> *"A non-chemical solution is exactly what's needed, both for the environment and for the public perception of farming."*

The right trait at the right time

Innovation Insight

BYDV resistance puts wheat growers within tantalising reach of an insecticide-free crop. *CPM* tells the story of the breeding triumphs that brought it to commercial reality.

By Tom Allen-Stevens

Every once in a while, there's an innovation in plant breeding that sets down a true milestone. Barley yellow dwarf virus (BYDV) resistance in wheat will be remembered as one of those. But what really makes it remarkable is that the first UK variety with this trait was launched in the very same year growers could no longer use the neonicotinoid chemistry on which they had relied for around two decades.

"BYDV resistance is the right trait at the right time," states Agrii seed technical manager John Miles. "While neonic seed dressings were available, genetic resistance to an aphid-borne virus came way down the pecking order of what growers wanted in a wheat. Now, a non-chemical solution is exactly what's needed, both for the environment and for the public perception of farming."

Jim Knight, seed business development manager at Frontier, agrees. "It's hugely significant — easily comparable with resistance to orange wheat blossom midge (OWBM), turnip yellows virus (TuYV) or the Clearfield trait. It really does open a whole new chapter in the approach growers can take in managing their wheat crop."

The story of BYDV resistance starts in the late 1970s, decades before any farmer had even heard of neonics. "It had long been an aspiration for many wheat breeders," notes head of cereal breeding and research at RAGT Dr Richard Summers. "There was occasionally the tantalising glimpse of some lines with a level of field resistance, but there was nothing obvious within the hexaploid, commercial germplasm. The right genes lay outside this pool."

Origins of wheat

The quest for resistance also lay outside the realms of commercial breeding. It was in fact government-funded plant scientists who made the discovery and they had to trace back to before the very origins of cultivated wheat over 10,000 years ago to do so.

"Modern wheat originates from a natural cross hybridisation between wild grass and wild durum wheat we believe happened at about that time," Richard explains. "So it's possible to repeat that process now and cross desirable traits from related grasses into wheat. Plant scientists at the French National Institute for Agricultural and Environmental Research (INRAE) did the screening work and identified one source — the resistance gene Bdv2 originating from the grass *Thinopyrum intermedium*."

It was one thing to identify the trait, but quite another to transfer it into wheat, especially from a species that wasn't a known close progenitor, or direct ancestor, of the crop. "In a time before genetic markers the technical challenges to do this were huge compared to the screening methods available to breeders today which are exponentially improved," he continues.

But eventually the cross was achieved by scientists at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an Australian Government agency. "They produced translocations carrying Bdv2 onto the wheat chromosome arm 7DL. The isogenic line, known as TC14 carried a segment of genetic material from *T. intermedium*. The excellent outcome was that this conveyed resistance to all current strains of BYDV known to affect wheat."

This eventually resulted in commercial Australian lines Manning and Mackellar, which still yield well compared with contemporary wheats under high BYDV pressure today but are uncompetitive when there is no pressure, he notes. The trait was also successfully introgressed into commercial lines in the US and New

Scientists had to look outside the hexaploid, commercial germplasm for the genes that would convey resistance to BYDV, notes Richard Summers.

Timeline to innovation

1978	*Thinopyrum intermedium* BYDV resistance described by INRAE
1995	TC14 wheat line developed by CSIRO introgressing Bdv2, BYDV resistance, from *T. intermedium* to wheat
1999	PBIC start work
2000	*Bdv2* resistance gene mapped in wheat (characterised)
2002	CSIRO in Australia report early breeding developments of BYDV-resistant wheat
2004	RAGT buys PBIC from Monsanto; CSIRO variety, Mackellar, introduced in Australia
2007	RAGT testing of internally developed Bdv2 crosses
2011	RAGT produces cross that will become Wolverine
2013	CSIRO variety, Manning, introduced in Australia
2014	RGT Wolverine selection and testing starts
2017	Wolverine in NL Trials
2019	Wolverine launched in UK; University of Minnesota variety, MH Washburn, introduced in USA; Ban on neonicotinoid seed dressings in EU
2020	RAGT fast-tracks Wolverine seed production

Zealand. But what about the UK?

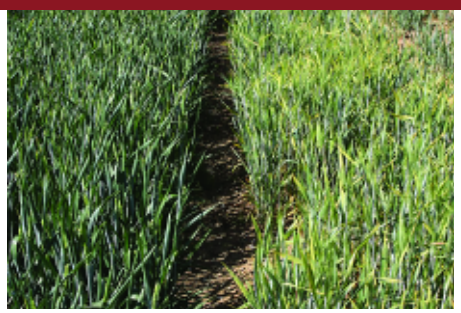
"Work started at Plant Breeding International Cambridge (PBIC) in the 1990s, undertaken by Bill Hollins and Stephen Brown," recalls Richard. "They took the TC14 line and successfully transferred the Bdv2 gene into the elite UK variety Charger. The difficulty was that it had a 10-15% yield drag compared with contemporary commercial lines."

It's a common conflict in plant breeding, he explains, especially when dealing with a segment of genetic material of this nature. "It's not a simple cross. You get a significant segment and sometimes a whole chromosome transferred, which means the breeding value of the resulting wheat will be poor. The challenge for the breeder is then to break up that segment — discard the genes that cause the yield drag but retain Bdv2. The likelihood of actually achieving that is very low."

Even if the link could be broken, there was still the 10-15% yield lag that had to be made up, meaning the material had to advance several times faster than the average 0.5% per year advance of elite commercial lines. This would add at least another 12 years to breeding development work. All this was taking place just at the time neonic seed dressings were being introduced, presenting growers with the apparent perfect solution for early BYDV control.

"But RAGT has always supported novel traits development if they're in a crossable background and has a strong pre-breeding programme. That's what kept the work on Bdv2 ticking over," says Richard.

The work was taken up senior UK wheat breeder Célia Bequain in collaboration with pathologists and molecular marker specialists



Seeing is believing – even under extreme pressure in inoculated trials, lines with the Bdv2 gene (left) appear unscathed by BYDV.

within RAGT. It was in 2011 that the cross was made that eventually became RGT Wolverine. "To get this variety was a massive achievement, given its long pre-breeding history," notes current senior wheat breeder at RAGT Dr David Schafer. "The yield results coming through showed it really did have the performance of a modern wheat. But would it confer resistance?"

In the laboratory, RGT Wolverine was compared against a widely grown UK variety and two of RAGT's French lines. These shared a similar genetic background (known as near isogenic), but one carried the same BYDV resistance as RGT Wolverine, while the other was susceptible.

When the resulting plants reached second-leaf stage, BYDV-infected aphids were transferred to each plant. After 42 days of incubation, aphid counts were undertaken and leaf tissue samples were sent for ELISA testing to detect virus presence. There was no difference in aphid numbers but the ELISA tests confirmed the resistant lines very rarely tested positive for virus, while the susceptible lines nearly always did. ▸

Insecticide-free wheat heralds exciting times for growers

Ask Kit Papworth about BYDV resistance and you'll see his face light up. "Wolverine is the first iteration of what is an exciting new period of genetics," he enthuses.

LF Papworth covers 1250ha of mainly light land in North Norfolk. As well as potatoes and sugar beet, there's 400ha of wheat in the arable rotation, a small beef herd and land given over to stewardship. Around 100ha of the wheat is grown for seed, which puts Kit closer than most growers to breeding innovations.

"This step forward in wheat is vital as we move to reduce insecticide use. Having genetics to replace it is so valuable."

With no blackgrass, Kit likes to drill his wheat relatively early. "From September we're rushing around lifting potatoes and sugar beet, so don't want to have to worry about the wheat."

He grew 50ha of Wolverine for seed for 2020 harvest and the variety was his mainstay early wheat for 2021, with 100ha grown. "The weather conditions on our light land made 2020 the poorest harvest we've ever had. But the Wolverine was irrigated, which made it the best crop of the year.

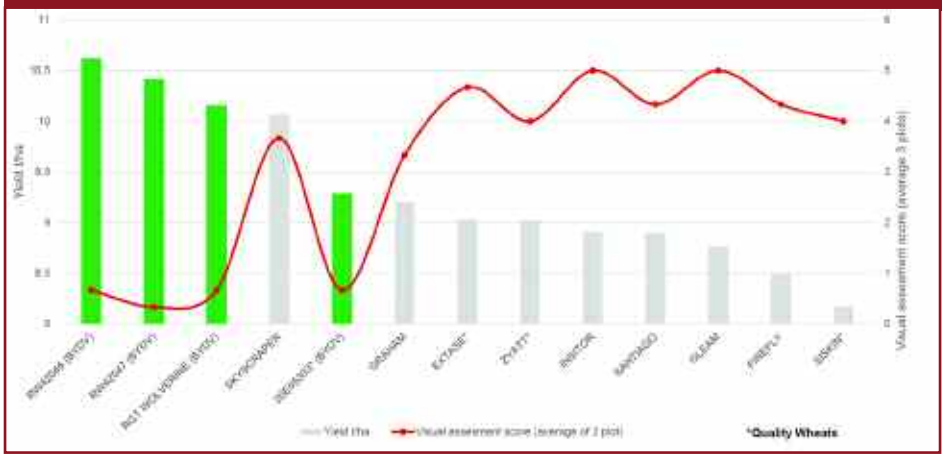
"What I learnt in the first year is that you can trust the genetics, which is why we grew so much the year after. It does give you that peace of mind in autumn, although you can't turn your back on the variety in spring."

Looking at the wheats now coming forward, Kit is excited about the prospect of insecticide-free wheat. "This really is the Holy Grail and I'm keen to see where the genetics will go. To my mind, the future of crop protection is to explore the crop's own resilience as we pull back on the chemistry. Breeding innovations like BYDV resistance gives us a future to look forward to."

From September, Kit Papworth is rushing around lifting potatoes and sugar beet, so doesn't want to have to worry about the wheat.

Further north, the grain aphid is a significant vector of BYDV, and resistance to pyrethroids is known in this species.

Performance of BYDV-resistance wheat



Source: RAGT trials at Ickleton, Cambs, 2021. Plants inoculated with aphids were placed within each plot at set times in the autumn and spring. The aphids were infected with the BYDV strain, PAV. Each plot was assessed weekly. Scores: 0 – no signs; 5 – very obvious symptoms and multiple stunted sites.

▸ In the field, trials of four wheats with the Bdv2 gene were compared with nine other popular AHDB Recommended List varieties in Cambridgeshire last year. All the susceptible lines were affected by BYDV, particularly when early sown with stark differences in terms of how much virus was present and how quickly it developed, as well as resulting yield (see chart above). Symptoms ranged from a few yellow and red-leaved plants to multiple stunted areas with severe leaf loss.

"Seeing is believing," says David. "While those with ordinary trials have remarked how effective it is, it's the inoculation trials where the difference really shows through."

RGT Wolverine was fast-tracked through seed production with around 7-10,000ha planted for 2021 harvest — a sell-out in its first commercial year. This coincided with the first year growers were unable to use neonic seed dressings, notes RAGT cereal and OSR product manager Tom Dummett.

"Around 60% of the UK cereal crop was previously treated with Deter (clothianidin), while around half the area is sprayed to control BYDV. AHDB estimates 82% of the wheat-growing area is potentially at risk with yield losses up to 60%."

The royalty on the seed is collected on an area basis through the Breeder's Intellectual Property Office (BIPO). Costing £33/ha, growers are required to declare the area they plant. "This allows growers to compare it like for like with other forms of control, but there are clear advantages," continues Tom.

"Pyrethroid sprays offer up to seven days protection, so 2-3 applications may be necessary, and this indiscriminate treatment will affect beneficial insects. The Bdv2 resistance is season-long protection with no application cost, completely safe to all wildlife."

John Miles points out that further north the grain aphid is a significant vector of BYDV, and resistance to pyrethroids is known in this species. "In Agrii BYDV trials, you couldn't make out the inoculated from uninfected plots of Wolverine and pipeline varieties — the difference really is quite astounding."

He believes growers most at risk are south of the M4 or along much of the East Anglian coast, then through The Wash and up into the Lincolnshire Wolds and Yorkshire Wolds, not forgetting the Cotswolds — these are historic areas of BYDV. "For south-west growers, it's a recognised cost of drilling early. But it's not just for early drillers — those with a heavy autumn workload will appreciate not having to make applications to the wheat, especially far-flung blocks.

No insecticides

"Many landowners are now stipulating no insecticides should be sprayed by contractors or tenants. With the rise of cover crops, and year-round green cover favoured by regenerative farmers, that provides a green bridge for aphids, so genetic resistance to BYDV will become increasingly valued," John predicts.

Jim Knight notes many growers treated seed with Deter because it brought peace of mind. "That's what BYDV resistance brings, and it's led OWBM-resistant varieties to cover more than half of the wheat market."

Wolverine accounted for about 1.5% of Frontier wheat seed sales over the past two seasons, he reports. "40% of these were in East Anglia and 24% in the South West, which overlays with the highest BYDV pressure.

"What would really make BYDV resistance take off is if it's stacked with OWBM resistance, or if it was in a milling variety. But we've seen with Wolverine that growers won't buy it at any cost — it can yield phenomenally well, but the variety's disease scores let it down last year where spray programmes weren't sufficiently robust. So Wolverine buys you peace of mind in the autumn, but still needs attention in the spring."

Wolverine's yellow rust resistance "is not as robust as we would have liked," admits David. But there are two new hard feed varieties with better disease scores currently in second year of National List trials, limited quantities of which will be available to plant this autumn. "They are KWS Santiago backgrounds and have both OWBM and BYDV resistance. So it's a unique and powerful resistance combination in a high-yielding package," he notes.

There are also milling varieties, including one with Skyfall in its parentage, currently in NL1 trials that will come under assessment by UK Flour Millers in 2023. "We're also looking closely at how we can bolster the BYDV resistance. Bdv2 is an introgressed gene element, likely not a single gene, but we're bringing in tolerance from other sources to protect the genetics," adds David.

For Richard Summers, Wolverine is "a first stab at BYDV resistance, but an impressive result in itself. To have both OWBM and BYDV resistance in a variety close to market is phenomenal. For the breeder, the treadmill continues, while growers can look forward to a mosaic of ways this genetic material can evolve." ■

Innovation Insight

CPM would like to thank RAGT for kindly sponsoring this article, and for providing privileged access to staff and material used to help put the article together.