datasets and reduce the value of collected information.
Equally important is the quality of the data itself. Predictive models, AI analyses and breeding decisions all depend on reliable and consistent datasets. Without clear structures and high-quality data, even the most advanced technologies deliver limited value.
So, a key question for breeding organizations is: how well structured, how well managed and how accessible is your data today?

### Hand in hand

At Agri Information Partners (AIP), we help breeding organizations build clear and future-proof solutions. Our approach combines technology with a deep understanding of breeding processes and data management in the agribusiness domain.
Our solutions, such as E-Brida, support the management and integration of breeding data, while Mercado structures variety and market information.
By connecting these data sources, organizations can create a reliable foundation for analysis, predictive models and new digital applications, including AI.
For companies that want to make better use of their data, establishing the right data structure is often the first step.

Lisa Brandt is Marketing Communication Specialist and Jan Willem Kruize is Senior Business Consultant, both at Agri Information Partners, Wageningen, the Netherlands. Agri Information Partners [AIP] supports breeding companies and certification bodies in the agri-food sector with tailored software, system integration and expert consultancy. Are you getting the most value out of the data you already collect? Visit our website to discover how AIP helps breeding companies turn data into practical insights and take the next step toward data-driven breeding.

# Developing **whitefly resistant** tomatoes

Anna Freudenreich and Pauline van Haperen



**Deep learning models excel at finding complex patterns. Here, we apply them to images in an example of digital phenotyping, the process of using computers to measure plant traits through photos. By marking key features like whitefly eggs and larvae on training images, we 'teach' the model to spot and count these on its own, turning visual data into valuable, quantifiable measurements.**

**It is a familiar scene in many plant breeding** labs: experts spending hours peering through microscopes, carefully examining samples, manually counting tiny pests, disease symptoms or other important traits on leaves and plants. This labour-intensive and error-prone work is crucial for identifying resistant varieties, yet takes up a lot of valuable time of skilled researchers.

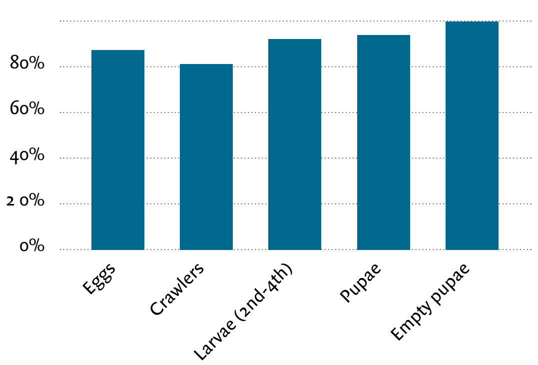
Computer vision can automate the detection of disease symptoms from images and speed up this process considerably. This makes it a great example of how AI can have an impact in plant breeding. AI is a powerful tool to create new solutions and opportunities to tackle complex challenges. By analysing vast amounts of data and recognizing meaningful patterns without being explicitly programmed, AI helps breeders develop better crop varieties faster and more efficiently.

### Detecting and quantifying

An example of how KeyGene has implemented AI to support plant breeding is the use of digital phenotyping in developing new tomato varieties that confer resistance to whiteflies. Whitefly (*Bemisia tabaci*) infestation and the subsequent transfer of plant viruses cause severe losses in tomato production. Traditionally, researchers monitor whitefly populations on large sets of tomato plants by quantifying different whitefly stages (*i.e.* eggs, larvae, pupae and empty pupae) using stereo microscopes. This is a labour-intensive and tedious process that requires an expert eye and is prone to mistakes. Therefore, KeyGene has developed a tool that can detect whiteflies from leaf pictures and quantify the different whitefly stages.

**The whitefly detection algorithm shows a high accuracy across all life stages**

Correlation manual-digital counts




To evaluate the algorithm's performance, its whitefly counts for each life stage were compared with manual counts performed by experts using stereo microscopes. The results showed a strong concurrence between the two methods, with correlation rates ranging from 81% for the hardest stage to identify (crawlers) up to an impressive 99% for empty pupae. This high level of accuracy confirms our digital phenotyping method as a reliable alternative to manual counting.

### Image capture

To generate pictures that can be used to train the Deep Learning algorithm to recognize different whitefly stages, adult whiteflies have been allowed to lay eggs in a confined area on tomato leaves using clip cages. After a few days, the adult whiteflies are removed, and the development of the eggs into nymphs, pupae and eventually adults (leaving empty pupae on the leaves) is being monitored. Once the first empty pupae are observed, the leaf area on which the clip cage was originally attached is photographed using a specific camera set up with fixed settings and optimal lighting conditions.

After capturing hundreds of high-quality images, a small portion is carefully reviewed and labelled by experts, who mark the different stages of whiteflies visible on the leaves. A part of this annotated set acts as a 'teacher' for the deep learning algorithm, showing it exactly what features are of interest. The algorithm is trained using these examples, gradually improving its ability to recognize the different whitefly life stages. Once trained, the model is tested on the remaining annotated images to see how well it performs. If any errors or inconsistencies are found, the algorithm can be refined further by adding new examples or adjusting its internal parameters, ensuring it becomes sufficiently accurate and reliable.

Ir. Anna Freudenreich is Researcher in Bioinformatics and AI; Ir. Pauline van Haperen is Scientist Biotic Interactions and expert in crop-insect interactions; both working at KeyGene, Wageningen, www.keygene.com





A number of leaf images were carefully annotated by experts, who identified and marked every whitefly stage visible, ranging from eggs and early crawlers (the first larval stage) to larvae, pupae and empty pupae left behind after the adults emerge. A part of these annotated pictures is then used as training data for the algorithm to learn what each stage looks like. Once trained, the AI model is tested on a holdout set of images to check how reliably it detects whiteflies on images it has never seen before. The algorithm produces counts of whiteflies staged for eggs, crawlers, larvae, pupae and empty pupae for each leaf picture, along with visual maps showing the detected insects. This allows researchers to verify the accuracy of detections and identify any missed or misclassified whiteflies.

### Camera set-up

The camera set-up that was used to make pictures of clip cage areas is a system in which settings, such as lighting conditions, are optimized and fixed as much as possible. The camera is mounted to a standard fixed height to make sure that the picture area and focus are the same for every picture. To avoid having out-of-focus regions in pictures of curvy leaves, the camera is set to make fifteen pictures with a slightly different focus and then stack those pictures into one, using the in-focus overlapping areas only. This way, the pictures that we use to train the algorithm are as uniform as possible, with the most notable differences being the different whiteflies in different stages.

### Efficient and accurate phenotyping

The whitefly detection algorithm shows a high accuracy across all life stages of whitefly and has been adopted as the standard way of phenotyping at KeyGene. The switch to this application of AI in our phenotyping approach has resulted in many advantages: not only by making the scoring of whiteflies stages less reliant on the availability of experts, but also by reducing the amount of time and efforts needed to score.
For example, a typical whitefly phenotyping at KeyGene required two experts counting whiteflies using the stereo microscope for a full working day; by using the whitefly detection algorithm, this was reduced to taking pictures for two hours and running the algorithm on selected pictures overnight. The application of AI in this step of the breeding process thereby allows researchers to design larger experiments and, at the same time, work more efficiently, thus improving and speeding up the breeding process.

### Valuable application

The use of AI in phenotyping has proven to be a valuable application. Therefore, we envisage extending this digital phenotyping method beyond whiteflies, adapting it to detect other insect pests and diseases. We also aim to improve the current system, for instance by allowing a more flexible camera setup, and developing a whitefly detection tool that can be run on a handheld device when screening your plants in the greenhouse.

# Predict **resilience** through smart data

Monique Westrik



**Computational approaches, such as AI and machine learning, are increasingly becoming part of high-tech plant breeding. The key question is how these tools can best be applied to advance the breeding of resilient crops. At CropXR, this question lies at the core of our work.**

CropXR is an international public–private partnership, bringing together universities and leading crop breeding and processing companies. Our mission is to make crops more resilient and climate-adapted, thereby contributing to a sustainable agricultural ecosystem.
Through large-scale lab and field experiments, we develop digital plant and crop models that contribute to understanding resilience and can predict breeding of more robust varieties. These models are expected to significantly accelerate the breeding of complex traits underlying resilience.

### Starting with fundamental research

At the heart of CropXR is fundamental research to understand resilience, a complex trait with many dimensions. We mainly focus on plant resilience to environmental stresses related to climate change, such as heat, drought, flooding and soil salinisation. To understand how plants respond to these stresses, we also study the underlying biological and physiological processes, such as networks of genes, hormones, metabolites, proteins and their interactions.

### Complicated

For processes involving only a handful of interacting factors in genotype–phenotype relations, the chances of identifying causal relationships are high. However, when studying complex traits, the situation becomes far more complicated. Many genetic factors, as well as highly diverse environmental influences, come into play. Together, they shape how plants respond when exposed to multiple abiotic stresses at different intensities, times and locations.

### Smart data breeding concept

To address the challenge of studying complex traits and interactions, CropXR is developing a novel and highly innovative methodology: a smart data breeding concept. The goal is to reveal the key factors that determine plant resilience by integrating experimental plant biology with a combination of mechanistic modelling, machine learning and other forms of artificial intelligence. This integrated approach has rarely been applied on this scale and makes the programme both unique and promising (Noordijk et al., 2024).

> 'We no longer need to start fundamental research from scratch for every crop'

**Experimental plant biology**

Important experimental data is collected from large experiments with plants exposed to combinations of stresses. For example, in the Demonstrator project we study seedling establishment by analysing plant gene expression responses to elevated temperature and drought. These experiments are carried out at NPEC (Netherlands Plant Eco-phenotyping Centre), where environmental conditions are carefully controlled.

In the CropXR Potato programme, extensive field trials are conducted in which plant and crop responses are measured and observed under various drought and nitrogen limitation regimes. In this case, experimental conditions cannot be fully controlled, as the plants are grown outdoors and therefore reflect real-world conditions and challenges.

**Mechanistic modelling and machine learning**

Mechanistic modelling and machine learning are both computational approaches. They offer two complementary ways to understand and predict how biological factors interact.
Mechanistic models are based on empirical knowledge and well-studied, known/published interactions, and aim to explain observed phenomena. In general, the mechanistic modelling approach seeks to simplify systems by reducing factors that have only a limited effect.
Machine learning (and AI in general) draws its strength from data. By analysing large amounts of high-quality data, it can detect patterns and predict how different biological factors interact in plant resilience. The more data available, the more accurate these predictions become.

Monique Westrik;
Communications Advisor CropXR, Utrecht, www.cropxr.org





### Demonstrator and Translator

The development of methodology to accelerate breeding for complex traits, such as resilience, is at the heart of CropXR. As a proof of concept for our smart data breeding approach, we run two closely connected projects: the Demonstrator and the Translator projects.
The Demonstrator project investigates how the combination of experimental biology with multiple computational approaches can lead to the identification of key regulatory mechanisms underlying plant resilience. In the Translator project, we subsequently translate these models to specific crop species.

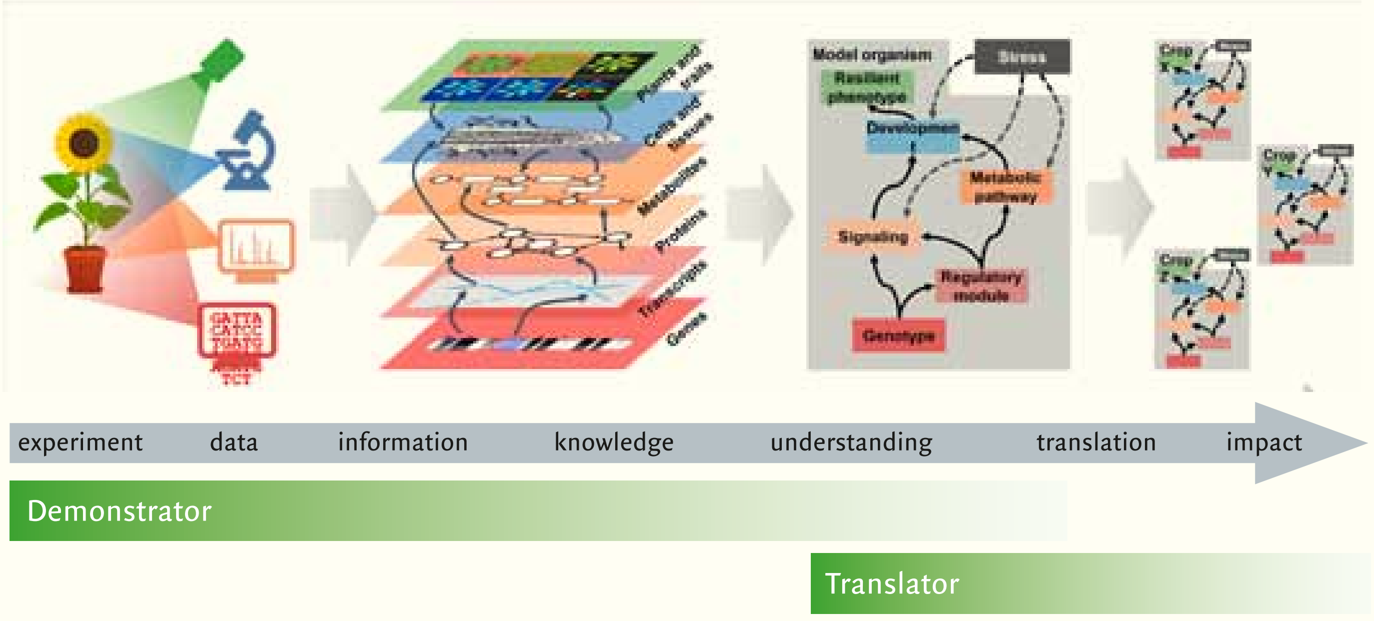
### Resilience outlines

It all starts in our laboratories, where we work with tens of thousands of *Arabidopsis thaliana* plants, the best-studied model plant. These experiments generate vast datasets that capture how plants behave under different environmental conditions and how resilience emerges when plants are challenged with diverse stresses. We integrate these experimental data into a detailed initial model of plant resilience.
With the knowledge from the initial model, the next round of experiments can be designed in a smarter way, requiring a smaller setup. This results in less data, but with greater relevance, filling knowledge gaps and generating higher-quality data to improve the models and make predictions more reliable. This is what we call the smart data breeding concept.
Within a timeframe of around five years, this approach aims to map the core regulatory mechanisms that govern resilience in *Arabidopsis* with a level of clarity that would be impossible using traditional methods alone.

### From model plant to crops

Of course, relying on our research on *Arabidopsis* alone will not directly impact crop improvement. The real test is whether we can apply the methodology from

# Frontiers in Systems Biology




CropXR's smart data breeding concept starts with experimental plant biology and subsequently progresses through the Demonstrator phase into models that are then translated to be deployed in specific crops (Translator phase).

the Demonstrator project - including our understanding and ability to predict plant stress responses and their underlying mechanisms - to crops.

> Onion cultivation in the Dutch province of Zeeland is becoming more challenging because of soil salinisation, compounded by the fact that existing onion cultivars are highly salt-sensitive

The second proof-of-concept project, called the Translator, is designed for this purpose. Which of the key factors in resilience are generic, and which are crop-specific? And how can we use this information to adjust models built on *Arabidopsis* to different crop species? In other words: how can we use this knowledge to formulate predictive models for crops?

Comparative genomics and tools, such as knowledge graphs, are being developed to support this translation. In addition, we use the outcomes of the Translator to develop and improve generic methodology to accelerate breeding for resilience.

By starting from an understanding of underlying mechanisms, rather than purely statistical patterns, we can adapt our models to other crops using far less crop-specific data than would otherwise be required. In other words, we no longer need to start fundamental research from scratch for every crop. That is where CropXR's accelerating power lies. Instead of rebuilding knowledge from the ground up for each species, we adjust and recalibrate existing models to reflect crop-specific traits.

## Specific set of Crops

At CropXR, we concentrate on a selection of crops that hold particular economic value for both our industrial partners and the broader breeding sector. We feel supported in our approach by the generous funding we receive from among others NWO (the Dutch Research Council) and the Dutch National Growth Fund, which invests in research aimed at strengthening the economic value of the Dutch breeding industry and keeping it at the forefront.
These crops all face different challenges, ranging from extreme weather conditions affecting open-field crops, such as potato, onion and Brassica, to reducing the use of crop protection products for crops in greenhouses.

Six crops that CropXR focuses on

| | | |
|---|---|---|
| Brassicas | Chrysanthemum | Lettuce |
| Onion | Potato | Tomato |

## Generic methodology

Ultimately, we aim to develop a generic methodology that will enable the breeding of resilience in any crop. Crops that are particularly vulnerable to the effects of climate change - for example, rice or wheat - could benefit greatly from this approach. In this way, we aim to create real impact and contribute to global food security.

Literature: Noordijk B., Garcia Gomez M.L., ten Tusscher K.H.W.J., de Ridder D., van Dijk A.D.J., Smith R.W. (2024). *The rise of scientific machine learning: a perspective on combining mechanistic modelling with machine learning for systems biology.*





Protecting plant innovation in an AI-driven decade

# Thirty Years On


Francesco Mattina

The image accompanying this article is created partially by AI

**Thirty years after its creation, the CPVO stands on a solid foundation built by its staff, Member States, examination offices and users. The events and activities of 2025 demonstrated that confidence in the CPVR system remains strong. Our task for the years ahead is to preserve that trust, while ensuring that the system continues to evolve in step with scientific progress and societal expectations.**

Francesco Mattina, President, Community Plant Variety Office (CPVO).

**In 2025, the Community Plant Variety Office** (CPVO) marked its 30th anniversary at a time when European agriculture is facing profound transformation. Innovation expectations are rising, technologies are evolving rapidly and breeders operate in an increasingly competitive global environment. Against this backdrop, the anniversary was not conceived as a retrospective exercise, but as a moment to reaffirm a shared responsibility: ensuring that Europe continues to offer a reliable, predictable and specialized system of plant variety protection.

## Firmly embedded

The central institutional milestone of the year took place on 24 April 2025 in Angers, with the seminar "*30 Years of CPVO Enabling Innovation for the Future of Plant Breeding.*" The event brought together senior representatives from EU institutions, Member States, international organisations, research bodies and industry. Discussions focused on how plant variety rights support investment in breeding, how intellectual property interacts with sustainability and food security objectives, and how policy frameworks can remain supportive of innovation in a fast-moving scientific landscape.
The presence of high-level speakers from the European Commission, the European Parliament and partner EU agencies gave a clear signal: plant breeding and plant variety protection are firmly embedded in broader EU policy discussions on competitiveness, resilience and the future of agriculture.

2025 was marked by a series of targeted institutional visits and conferences across Europe, where CPVO participated in high-level discussions, linking plant breeding, innovation policy and intellectual property. These moments of dialogue are important opportunities to explain the role of the CPVR system, listen to national perspectives and reinforce cooperation with ministries, research organisations and professional associations.
The CPVO's external engagement also extended beyond the European Union. International missions and technical exchanges in Asia and other regions strengthened cooperation with partner authorities and contributed to the convergence of examination practices. In a globalised breeding environment, such cooperation is not optional; it is a practical necessity to ensure efficiency, quality and mutual confidence between systems.

## Progressively modernising

Digital transformation is another strategic strand shaping our future. The CPVO is progressively modernising its services and internal workflows with a clear objective: better accessibility for users and greater efficiency for the Office. Within this context, Artificial Intelligence is approached in a pragmatic and cautious manner. AI may offer valuable support for document handling, language processing or user assistance, but it cannot replace expert judgement. Quality, transparency and human oversight remain non-negotiable principles.

# Hormone-free **regeneration**

Renze Heidstra



**Regeneration is a developmental process involving stem cell biology, but its application is hampered by the recalcitrance displayed by many plant species. Taking the stem cell-related genes as a starting point, researchers at Wageningen University & Research (WUR), working in close collaboration with KeyGene, have now developed a hormone-free regeneration able to break this recalcitrance. The promising findings have been published in The Plant Cell (https://doi.org/10.1093/plcell/koaf252).**

Like all living organisms, plants have developed resilience mechanisms to effectively endure and overcome physical damage and environmental challenges throughout their life span. The most straightforward way for plants to deal with the environment and ensure continued growth, is to form de novo stem cell pools that allow the development of lateral roots and shoots. For example, damage can result in wound sealing, but it can also induce reprogramming of somatic cells towards stem cells for de novo organogenesis. This regenerative capacity of plant cells is exploited for plant propagation and genetic engineering via phytohormone mediated tissue culture methods.

## Significant hurdle

The past decade has witnessed an increasing interest in plant regeneration, not in the least by the opportunities provided by CRISPR/Cas-mediated gene editing to enhance yield, resistance to pathogens and mitigate environmental stress. However, recalcitrance to hormone-based regeneration procedures remains a significant hurdle for many economically important species and cultivars thereof. With many variables, including genotype, explant origin and age, hormone balance and concentrations, the optimizing of protocols is a labour-intensive trial and error endeavour with no guarantee of success.

Notably, observations in the 1950s demonstrated the influence of the auxin-cytokinin balance for in vitro regeneration of tissues or even somatic embryos from callus. These and many follow-up studies showed that somatic cells could be reprogrammed towards pluri- or totipotency, respectively. In addition, we now know that callus is more than a mass of unorganized plant cells. Callus can be subdivided into three layers, of which the middle layer expresses root stem cell-related transcription factor genes, and it is from this layer that regenerating structures originate. The same genes are expressed and important during hormone-induced de novo shoot regeneration from root, cotyledon and petal explants of Arabidopsis. This in turn indicates that regenerating cells from whatever explant origin, first transit through a root stem cell-like stage before progressing towards organogenesis.

## Rational design of PLT/WOX

The correlation between hormone-induced regeneration and root stem cells prompted researchers from Wageningen University & Research, together with KeyGene, to take a shortcut and directly induce the stem cell-related genes. Similar to the strategy of inducing animal-induced pluripotent stem cells (iPS) cells, a larger set of stem cell genes was reduced to just 2 transcription factors, that synergistically induced abundant regeneration in transgenic Arabidopsis. This minimal set consisted of AINTEGUMENTA-LIKE3/PLETHORA1 (PLT1) and WUSCHEL-related homeobox 5 (WOX5). This synergistic PLT/WOX effect was also observed for the combination of BABYBOOM/WUSCHEL and corroborated by findings in maize and rice, with family member combinations giving cooperative regeneration and parthenogenesis, respectively.

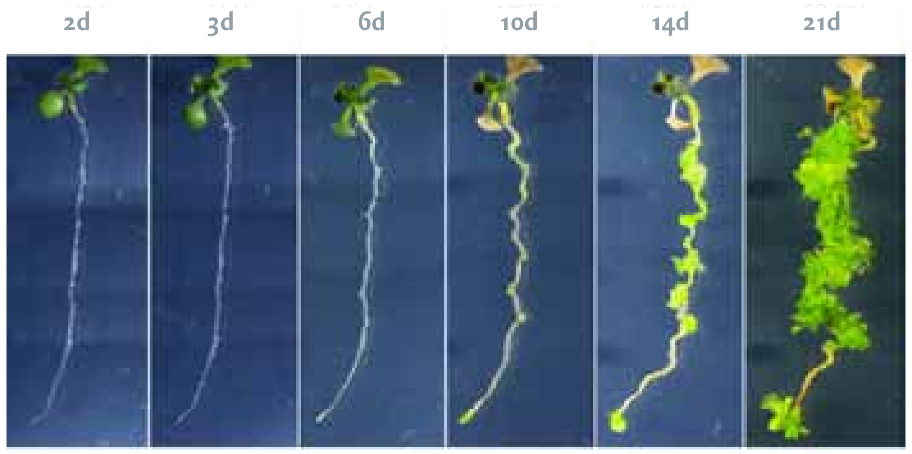



Fig 1 Activating PLT/WOX induces regeneration through somatic embryogenesis in the absence of exogenous hormones. Images by Menno Pijnenburg

Renze Heidstra, Cell and Developmental Biology, Cluster Plant Developmental Biology, Wageningen University & Research



Fig 2 Sudan Red staining shows fatty acid accumulation indicative of regenerating somatic embryos at 14 days after PLT1/WOX5 induction. Image by Jana Wittmer.



## Difference

So, what is different between hormone-induced de novo shoot regeneration and PLT/WOX induced hormone-free regeneration? First, hormones induce callus from the pericycle, ending up with a middle layer of competent cells, while PLT/WOX induced callus differs with tissue type and developmental stage. For example, in the root meristem, cortex and epidermis tissue proliferate and express competence markers, whereas in the differentiated parts, proliferation and competence again originated from the pericycle. Second, time course RNA sequencing and detailed phenotyping showed that PLT/WOX induces regeneration via somatic embryogenesis.

Indeed, many genes related to callus middle layer and somatic embryogenesis can be bound by PLT/WOX family members, indicating direct regulation. Among these are the well-known LAFL genes (LEC1, ABI3, FUS3 and LEC2), of which LEC1 and LEC2 themselves can induce somatic embryos when ectopically expressed. Interestingly, LEC1 expression was observed as early as 4 days after PLT/WOX induction, which correlated with the minimum induction time being sufficient for cells to self-organize and gain autonomy to regenerate.

## Hormone-free regeneration

The important question to address next is whether PLT/WOX induction can overcome the regeneration recalcitrance of plants observed under hormone conditions. Here, the advantage of the Arabidopsis floral dip transformation was exploited to introduce the inducible PLT/WOX construct into a panel of highly hormone recalcitrant accessions. In all cases, PLT/WOX induced regeneration. Next, PLT/WOX was found to induce regeneration in tomato and lettuce upon agrobacterium transformation via cocultivation. However, their introduction into the highly regeneration recalcitrant bell pepper was troublesome. Nevertheless, once inside, local PLT/WOX induction resulted in efficient somatic embryo formation and yielded fertile regenerated plants. Together, these results demonstrate that PLT/WOX can induce hormone-free regeneration in plants so far deemed highly recalcitrant.

## Outlook

Introduction and expression of PLT/WOX bypasses the requirement for hormone application for regeneration across multiple species. Although PLT/WOX can break regeneration recalcitrance, the case of bell pepper shows that a bottleneck may lie at the transformation step, getting the genes inside of a sufficient quantity of cells. Knowing that the majority of Agrobacteria originate from only a few strains originally developed in the 1980s, suggests opportunities to explore naturally occurring strains. An alternative strategy may be to directly introduce the proteins or encoding mRNAs, for example encapsulated in nanoparticles, which also provides a GMO-free regeneration setup. Either way, the PLT/WOX setup will be a valuable tool to further investigate regeneration in terms of gene regulation and epigenetic reprogramming, aiming towards a genotype independent regeneration system.

Focus on hydrangea

# From artisanal to **large-scale**

Steven van Paassen

**Hydrangea, also known as Hortensia, is still a complex and therefore artisanal crop, from Asia to Europe. But constantly evolving genetics, combined with targeted marketing, could well mean the breakthrough to large-scale cultivation. Early hydrangea innovator, Sjaak van Schie, and Martijn Kuiper, commercial manager of Agriom, share their perspective.**

Steven van Paassen, chief editor Prophyta. stevenvanpaassen@prophyta.org

Hydrangea is a genus in the hydrangea family (Hydrangeaceae). It primarily comprises evergreen and deciduous shrubs and a few trees. In total, there are nearly one hundred species native to America, China and Japan.

The Hi Mars Red variety by Sjaak van Schie

**Ancient species**

Fossil finds show that hydrangea already existed in North America 40–65 million years ago. Later, species were discovered in China, Japan, Korea, Taiwan and the Philippines, where hydrangea has been cultivated for many thousands of years, primarily as a medicinal plant. The first Hydrangea arborescens was imported to England from Pennsylvania by Peter Collison around 1736. Grovonius first named the plant Hydrangea in his 1739 work "Flora Virginica." The botanist Carolus Linnaeus mentioned the name Hydrangea arborescens in 1753.
Numerous botanical voyages from America and Europe to China and Japan yielded a wide range of hydrangea genetic material, which was crossbred primarily for use in ornamental gardens.
Thanks to the Dutch international bulb trade, which benefited the hydrangea trade, important cutting and production centres emerged in Aalsmeer and Boskoop in the Netherlands, Ghent in Belgium and Dresden in Germany. Italy is also particularly important for patio hydrangeas.

Some varieties bloom with a large, pyramidal panicle, while others have a flattened umbel or a more spherical inflorescence. The most commonly cultivated species is the large Hydrangea macrophylla. Hydrangeas have been highly valued by consumers for centuries as potted and garden plants. However, it has not yet been possible to penetrate the top of the commercial world. The reason is clear, according to Dutchman Sjaak van Schie, an entrepreneur and international hydrangea consultant for decades. "Hydrangea cultivation is still too complex and time-consuming to be carried out on a large scale, automated and efficient basis. Hydrangea cultivation is biennial, making it a relatively expensive plant."

### Two-year cultivation

In the spring of the first year, cuttings are harvested from mother plants, primarily in Uganda and Kenya, and then flown – unrooted – to Europe. These cuttings are rooted by specialized growers, then grown outdoors and topped into semi-finished products. The buds then form in the field under the influence of shorter days and lower temperatures. The plants are then placed in a cold storage room with a cold period of approximately 1,000 hours at 3-5°C. In the spring of the second year, the plants are actually forced to flower and can then be sold from May to August.
Martijn Kuiper of the Dutch breeding company Agriom adds: "Every step in that long cultivation process must run smoothly, because the final cost of a hydrangea is relatively high. You can hardly afford to have losses or flowerless branches. It's primarily handcrafted work by specialists. You can't just do that on the side."

### Complex

"Highly automated hydrangea cultivation on large farms isn't yet feasible. The cultivation process is too complex. To still benefit from the advantages of scale and specialization, we collaborate intensively and internationally."
Van Schie: "Central to our operations is the company Sjaak van Schie BV. They produce hydrangea cuttings exclusively, with locations in Uganda and Portugal. We also handle the propagation and sales at and from locations in Portugal (40 hectares) and the Netherlands (8 hectares of greenhouses and open ground).



Martijn Kuiper in the Agriom breeding greenhouse

**'Every step in that long cultivation process must run smoothly'**

For breeding, there's a separate company, HiBreeding, which stands for Hydrangea Innovation Breeding. It employs its own breeder but collaborates with a similar company, MasterGrowers, both located in Westland. "HiBreeding focuses solely on hydrangea. This allows for a strong focus on new genetics and the best selections. Together with MasterGrowers, we can share the costs of the facilities involved in the otherwise expensive breeding process."

### Networks

The breeding company, Agriom, in Aalsmeer, the Netherlands, where Kuiper works, also has partnerships. And they certainly work with a wider range of crops than just hydrangea. Kuiper: "Agriom is essentially a breeder that clients can hire: on an hourly basis, for a project or on a contract basis. We have basic knowledge and facilities for crossing, selecting and marketing. We're certainly willing to take risks, but thanks to the diversity of our clients and crops, we can spread substantial investments in breeding. To also have the specific expertise in-house, we've been working exclusively with two German hydrangea breeders/producers for many years. These three companies together form the HBA, Hydrangea Breeders Association."
This creates networks within which partners can also compete. "Good agreements regarding variety ownership and royalties are therefore very important," adds Kuiper.

**Species at a glance**

The world's most important commercial hydrangea:

- **Hydrangea macrophylla.** Approximately 75% market share. Has large, round inflorescences and comes in many colours. For pot plants, cut flowers and landscaping.
- **Hydrangea paniculata.** Approximately 15% market share. Has upright, panicle-shaped flowers and grows well in various climates.
- **Hydrangea arborescens.** Approximately 7% market share. With large, round inflorescences, often white or green. Primarily for landscaping.
- **Hydrangea scandens.** Approximately 2% market share. With beautiful, large flower clusters. Primarily for landscaping.
- **Hydrangea quersifolia.** Approximately 1% market share. With panicle-shaped inflorescences and dark foliage. Primarily for landscaping.

### Eight years selection

"Investments in crossing, breeding and marketing hydrangea are necessary to continuously strengthen the popularity of this plant. The constant competition on the shelves with other plants is always fierce," says Van Schie. HiBreeding sows approximately 20,000 seeds annually from targeted hydrangea crosses. "When these are in bloom, we are allowed to select a maximum of 100 plants ourselves, which we then continue with. We take 20 cuttings from these plants: 10 for spring flowering and 10 for perennial cultivation. Of these 200 plants, we are allowed to keep a maximum of 10. After about eight years of selection, we ultimately end up with one or two new varieties that meet at least the 20 primary criteria set by the MasterGrowers and HiBreeding."

At Agriom, the primary focus is on cultivation characteristics for successful cultivation. Kuiper: "As mentioned before, you can't afford any losses, and skilled labour is scarce and expensive. That's why we focus,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Half-grown hydrangea plants

Hydrangea cultivation in Sjaak van Schie's outdoor field in Portugal



**'We can share the costs of the facilities involved in the otherwise expensive breeding process'**

Estimated annual volume of finished hydrangea products

Europe: 60 million
USA/Canada: 40
Japan: 6
China: 3
Indonesia: 1
Korea: 1

Most popular colours: blue, white, pink, red and bicolour

among other things, on how the plant handles the cold period. Isn't there too much loss due to Botrytis? Have buds formed on all the branches? But good and, above all, rapid bud formation during the cold period is also important. The sooner you get enough buds, the sooner you can enter the market. Preferably as early as February, before Valentine's Day."

### Long growing season

Kuiper says that breeding may have been a bit too generous in this regard. "Retailers demand a minimum of 5 flowers per plant, but thanks to more branched plants, we now deliver an average of 7 to 9 flowers per plant, without a significant price premium. So, you can also overdo it," he laughs.
"We now also have hydrangea with a long growing season. These also produce flowers on new shoots that grow during the flowering season. So, if consumers prune their hydrangea too short in winter, it will still bloom."

Van Schie also continues to innovate its range. "We stand for 'experience,' so the final product must also perform optimally. That's why we also test all our new varieties in practice. This primarily means good shelf life. We now offer a flowering, or experience, guarantee for our varieties of at least 100 days."
Water tolerance is also a major priority at Van Schie. "Hydrangeas need frequent and copious amounts of water, and many supermarkets and consumers don't have time for that," says Van Schie. "Varieties that are more tolerant of temporary water shortages are a very useful characteristic. This prevents the plants from looking droopy on the shelf. Because consumers are very clear about this; such a plant, no matter how beautiful, won't be bought." He also mentions heat tolerance as an important characteristic. "Because I see the hydrangea market shifting towards Southern Europe, especially for patio plants."

Although cutting production primarily takes place in Africa and Portugal, global production of finished hydrangea products is concentrated in areas with cooler temperatures and market opportunities.

Hydrangea must continue to innovate to hold its own in the battle with consumers. "Hydrangeas are primarily sold through garden centres and florists. There's room there to sell a beautiful, large flowering plant for the garden or patio. Consumers are specifically buying plants there; they have to be 'ready to use.' Beautifully shaped, with spectacular colours and in full bloom. Then you can charge a good price for them. And that's possible, because I'm seeing a slow shift in Europe from bedding plants to more luxurious garden plants," says Kuiper.
Van Schie: "As a houseplant, hydrangea is often still too large and too expensive a product for retailers and supermarkets. That's where the opportunity lies. A smaller, compact and affordable plant that's resistant to heat and dehydration, and also more plants per cart and per square meter of shelf space, with faster turnover. Then we can compete with the most popular houseplants."

### Agreements

Hydrangea flowering can now be controlled using heating and lighting to the point that 50-60% of sales can be planned down to the day. This makes it increasingly possible to make firm agreements with wholesalers regarding large deliveries.
Van Schie: "Hydrangea cultivation is slowly shifting from traditional to larger-scale. Our customers are also growing; we have to keep pace with that."
Kuiper adds: "The challenge now is having sufficient in-house staff with the necessary knowledge and expertise. Because no matter how much automation you implement, the cultivation and sale of hydrangeas remain a complex matter."

Plenty of innovation in rootstocks

# Resistance and **resilience** growing in importance

John van Ruiten



**The world of rootstocks in vegetable farming is in full swing. Breeders worldwide are working on a further expansion of the range and on new traits and applications. Rootstocks are used primarily in tomato cultivation, but their use is also increasing rapidly in peppers grown on substrate and in open-field crops, such as melons.**

**Organic vegetable cultivation largely** still takes place in open fields. This requires resilient rootstocks that help breeders to tackle diseases and pests. In the cultivation of peppers, there was a great need for resistance to root-knot nematodes, explains Frans Carree, breeder at organic breeding company De Bolster.

“Farmers needed resistant rootstocks to be able to continue cultivating. Therefore, De Bolster developed the Skyborn F1 rootstock, which has high resistance to root-knot nematodes,” says Carree. When, from 2022 onwards, the pepper cultivation on substrate also began to encounter more frequent crop failures, this very resilient rootstock appeared to offer a solution there as well. Now the new challenge lies in finding resistance to a new strain of Verticillium.

## Ancient technique

Grafting plants is anything but new. This technique has been used for centuries in fruit cultivation. Greeks and Romans grafted vegetatively propagated cuttings of dates, figs, apples, cherries and plums, among others, onto rootstocks with a strong root system. Also famous is the grafting of European grape varieties onto American, Phylloxera-resistant rootstocks at the end of the nineteenth century.

In Japan, at the start of the twentieth century, watermelons were grafted onto gourds as a solution to serious Fusarium problems. In Europe, grafting gathered pace after the Second World War. The first generation of rootstocks, often originating from Japan, provided Fusarium resistance in cucumber cultivation, among other things.

From 1987 onwards, usage increased again significantly, partly because the use of the highly toxic methyl bromide in horticulture was restricted. Since then, breeders have introduced many new rootstocks for tomato, cucumber, melon and aubergine.

## Breakthrough in tomato cultivation

A significant boost came from tomato cultivation. Theo Schotte, working at De Ruiter Seeds at the time, was fundamental in the introduction of modern tomato rootstocks in Europe. “From the early 1970s, we worked on crossbreeding resistances to Fusarium wilt, Fusarium root rot and Verticillium,” he explains. This led to the introduction of the Maxifort rootstock in the 1990s. This variety grew to become the most widely used tomato rootstock in the world and is still the market leader in tomato cultivation on rockwool.

For a long time, Cucurbita ficifolia and crosses of C. maxima and C. moschata were used in the cultivation of cucurbits. Here, grafting mainly took place in organic farming, because rootstocks offered a better tolerance to lower soil temperatures, in addition to resistances.

On the other hand, in conventional pepper cultivation, the use of rootstocks remained limited for a long time. The fusion between variety and rootstock was difficult and grafting costs were high, which meant that the added value for growers was insufficient.

## New demands

The global introduction of substrate cultivation, often in combination with artificial lighting, has profoundly changed vegetable cultivation. Since then, rootstocks have had to enable a longer cultivation period and a larger plant load. In tomato cultivation, this means that crops must provide peak production for nine to eleven months.

Consequently, the breeding focus shifted towards rootstocks with a larger and more efficient root system, a better uptake of water and nutrients, a more vegetative balance and a high stress resistance.

In many important growing regions, problems with climate and water are increasing. Water scarcity seems to be becoming systemic and periods of extreme heat are occurring more frequently. This places great demands on crops. New rootstocks can help to ensure yield and quality, even under these conditions.

“Resilience is of critical importance,” states Ronald Visser, director of the Rootstock Company, a Dutch company that specialises in rootstock breeding and supplies globally. The range includes the Carbonite variety, suitable for tomato and aubergine, as an example of this new generation of rootstocks.

A tomato variety grafted on a rootstock

## New resistances, new problems

With the increasing use of rootstocks, new challenges are also arising. In tomato cultivation, the widely used Mi-1-resistance to the root-knot nematode Meloidogyne was breached worldwide.

Takii recently introduced the Sanaterra F1 rootstock, which is resistant to multiple Meloidogyne species. As a result, breeders who would otherwise have been forced to stop tomato cultivation are able to continue producing this crop. The Japanese company Takii, with 190 years of history, was at the heart of modern rootstock breeding.

In addition, new pathogens are appearing. The rise of the tomato virus ToBRFV since 2014 has had major consequences for the sector. Not only did the variety range change radically, but it also created the desire to incorporate this resistance into rootstocks, so that virus reservoirs in the growing environment remain as small as possible. These rootstocks are currently being developed.

Although grafted plants are relatively expensive, the protection offered by rootstocks is becoming increasingly important. The combination of disease resistance, stress resistance and potential yield increase makes their use more attractive. Application is also increasing in outdoor cultivation, particularly in the organic and sustainable conventional sectors. This often occurs in combination with integrated cultivation systems which are aimed at fortifying soil life.

## Grafting technology

Grafting technology itself is also developing rapidly. The Japanese head grafting method has largely replaced the classic cleft grafting. The grafting process is being increasingly robotised. With specially developed equipment and vision technology, grafting can be carried out above and below the cotyledons with a very high success rate.

This results in significant labour savings, reduces costs and enables a very hygienic working method, thereby limiting the spread of disease during the grafting process. Consequently, more and more plant breeders are making use of robotised grafting systems.

Precise recent figures regarding the use of rootstocks are unavailable. Estimates indicate that in protected crops, approximately 90% of tomatoes, 50% of aubergines, 20% of cucumbers and 10 to 15% of peppers are now grafted.

Ir. J.E.M. van Ruiten is treasurer of the Prophyta Foundation, Leiden, the Netherlands.
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Growpact Global

# From roadside trays to **resilient** food systems

Kees Veldhuijzen

**Growpact Global is an initiative focused on one simple but powerful idea: good farming starts with healthy starting material. Our mission is to professionalise the production and distribution of vegetable seedlings across Africa, making high-quality, reliable planting material accessible to small and medium-scale farmers.**

I still remember the first time I stopped along a dusty roadside in West Africa and watched farmers buying vegetable seedlings from large open bowls. The plants looked green enough, but their roots were weak, grown from saved seeds and survival uncertain. That moment stayed with me. It captured both the ingenuity of farmers and the structural gap that holds productivity back. That gap is where Growpact Global comes in.

### Centres of excellence

The Growpact Global approach is practical and partnership-driven. We develop and support local nurseries - owned and run by trained local entrepreneurs - that produce uniform, disease-free seedlings using professional nursery protocols. These nurseries serve as centres of excellence: places where farmers can access not only seedlings, but also knowledge, trust and consistency. Instead of guessing what will grow, farmers start with certainty.

### Bridge

Seed quality is of utmost importance. Hybrid vegetable seeds offer higher yields, uniformity and resistance, but only if they are handled correctly. Poor germination environments or weak nursery practices can erase the advantages of even the best genetics. Growpact Global bridges this gap by aligning hybrid seed performance with professional seedling production, ensuring that the value created by breeders is fully realised in farmers' fields.

### Together

Growpact Global is a Dutch cooperative inspired by the success of Growpact Nurseries in Kitale, Kenya, and is now scaling across the rest of the continent. Collaboration is essential. We invite vegetable seed breeders, young plant producers and other stakeholders to engage with us. Together, we can bring good genetics to local contexts, test varieties under real African conditions and build resilient horticultural systems from the ground up.

Because transformation in agriculture does not wait for the harvest. It begins with a seed and how we help it grow.

Kees Veldhuijzen; Director, Growpact Global; www.growpactglobal.com



ISF regulated pest list initiative

# New **pest list** available for radish

Bénédicte Lebas

***Raphanus sativus* (radish), of the family *Brassicaceae*, includes several subspecies, namely subsp. *caudatus* (green radish), subsp. *longipinnatus* (daikon radish), subsp. *niger* (black radish), and subsp. *sativus* (red radish). The crop is mainly grown for its large taproot, though the entire plant is edible and the leaves can be consumed as greens. First domesticated in Asia, radish is now cultivated globally. Combined production of the top ten producing countries is projected to exceed 6.8 million metric tons in 2025, with China contributing nearly half of the production.**

Like many crops, radish is propagated from seeds, which may act as a carrier for harmful pests, such as bacteria, fungi, and viruses. Healthy seeds are therefore essential for successful crop production. Access to healthy seeds depends on predictable international seed movement supported by phytosanitary measures grounded in scientific evidence. The International Seed Federation's Regulated Pest List Initiative identified 49 pests regulated on radish seed (https://worldseed.org/our-work/phytosanitary-matters/pest-list/). This summary synthesizes the scientific findings on whether radish seeds serve as a pathway for these pests.

### Proven for only one

The assessment concluded that only one of the 49 pests regulated on radish seeds, *Alternaria japonica*, has a proven seed transmission pathway. This fungus has been isolated from disinfected and non-disinfected radish seeds, including embryos and seed coats. *Alternaria japonica* causes disease in seedlings grown from infected seeds. The pathogen can be found from different parts of the seedlings and mature plants in which it causes black spot. Seed yield losses of more than 30% have been reported in radish. *Alternaria japonica* occurs mainly in temperate and cold regions worldwide where radish is cultivated. The fungus is one of the species causing Alternaria leaf blight. This necrotrophic pathogen primarily attacks *Brassicaceae* such as cabbage, Chinese cabbage, mustard, rapeseed, rocket, and turnip with radish being its main host. *Alternaria japonica* is seed-borne in several brassica crops such as cabbage and Chinese cabbage.

### Not a pathway

No scientific evidence supports radish seed as a pathway for 36 of the 49 pests regulated on this crop. For 16 of these pests, extensive literature review shows no indication that they are seed-transmitted. Their life cycle does not involve seeds at any stage (i.e., not seed-borne). For example, *Delia platura* is soil-borne, while *Pseudomonas marginalis* pv. *marginalis* is a foliage-pest. Other pests rely on mechanical transmission or insect vectors (e.g., *Candidatus Phytoplasma asteris*, *Caulimovirus tessellobrassicae*).

For the remaining 20 of the 36 pests, radish is not known to be a natural host. Twelve of these pests have host ranges limited to unrelated species or families like *Erysiphe heraclei* that is a pathogen of *Apiaceae* family. In some cases, the host range is very narrow such as *Peronospora schachtii* that only infects sugar beet and Swiss chard. Five pests were tested experimentally on radish, but no natural infection has been reported. Finally, three pests were listed in databases without scientific evidence supporting radish as a host.

### Inconclusive evidence

The available scientific data were insufficient to reach a definitive conclusion for 11 of the 49 pests regulated on radish seed. Most studies relied on plating or blotter assays to detect bacteria or fungi on seeds, without conducting grow-out assays. When these assays were performed, seedlings were rarely grown to maturity to verify the movement of viable, infectious pathogens from seed to plant and disease development. For example, *Pseudomonas viridiflava* was isolated from an imported radish seed lot, and seedlings developed necrotic cotyledons. However, the bacterium did not cause disease on mature plants in growth-chamber trials.

Additional uncertainties arise from experiments using artificially inoculated seeds, which may not reflect natural infection. For instance, stem necrosis and root rotting developed on radish sprouts from seeds that had been artificially inoculated with *Stemphylium vesicarium*. However, no seed-to-mature plant studies have been conducted to verify natural transmission. While such experiments are useful to elucidate the biological features of a pathogen, they do not allow for reliable conclusions about transmission risk in natural conditions.

### Unjustified regulations

Two pests are regulated on radish seed at genus level: *Sclerotinia* and *Trogoderma*. The ISPM 38 - *International movement of seeds* states that pest assessments should be carried out at the species level because species within a genus may differ in host range and transmission characteristics. For example, in the genera *Sclerotinia*, which contains more than 10 species, only the cosmopolitan pathogen *Sclerotinia sclerotiorum* infects radish. For the genera *Trogoderma*, no species are known to feed on seeds or plants of radish. Consequently, assessing radish seed as a potential pathway at the genus level is not scientifically justified.

### Conclusion

This assessment highlights the importance of basing phytosanitary requirements on robust scientific evidence to ensure that regulations target only pests that truly pose a risk via the seed pathway. Many pests currently regulated on radish seeds are neither seed-associated nor able to use radish as a host, indicating that several existing requirements may be unwarranted. Although data gaps remain for some pests, the complexity of seed transmission studies combined with the use of inconsistent terminology highlight the need for cautious interpretation. Continued refinement of pest assessments, in line with international standards, will help ensure that regulations target only those pests that genuinely pose a threat through the seed pathway, thereby supporting safe seed movement.

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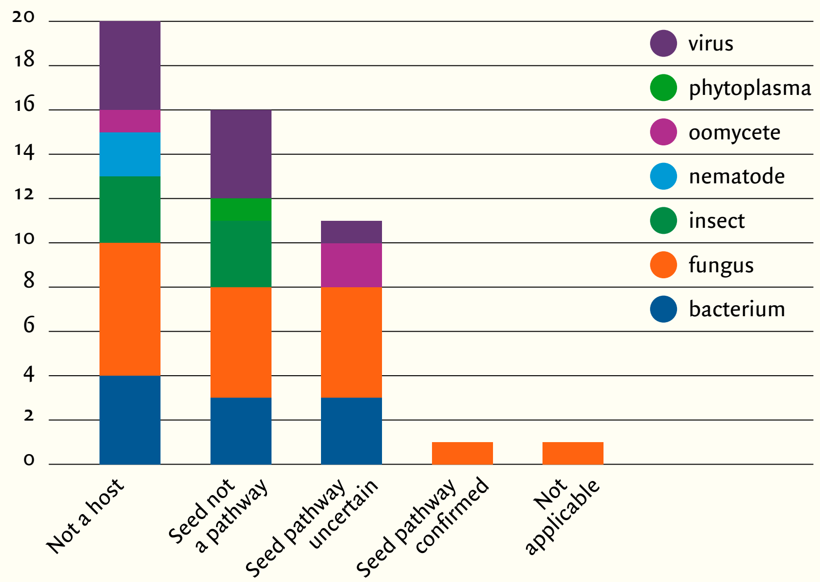



Results of the categorization of pests regulated on radish seeds, based on scientific evidence.

Biotech's green engine

# Somatic embryogenesis and **tomorrow**'s crops

Rayan Awada, Sandra Queiroz and Alewijn Broere

**Somatic embryogenesis (SE) is a cutting-edge plant biotechnology technique that allows scientists to generate embryos from somatic, or non-reproductive, cells. Unlike conventional propagation through seeds, SE produces genetically identical plants that maintain the traits of the elite donor material. By producing embryos *in vitro*, SE provides a pathway to mass-produce uniform, disease-free and high-performance planting material. In essence, somatic embryogenesis represents a bridge between traditional agriculture and advanced biotechnological solutions, offering scalability, quality assurance and long-term sustainability.**

Alewijn Broere is the Managing Director of SBW International, an organization specializing in the development and application of tissue culture protocols and techniques in horticulture, with offices in many countries, including Ghana and Brazil. www.sbwbrasil.com.br

**Coffee, cocoa and palm species** are three of the most commercially important crops worldwide. All three face increasing production challenges as global demand rises while productivity stagnates or declines due to pests, diseases and climate stress.

In coffee, demand for premium Arabica and disease-resistant Robusta is expanding rapidly, yet productivity is threatened by leaf rust and changing climatic conditions. Somatic embryogenesis allows for the rapid multiplication of elite coffee cultivars that combine high yield, cup quality and resilience. It provides producers with a reliable supply of uniform plants that can replace ageing plantations and meet the needs of global markets.

Embrioes Macauba

Cocoa is another crop where SE can deliver transformative benefits. The chocolate industry depends on a stable supply of cocoa beans, yet many plantations are also ageing and yields are under pressure from diseases such as black pod rot. Somatic embryogenesis makes it possible to rejuvenate plantations with vigorous, disease-resistant and high-yielding clones. This technology ensures that farmers can maintain profitability while chocolate manufacturers secure consistent supply chains.
Palm species, particularly those cultivated for biofuel production, are under increasing global pressure to sustain and intensify oil yields, amid mounting environmental restrictions on land expansion. Somatic embryogenesis offers a transformative solution - not only by enabling the mass propagation of elite "super palms" with superior oil output per hectare, but also by unlocking the potential of newly identified wild varieties. These emerging genotypes show remarkable resilience to dry climates and require significantly less water, making them ideal candidates for large-scale cultivation in arid regions.
Given the urgent demand for sustainable aviation fuel, the industry is racing to deploy these high-performing palms across extensive plantations. However, natural seed propagation is limited by scarcity and high genetic variability, which hinders uniformity and productivity. Somatic embryogenesis allows for the precise selection and cloning of superior mother plants, ensuring genetic consistency and enhanced agronomic traits. Current protocols under development - utilizing diverse explants such as palm heart, flower buds, leaves and even seeds - are accelerating the production of robust young plants. Although still in the early stages, our company has already transitioned promising embryogenic lines to field trials within just two years, marking a significant step toward commercial scalability.

### Commercial Advantages

From a commercial standpoint, somatic embryogenesis offers several compelling advantages. More consistent yields, improved product quality and predictable field performance, which are critical for globally traded commodities like coffee, cocoa and palm oil. Over time, SE technology also lowers costs compared to labour-intensive traditional propagation methods, particularly when integrated with automated systems and bioreactor technology.

### Application of SE at MultiCropsPlus

At MultiCropsPlus, intensive research and experience gained allowed the company to master the protocols of SE of tomorrow´s crops (coffee, cocoa, palm





TIB Room for large scale multiplication

Hardening in vertical farming

species). Starting with a collection of basic explants (leaves for coffee, flower buds for cocoa, palm hearts and inflorescences for palm species), the SE process from initiation to plant acclimatization can be achieved in 1-2 years. A high biological efficiency has been demonstrated for propagated varieties, reaching propagation factors of 1500 embryos/ g calli. Innovations have been decisive for successful scaling-up and reduction of labour costs, such as the development of temporary immersion bioreactors (TIB system) for the mass production of pre-germinated embryos. Combining the TIB system with vertical farming practices, MultiCropsPlus achieves a synergistic approach that further enhances efficiency, scalability and overall plant quality. MultiCropsPlus is also proud of its full production traceability system that allows elimination of somaclonal variation risks by tracing each lot to its source.

### Commercial Outlook

The commercial outlook for somatic embryogenesis is highly promising. The combined global markets for coffee, cocoa and palm oil are projected to exceed USD 400 billion by 2030, and demand continues to grow, particularly in emerging economies. For investors, agribusinesses and governments seeking long-term solutions for food security, sustainability and profitability, somatic embryogenesis represents a strategic opportunity.

A technical perspective from Incotec

# Transforming **Seed Treatment**

Marta Dobrowolska-Haywood and Sander Willemse



**Seed treatment has long depended on craftsmanship and the deep, tacit knowledge of experienced operators. But one of the most consequential digitalization transformations is taking place with seed treatment.**

The integration of artificial intelligence (AI), advanced sensing and digital analytics is enabling seed enhancement companies to improve precision, consistency and predictability across priming, pelleting, coating and screening processes.
Today's digital tools do not replace the personal expertise; they enhance it and create new opportunities to improve seed performance, traceability and sustainability. Traditional seed enhancement workflows involved operators manually adjusting equipment settings, evaluating seeds visually and making process decisions based on experience. While effective, this approach created variability and limited opportunities to scale precision. Modern, digitally enabled systems incorporate:

– Sensor data on temperature, humidity, moisture, airflow, vibration and material flow
– Automated controls that stabilize priming and pelleting conditions
– Digital traceability, linking operational parameters to each seed lot
– Connectivity to quality labs, analytics platforms and electronic resource planning (ERP) systems

This evolution establishes the foundation for predictive models, real-time optimization and fully traceable production. Sander Willemse comments: "Digitalization does not replace operator expertise, it amplifies it. By combining sensor-driven data with the craftmanship and experience of the teams involved, it is possible to create seed treatments that are more predictable, more consistent and ultimately more valuable for growers."

Sander gives an example of standardising and automating seed enhancement production lines. "Many seed enhancement steps - like priming, pelleting, coating and drying - are historically run by experienced operators who adjust parameters by feel. This skilled craftsmanship delivers high quality, but introduces variability between shifts, sites and seasons, and makes it harder to scale-up and audit. With the help of AI and digital methods, Incotec is currently working on a transformation towards a recipe-driven, sensor-rich production line with closed-loop controls, digital batch records and in-line quality checks. Operators remain central, but the system makes the 'golden run' repeatable. They will shift from maalarms andd-judge to monitoring control charts, responding to targeted alarms, and managing exceptions; training focuses on control limits, recipe intent and first-level troubleshooting. To be able to do this, much data needs to be considered, processed and used. Think about seed lot intake and characterization; digital registration; barcoded containers; rapid moisture; thousand-seed weight; optional imaging for initial uniformity. But also, moisture and temperature data; binder and powder dosing data; pan speed/tilt/airflow; viscosity and flow, detection of early defects, dust, abrasion."



Marta Dobrowolska-Haywood and Sander Willemse

### Data Quality Essential

AI is only as powerful as the data behind it.
High-quality datasets make it possible to build meaningful models, detect trends and automate decisions. Poor data quality, misaligned identifiers, inconsistent formats or missing values can severely limit the performance of even the most advanced algorithms.
"Good quality data can make all sorts of magic happen," Marta Dobrowolska-Haywood says. "This reflects a core belief: once data is trustworthy, a wide range of analytical and AI techniques become possible, from optimization to prediction to automation."

### Various Ways

AI can help to optimize seed priming, smart screening and sorting with imaging and seed coating.
Already AI is transforming seed treatment into various ways. Sander Willemse: "Seed priming requires a delicate balance of hydration kinetics, temperature, duration and additives. This helps deliver more uniform performance and shortens development cycles, a key benefit in fast-paced markets."
Deep learning models trained on long-term imaging databases can classify seeds by viability with high precision. This can also accelerate R&D cycles and improve commercial reliability. "These models become increasingly powerful as datasets grow, demonstrating why long-term data stewardship is crucial," Willemse says.

### Safe and Fast

Marta adds with an example of X-ray Image Analysis of Tomato Seeds. "Seed producers sometimes have poor quality seed batches. Incotec can improve the quality by removing the non-viable seed using AI-based image analysis by identifying subtle differences in the morphology of the embryos. We introduced a non-destructive X-ray imaging workflow for representative samples. These images capture embryo presence, position and morphology. We linked images to historical germination outcomes and trained a prediction model that combines image-derived features with lot metadata, returning seed- and lot-level predictions with confidence bands aligned to QA thresholds. 
The result? More consistent commercial lots by removing non-viable seeds early and selecting optimal treatments. Non-destructive embryo assessment plus historical germination data turns imaging into an operational decision tool - bringing accuracy and speed, without sacrificing quality."

### Future Directions

Upcoming innovations in seed treatment can support more resilient, sustainable and traceable seed systems. These innovations may include:
Digital twins of seed lots that simulate performance under different environmental scenarios
Portable AI quality analysers used by farmers or distributors at point-of-use
Sustainability-aware optimization models that evaluate both yield and environmental impact
Predictive logistics systems, allowing production and inventory to adapt dynamically to global demand.

### Collaboration Needed

AI and digital methods are transforming seed treatment from a largely manual craft into a data-enhanced discipline. Marta Dobrowolska-Haywood: "With high-quality data at the centre, which is the "magic" that unlocks the potential of AI, seed enhancement companies can achieve higher consistency, greater sustainability and improved value for growers worldwide."
"But, as seed treatment becomes increasingly data-driven, collaboration between stakeholders becomes essential. Seed companies, enhancement specialists, breeders and digital partners all generate complementary data streams. The future of seed enhancement depends on secure and transparent data exchange. When we align on standards and build trust around how data is used, the entire industry benefits, from breeders to growers."

Marta Dobrowolska-Haywood is Head of Croda Data Science and Knowledge Management and Sander Willemse is Global Process manager at Incotec.

# New **atypical strains** of *Clavibacter michiganensis*

Harrie Koenraadt, Gerbert Hiddink, Sven Berendsen, Ludivine Thomas and Joyce Woudenberg



***Clavibacter michiganensis*, a gram-positive bacterium, is the causal agent of bacterial canker and wilting in tomato (*Solanum lycopersicum*), including rootstock tomato and interspecific hybrids. The pathogen is of major economic importance, as infection can lead to a significant loss in crop yield. Seeds are an important route for its dispersal. Rigorous seed testing is essential to prevent introduction and spread of *C. michiganensis* in tomato production systems.**

**In the ISHI method for the detection** of *C. michiganensis* in tomato seed, the bacterium is extracted from seeds through stomaching and is plated onto semi-selective media. Suspect colonies, identified based on their morphology, are tested for pathogenicity on tomato seedlings. Optionally, suspect colonies isolated by dilution plating can be identified by two quantitative polymerase chain reaction (QPCR) assays: MVS21 and PTSSK. A positive result should be confirmed by pathogenicity assay. An optional seed extract QPCR assay (SE-QPCR) may be performed as pre-screen. If the SE-QPCR yields a positive result, it should be followed by the dilution plating and downstream analyses to verify viability and pathogenicity of *C. michiganensis*. In case of a negative pre-screen, *C. michiganensis* is regarded absent.

## Suspect colonies

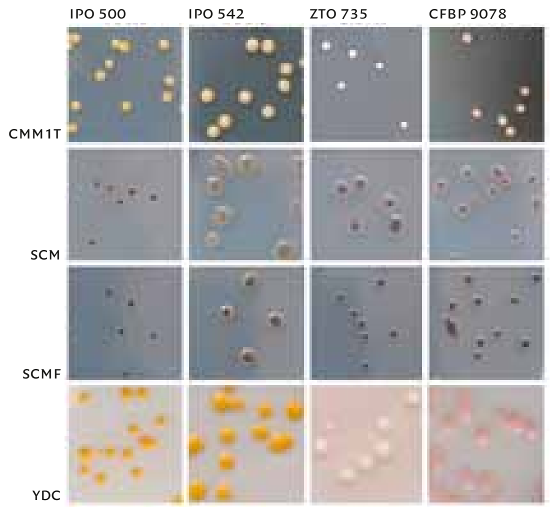
In dilution plating two semi-specific media, CMM1T and SCM or SCM Fast (SCMF), are used to support recovery and growth of *C. michiganensis*, while limiting saprophyte development. After 10 days in the dark at 26-28 ºC, typical colonies on CMM1T appear yellow, mucoid and convex. On SCM and SCMF, they appear translucent grey, mucoid and often irregularly shaped, with a grey to grey-black centre. Suspect colonies are subcultured on YDC, on which typical colonies appear yellow, domed and mucoid after three days of incubation at 26-28 ºC.

Historically, colony morphology of *C. michiganensis* has been well-defined; however, new strains have been described with divergent colour. To ensure the dilution plating remains suitable, a study was conducted on 23 strains of *C. michiganensis* (publication in preparation). These strains originated from different countries and years and were selected based on their genetic variability in Amplified Fragment Length Polymorphism (AFLP) and atypical colony coloration.

## Outcome study

Recovery of each strain on semi-selective media was compared with recovery on non-selective King's B (KB) medium. All strains were recovered on the three semi-selective media (average rates: 77% on CMM1T, 78% on SCM and 64% on SCMF), although some displayed a reduced recovery on SCMF.

On SCM and SCMF, all 23 strains conformed to the morphology described in the ISHI protocol. On CMM1T and YDC, however, the atypical strains produced whitish or pinkish colonies (See figure). Target DNA from all strains was amplified by the PTSSK and MVS21 QPCR assays, confirming the suitability and robustness of the ISHI QPCR assays for all known morphological variants.




Colony morphology of four *Clavibacter michiganensis* strains on CMM1T, SCM, SCMF and YDC media

## Conclusion

This study demonstrated that the current ISHI method remain suitable for the detection and identification of *Clavibacter michiganensis*, including atypical strains. Although some variability in recovery efficiency was observed, particularly on SCMF, the three semi-selective media supported growth of all strains. Their identification was not hindered on SCM or SCMF, although pigmentation differences were noted on CMM1T and YDC.

To support reliable detection of these atypical strains, enhanced morphological descriptions and photos have been added to the ISHI protocol. All strains were detected by PTSSK and MVS21 QPCR, underscoring their diagnostic robustness. These results confirm the robustness and reliability of the ISHI method and endorse its continued use in seed health testing to safeguard tomato production from *C. michiganensis*.

Harrie Koenraadt (Naktuinbouw), Gerbert Hiddink (Enza Zaden), Sven Berendsen (Rijk Zwaan), Ludivine Thomas and Joyce Woudenberg (International Seed Federation). For more information: https://worldseed.org/our-work/seed-health/ishi-methods



**Sow to Grow**

Sow to Grow is a so-called 'plant science experience centre', where people can learn more about plant breeding and its crucial importance for human health and wellbeing, as well as for the environment. It is based on self-discovery learning, for instance, by making changes in a giant DNA string to develop a healthy, red-coloured sweet pepper, made visible on a large screen. Besides the regular visitors, the museum also receives school groups for a one-morning experience. Another activity is a 6-week course for new employees in the seed industry to learn about plant breeding, seed production and regulatory aspects. Contact: Sow to Grow, Westerstraat 111, 1601 AD Enkhuizen, the Netherlands, www.sowtogrow.nl, info@sowtogrow.nl



## Spotlight on

# plaster models

Jan Timmerman

**Between 1946 and 1950**, the staff of the Institute for Horticultural Plant Breeding (IVT) in Wageningen, the Netherlands, made plaster models of fruit, root and tuber crops to record their varietal characteristics. Plaster was not suitable for leafy vegetables, so instead, water colours were painted. The aim was to be able to compare new breeding results with existing varieties. Today, these models are on display in Sow to Grow.

It was the initiative of the director of the institute, Dr. Otto Banga, who believed that recording vegetable varieties in plaster models was a suitable tool for documenting the available varieties. In addition to the written description of a variety, the plaster models offered a visual documentation of the phenotype of the crop. At the time, colour photography was still in its infancy, with colours that lacked the necessary accuracy. The plaster models have the proper size and were painted lifelike by a group of young artists. The advantage of these models was that they were always available, also in out of season periods.

In addition to recording characteristics, the models were also used in the training of inspectors and breeders. This spring, a new purpose for the plaster models was revealed. Fifteen of the models were on display at an exhibition at Soestdijk Palace, the residence of our former Queen Juliana. 'The Taste of Soestdijk' shows the royal dining culture and the art of hospitality. From grand dinners for international guests to intimate family gatherings. It is well known that Queen Juliana preferred the traditional Dutch cuisine, hence among the displayed objects was a life-sized plaster model of one of her favourite vegetables: a cauliflower.

PROPHYTA ANNUAL 2026

A remarkable innovation process

# Combining **priming** and disinfection

Monique Krinkels

**With seed-applied crop-protection registration already being a major and lengthy challenge in the EU, seed disinfection methods, such as hot-water treatment, are becoming increasingly standard. This significant exposure to water can trigger germination processes within a seed – an effect which can be made use of for seed priming.**

Seed priming is a well-established method for improving germination speed, seedling vigour and stress tolerance. Numerous laboratory and pilot-scale studies have demonstrated its biological effectiveness. However, despite decades of research, seed priming has remained difficult to implement reliably on an industrial scale. Would it be possible to upscale and automate the process? Jan Willem Hoopman of Hoopman Equipment & Engineering and Dr. Jörn Dau of SUET Saat- und Erntetechnik identified the advantages of seed priming combined with disinfection. They decided to take up the shared endeavour.

## Close cooperation

As a seed processor, the goal of SUET was to find a technical solution to implement stable, science-based state-of-the-art industrial priming equipment. Hoopman, as a manufacturer, aims to automate a highly complex biological process. This mutual understanding has set the starting point for a multi-year development effort. “The development and construction of the new priming facility was not a quick undertaking. From the initial idea to the first operational system, the project unfolded over four years,” says Bram Ribbers, project engineer at Hoopman.

During this time, the engineering, construction and development teams of both companies worked together extremely closely. Design concepts, mechanical layouts, process parameter studies and automation logic were jointly developed, reviewed and refined. Technical challenges were analyzed from both an engineering and biological perspective, resulting in a system that reflects the combined expertise of both partners.

## Biological variability

The primary problem is not the priming principle itself, but the biological variability of seed batches. “Each batch differs in physiological state, moisture sensitivity and reaction kinetics. As a result, priming cannot be reduced to static recipes. Instead, it requires continuous parameter adaptation and precise process control, a requirement that conventional large-scale seed treatment systems have been unable to meet,” explains Dr. Rebecca Liese of the R&D department at SUET. This gap between laboratory methodology and industrial feasibility represents a central bottleneck in the broader adoption of priming technologies.

Traditional upscaling strategies in seed processing focus on mechanical robustness, throughput and reproducibility of predefined process steps. While effective for many treatments, this paradigm reaches its limits when applied to biologically sensitive processes such as priming. In conventional systems, process parameters are often fixed or only adjusted between batches, biological feedback during processing is limited and deviations accumulate unnoticed until quality losses occur. “For priming, where minute deviations in hydration, temperature or residence time can decisively influence seed physiology, this approach is insufficient. The central scientific challenge is therefore not automation per se, but the translation of adaptive, biology-driven protocols into a stable industrial process environment,” according to Dr. Liese.

The modular BioRinse 100L disinfection and priming system is the result of a close cooperation between Hoopman Equipment & Engineering and SUET Saat- und Erntetechnik

## Dynamic process control

The key innovation that the teams at SUET and Hoopman came up with lies in a methodological shift: priming is treated not as a fixed sequence of steps, but as a dynamic process requiring continuous monitoring and adjustment. To enable this shift, the process architecture was designed around three core principles:

Full integration of all process steps: hydration, washing, centrifugation, conditioning and drying are not isolated operations but parts of a continuous, coordinated system.

Comprehensive parameter monitoring: all biologically relevant process parameters are continuously recorded, allowing deviations to be detected and corrected in real time. In particular, this capability is enabled by a unique real-time absolute moisture monitoring system.

Batch-specific process logic: instead of enforcing uniform settings, the system allows parameters to be adapted to the physiological requirements of each individual seed batch.

This approach transforms priming and disinfection from a largely empirical operation into a controlled bio-process suitable for industrial environments.

Monique Krinkels is board member of the Prophyta foundation.
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The ‘base’ of the system is a seed container, suitable for up to 100 litres of seeds. The seeds will stay in this drum during the complete process

> A system that reflects the combined expertise of both partners



A decisive aspect of industrial priming is the transfer of laboratory-derived protocols into large-scale execution, without losing biological precision. This requires close coupling between process engineering and seed science. Parameter optimization does not end once a protocol is defined; it is a continuous, iterative process embedded in daily operation. Data generated during processing are used to refine parameter ranges, improve reproducibility and stabilize outcomes across different seed species and qualities. By embedding scientific parameter logic directly into the automation architecture, it becomes possible to reproduce laboratory-level precision under industrial conditions, while maintaining flexibility for ongoing optimization.

The resulting joint effort between SUET and Hoopman demonstrates that biologically sensitive priming processes can be industrialized without compromising control or reproducibility. “Key outcomes include reliable handling of diverse seed species and batch qualities, high process transparency and full documentation, reproducible execution of adaptive priming protocols on a commercial scale,” describes Bram Ribbers.

From a scientific perspective, this confirms that dynamic, data-driven process control is a viable pathway for scaling complex biological treatments. The approach is transferable beyond priming and may serve as a model for other seed enhancement technologies facing similar upscaling challenges.

## Future

Because the system architecture is modular and data-rich, it provides a foundation for future methodological advances. Potential developments include biological priming variants, seed disinfection processes and data-driven optimization strategies, including AI-supported analysis of process–response relationships. More broadly, the work illustrates how interdisciplinary collaboration between seed science and process engineering can overcome long-standing barriers in agricultural technology. “By reframing priming as a controllable bioprocess rather than a fixed treatment, a new level of industrial applicability becomes achievable,” he concludes.

# Hidden environmental **variation** in trials

M. Schaks, I. Staudinger, L. Homeister, B. Di Biase, B.R. Steinkraus, A.N. Spiess



**Soil microbial communities are increasingly recognized as integral components of the plant production environment. For plant breeding and seed science, the key question is not merely whether microbes influence plant growth, but whether microbial community descriptors provide stable, transferable information that can improve the characterization of environments used in genotype evaluation. Soilytix addresses this question by testing whether soil bacterial signatures associated with maize yield in a single field can explain plant growth variation across geographically and ecologically distinct systems.**

Matthias Schaks is head of Science at Soilytix GmbH in Hamburg. He and his team conduct metabarcoding and biological soil profiling for breeding programmes and are actively seeking partners to integrate soil microbiome intelligence into a multi-environment trial strategy through co-developed mega-environment frameworks and variety-soil compatibility testing. soilytix.com

**With the help of Soilytix**, the authors collected 80 spatially referenced soil cores from a conventionally managed maize field in eastern Germany following harvest. Bacterial community composition was characterized using 16S rRNA gene sequencing and paired with high-resolution yield data obtained via volume-flow measurements. Using LASSO (least absolute shrinkage and selection operator) regression with cross-validation, the authors developed a predictive model that explained approximately 65% of within-field yield variance. From the 100 most abundant genera, the optimized model retained 26 bacterial genera as yield-associated predictors.

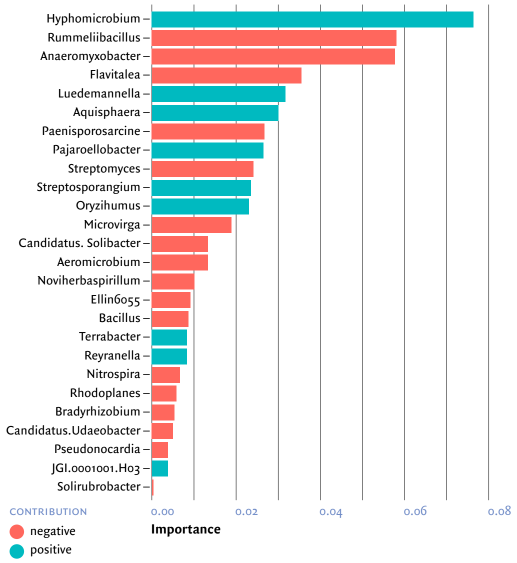
## Significant positive associations

To test transferability beyond the original field, the model was applied to 7 independent, publicly available 16S datasets encompassing croplands, grasslands, and pastures across multiple continents. These datasets included measured yield, soil health indicators, net primary production or NDVI-derived vegetation productivity proxies. Despite the ecological heterogeneity, predicted 'yield scores' derived from the original maize model showed significant positive associations with productivity metrics in most datasets, explaining up to 37% of variance in global plant growth indicators.

To disentangle microbial effects from environmental confounding, generalized additive models incorporating mean temperature, precipitation and soil pH were evaluated. In several datasets, inclusion of microbial predictors significantly improved model fit beyond abiotic variables alone. Although the study does not establish causality, these results indicate that microbial community composition may capture structured environmental information not fully represented by conventional climatic and edaphic descriptors.

## Implications Research

Interpreted alongside the findings of Wilhelm et al. 2022, the results of Schaks et al. suggest that soil microbial communities may function as integrated indicators of environmental variation. Wilhelm and colleagues demonstrated that the soil microbiome captures a substantial proportion of abiotic and management-related signals and can serve as a




Soil bacterial genera identified by LASSO regression as associated with maize yield variation at field level ($R^2 = 0.65$, n = 80)

biologically integrated measure of soil health. In this context, microbial community profiles are not merely additional variables but, in part, condensed representations of complex environmental conditions.

For plant breeding, this has direct implications for modelling genotype × environment (G×E) interactions. Multi-environment trials typically rely on climatic and edaphic descriptors that only partially explain environmental variance. Because microbial communities reflect cumulative influences of soil physical properties, nutrient dynamics, historical management, climatic factors and plant–soil feedback, they may serve as composite environmental covariates. Incorporating microbiome-derived descriptors into genomic prediction or reaction-norm models could therefore improve environmental characterization and reduce unexplained variance in performance predictions.

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