THE VIRUS YELLOWS EPIDEMIC IN SUGAR BEET IN THE UK IN 2020 AND THE ADVERSE EFFECT OF THE EU BAN ON NEONICOTINOIDS ON SUGAR BEET PRODUCTION

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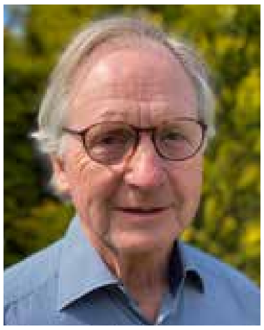

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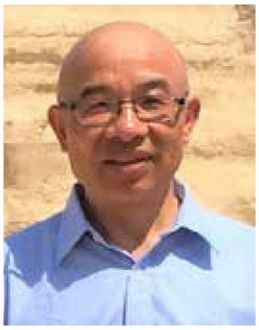

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Introduction

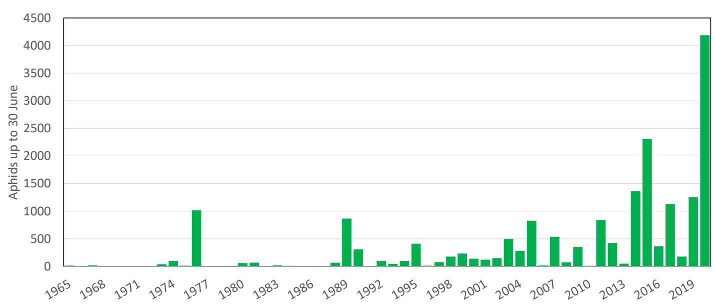
Virus yellows, the disease that was regarded as the worst scourge of sugar beet production in northern Europe in the 20th century (Jaggard *et al.*, 1998), made a dramatic and devastating comeback in 2020 (Photo 1), infecting up to 100 % of some fields in the Fens of Cambridgeshire, and culminating in 38.1% infection of the national crop (Stevens & Bowen 2021), the highest incidence of this pernicious disease since the epidemics of 1974–1976. The causes of the latest epidemic were the consequences of a perfect storm – high overwintering survival of the principal vector, the peach potato aphid, *Myzus persicae*, following a very mild winter, that resulted in early migration of infective aphids from overwintering hosts into newly emerging beet crops in April. These events, coupled with removal by EU dictate of the most efficient method of controlling the disease, namely the neonicotinoid seed treatments that had kept it under control for the previous 26 years, and the depletion of alternative insecticide spray products, either due to other bans, or having been rendered ineffective by the development of resistance in the vectors (Foster & Dewar, 2013), meant that growers were fighting a losing battle almost from the day they sowed their seed.

This article examines in detail how the 2020 epidemic developed, and the impact it had on the profitability of the sugar beet industry in the UK, and other parts of Europe. We also argue for a return of neonicotinoid seed treatments in future years to provide more effective control of future pandemics, and thus maintain the presence of this important break crop in arable rotations.

Photo 1. Virus yellows infection in sugar beet in Suffolk.

Epidemiology of Virus Yellows in Sugar Beet

Virus yellows is caused by a complex of up to three viruses, the persistent poleroviruses, beet mild yellowing virus (BMYV) and beet chlorosis virus (BChV), and the semi-persistent closterovirus, beet yellows virus (BYV) (recently reviewed by O'Driscoll *et al.*, 2019; Stevens *et al.*, 2006). All three viruses are transmitted by aphids, of which the peach-potato aphid, *Myzus persicae,* is the most important vector, and against which control measures are targeted (Dewar & Cooke, 2006). Winged migrant anholocyclic (asexual) forms of this species transfer these viruses from overwintering hosts, such as certain weeds, or overwintering beet, into newly emerged



Source: Qi *et al*, 2004; Rothamsted Insect Survey (James Bell and Suzanne Clark)

Figure 1. The number of *Myzus persicae* caught in the Broom's Barn suction trap up to 30 June, 1965–2020.

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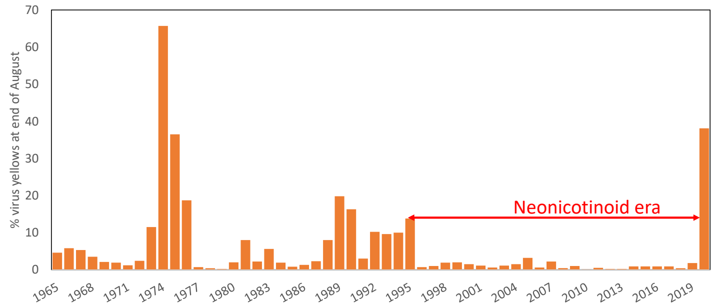
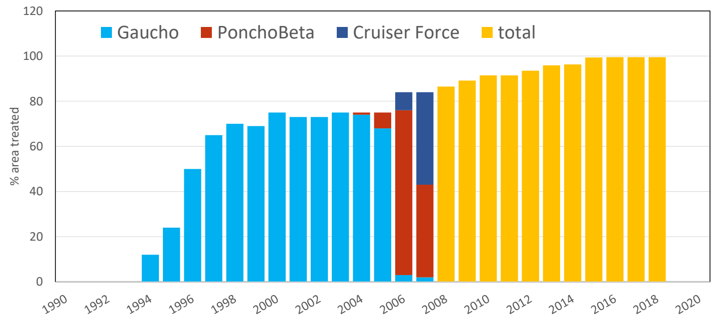


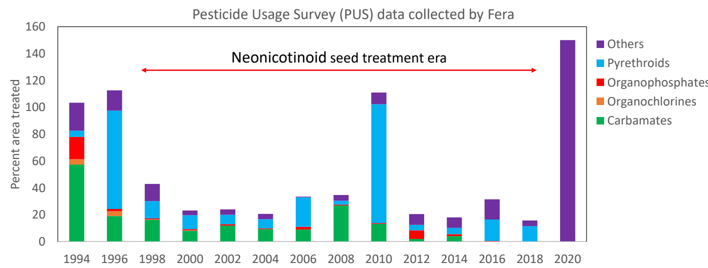
Source: Qi *et al*, 2004; Stevens, and Stevens et al., 2007-2019

Figure 2. The national incidence of virus yellows at the end of August in sugar beet in the UK from 1965–2020.



Source: British Sugar seed sales (to 2007); Stevens, and Stevens et al., 2007-2019

Figure 3. The use of neonicotinoid seed treatments in sugar beet in the UK 1990–2020.



Others in 2020, comprised of thiacloprid, acetamiprid and flonicamid, is a conservative estimate based on anecdotal evidence. 2020 PUS results were not available at the time of writing.
Data from *Garthwaite et al.*, 1995, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019

Figure 4. Insecticide use in sugar beet before and after the introduction of neonicotinoids in 1994 in the UK, and after the ban in 2018.

sugar beet crops in the spring and summer, where the viruses are spread by the offspring of the colonizing aphids and other migrants if they are not controlled.

Consideration of the migrations of *M persicae* as measured by the Rothamsted Insect Survey suction traps, which have been operating continuously in the sugar beet growing areas of the UK since 1965 (https://www.rothamsted.ac.uk/national-capabilities) showed that there have been several peaks of activity in the last 55 years, for example in the mid-1970's, 1989, 1995, and many times in the 21st century (Figure 1). Indeed, the five highest migrations of aphids to the end of June have been recorded in the last seven years, culminating in the highest of all in 2020. This perhaps is an indication of global warming, resulting in warmer winters, but also a reflection of the overwintering success of the aphids on the burgeoning oilseed rape crop that expanded its area massively during that time. Oilseed rape is a favoured overwintering host for *M persicae*.

The incidence of virus yellows in sugar beet during this period mirrors the number of aphids migrating, at least from 1965–1995, suggesting a strong causal relationship (Figure 2). Epidemics of 1974–1976, 1989 and 1995 were closely associated with the aphids' migratory activity. However, it is very clear that between 1996 and 2019 the incidence of virus yellows declined dramatically despite the high activity of aphids during that period, due largely to the introduction of neonicotinoid seed treatments, which were much more effective than the aphicide granules and sprays that they replaced (Werker *et al.*, 1998; Hauer *et al.*, 2016; Dewar *et al.*, 2005; Foster & Dewar, 2013).

The Rise and Fall of Neonicotinoid Use in Sugar Beet in the UK

Neonicotinoids were first introduced in the sugar beet crop in the UK in 1994, when imidacloprid, sold as Gaucho by Bayer, was registered. It was an immediate success, particularly in controlling aphids, and the virus yellows disease they carry, but also gave useful control of some soil pests, particularly those which comprised the soil pest complex – millepedes, symphylids and springtails (Dewar & Cooke, 2006). Prior to its introduction, these pests had been controlled by carbamate granules applied to the soil at drilling alongside the seed, or, in the case of the soil pest complex, using overall sprays of gamma-HCH, an organochlorine pesticide with persistent broad-spectrum activity in the soil. By any measure, the environmental benefits of using a seed treatment targeted solely around the developing seedling were obvious.

Within the next ten years, most of the carbamate products had been banned from use in the sugar beet crop, along with gamma-HCH, a decision that was widely accepted by the industry in the knowledge that the seed treatments were good, if not better alternatives, both from an efficacy point of view, and an environmental point of view. This transformation also occurred throughout Northern Europe (Hauer *et al.*, 2017). The quantity of insecticidal chemicals applied to the soil was reduced by up to 90%. The one exception to this development in the UK was the retention of the carbamate oxamyl (as Vydate and others) to control free-living nematodes in the sandy soils of North Norfolk and the Brecklands. None of the available seed treatments, whether neonicotinoid, or the pyrethroid, tefluthrin (Force, Syngenta), gave any control of these nematodes that could cause Docking Disorder – a condition that caused multiple yield-reducing fanginess in the roots (Cooke and Dewar, 1992).

Within five years of introduction, Gaucho became the treatment of choice for almost all the pest problems in sugar beet (Figure 3), contributing to a massive decline in use of insecticide sprays (Figure 4) that would have been applied to control the aphids in former years. Such was the persistence of imidacloprid in the plants that there was no need for subsequent sprays. This in turn led to cessation of the Virus Yellows Spray Warning Scheme, which had been the main source of advice in controlling this devastating disease throughout the late 20th century (Dewar & Smith, 1999). By 2005, the first of

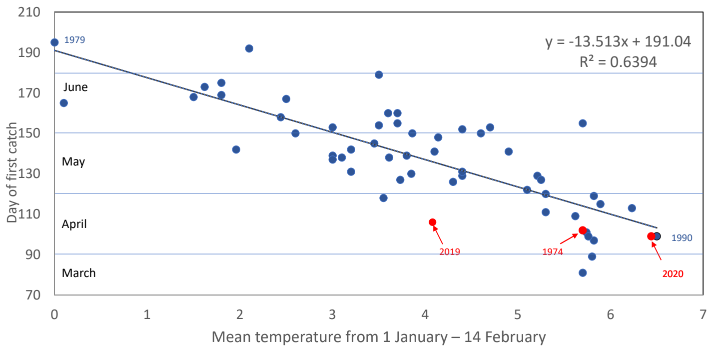


Figure 5. Comparison of mean temperature from January to February 14 with first catch of *Myzus persicae* in the Broom's Barn suction trap, operated by the Rothamsted Insect Survey from 1965–2020 (After Qi *et al.*, 2004).

the second generation of neonicotinoids, clothianidin plus the pyrethroid beta-cyfluthrin (PonchoBeta, Bayer), became available, followed shortly after in 2007 by thiamethoxam plus tefluthrin (as Cruiser Force, Syngenta), and these supplanted Gaucho as the treatments of choice (Dewar & Haylock, 2006; Dewar & Cooke, 2006; Dewar, 2007). They were applied at 30% lower rates than imidacloprid whilst still providing the same long-term persistence. Since 2008, PonchoBeta and Cruiser Force were used on over 80% of sugar beet in the UK, with a roughly even split between the two products. (Stevens and Stevens *et at*., 2007–2019). Until 2019……..

Complete cessation of the use of all three neonicotinoids was implemented in 2019 following the extension of the neonicotinoid seed treatment ban that had first been applied to flowering crops, such as oilseed rape, sunflowers and maize, in 2013 (EFSA 2013, a, b and c; reviewed in Wood and Goulson, 2017).

The Adverse Effects of the Neonicotinoid Ban on Sugar Beet Production

The first year following the neonic ban in sugar beet could be regarded as a honeymoon period, allowing growers to get used to a different regime when controlling virus carrying aphids, after 26 years without worrying. The winter was of average severity. Aphid migrations were not particularly early, but neither were they late (Figure 5), and the proportion of the aphids carrying yellowing virus, as measured by the yellow water pan trap network operated by the British Beet Research Organisation (BBRO) was low – <0.4% (Stevens *et al*., 2020). Nevertheless, most, if not all the sugar beet in England was sprayed with at least one insecticide to limit the spread of virus yellows in the crop.

The end result was positive. Only 1.8% of the national crop was infected with virus yellows in August 2019, and yields held up. They weren't the highest, but neither were they the lowest (Stevens *et al*., 2020).

Unfortunately, this success story was not repeated in 2020. Following an extremely mild winter (from an aphid's point of view), the first *Myzus persicae* began to migrate in early April, an event that was first recorded in the Broom's Barn suction trap on 9 April (Figure 5), heralding one of the earliest and certainly the largest migration of this species ever recorded at Broom's Barn since the Rothamsted Insect Survey was set up in 1965. Consequently, emerging sugar beet seedlings were colonized almost as soon as they popped above ground (Stevens & Bowen, 2021). In such circumstances it is very difficult to prevent colonization of plants and subsequent multiplication of aphid populations using topical sprays that do not persist long enough on fast-growing plants. In addition, growers were hamstrung by the restrictions placed on the number of applications that could be made. Only one spray of the only approved product, Teppeki (containing flonicamid), was allowed, but fortunately up to two sprays of other insecticides, including Biscaya (containing the neonicotinoid, thiacloprid) and Gazelle (containing the neonicotinoid, acetamiprid,) and one spray of Insyst (also containing acetamiprid) could be applied thanks to emergency approvals (CRD9) that were granted at the last minute to help cope with this unprecedented season (BBRO Special Advisory Bulletin, 2020; https://bbro.co.uk/media/50254/20-4-aphid-special-bbro-bulletin_.pdf). It was not enough.

Virus yellows symptoms started to appear very early in the season (June) confirming the early immigration of virus-carrying aphids, and, even though a similar proportion (0.4%) of aphids were carrying the virus as in the previous year (BBRO Advisory Bulletin 10), the sheer numbers of aphids colonizing crops (Figure 1) meant that many more plants became infected, despite the low incidence of infectivity. By the end of August, 38.1 % of the national crop had developed virus yellows symptoms, ranging from 100% in some parts of the Fens, to less than 10% in coastal areas of East Anglia (Stevens pers comm.). Unusually, the majority of this infection was caused by beet yellows virus (BYV), normally the least abundant of the three aphid-transmitted yellowing viruses. This virus causes a much higher yield loss (up to 50%) than either of the other two viruses, beet mild yellowing virus (BMYV) and beet chlorosis virus (BChV) (up to 25%) (Stevens *et al*., 2004; 2006).

In the event, yield losses were to prove much higher than expected in many crops, with some losses as high as 80% recorded, some of this due to drought and cercospora infections (Stevens and Bowen, 2021). It is estimated that 25% of the national yield was lost in 2020, but not all the crop had been harvested at the time of writing, so this remains an estimate.

The Pros and Cons for Neonicotinoid Seed Treatments in Sugar Beet

Pros

- Neonicotinoid seed treatments have given excellent control of many pest problems in sugar beet, especially of aphids and virus yellows, with just one application point at drilling.
- This resulted in huge reductions in applications of insecticide sprays (see PUS surveys: Figure 4)
- The quantities of active ingredients were reduced by up to 90% compared to previous practice.
- There was no need for further application of insecticides in most years, thus reducing soil compaction damage caused by traffic on the land, and fuel to apply the products.

- The reduced applications of insecticides are likely to have had less environmental impact on non-target organisms.

Cons

- Neonicotinoid seed treatments have quite long persistence in the soil (Jones *et al.*, 2014), which could have an environmental impact on non-target organisms there. A greater impact on pollinators above ground has been implied by some researchers, who demonstrated that neonicotinoid residues in the soil could be picked up by flowering weeds in field margins through run-off, and thus potentially contaminate pollen, and in turn affect pollinators such as bees (Botías *et al.*, 2016).
- Seed treatments tend to encourage prophylactic insurance use of pesticides due to the long lead time required to apply the treatments to the seeds prior to sowing.

  However, modern seed treatment methods are much faster than a decade ago, as has been demonstrated this year by Germains, the main sugar beet seed treatment company in the UK. Most seed treatments for the 2021 sugar beet crop in the UK were applied after the forecast was announced on 1 March, though this did result in many crops being sown later than planned – in April rather than in March.
- The quantity and number of insecticide applications that have been applied to sugar beet since the ban was implemented has increased massively. Most crops in 2019 received at least one spray for aphid control alone, and in 2020, many received two or three, and some up to four sprays (Stevens & Bowen, 2021). From 1996–2018, when neonicotinoids were applied to the majority of the sugar beet crop, the number of sprays applied to beet was less than 0.2 per hectare (Figure 4) – a 90% reduction, except for 2010, when there was an epidemic of silver Y moth caterpillars in July and August (Stevens *et al.*, 2011) requiring applications of pyrethroids late in the season.

  We would contend that this increase in insecticide usage applied overall to the crops has a greater impact on the environment than has been shown with residues of neonicotinoids. Unfortunately, it does not appear that any research is being done currently to determine this.

Neonicotinoid Usage in Sugar Beet in Europe

The decision to ban neonicotinoid seed treatments in the EU was taken by the European Parliament in 2012, originally regarding flowering bee-friendly crops such as oilseed rape, sunflowers and maize (EFSA 2013 a, b, c). The decision to extend and expand the ban to include non-flowering crops such as cereals and sugar beet, as well as vegetables such as carrots and lettuce, also non-flowering crops, was based on perceived, but controversial indirect risks to pollinators and other non-target organisms through persistent residues in the soil, and run-off into field margins. It was shown to be possible that these neonicotinoids could be taken up by flowering weeds, and thence by bees, both honey-bees and wild bees, causing sublethal effects to their health and fertility (reviewed by Wood and Goulson, 2017).

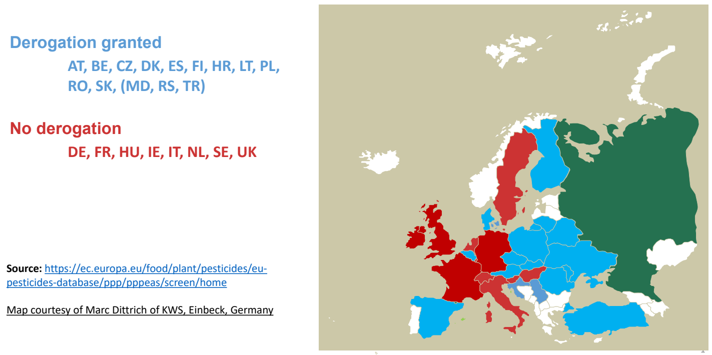


Figure 6. Derogation of neonicotinoids for use in sugar beet in Europe for the 2020 crop.

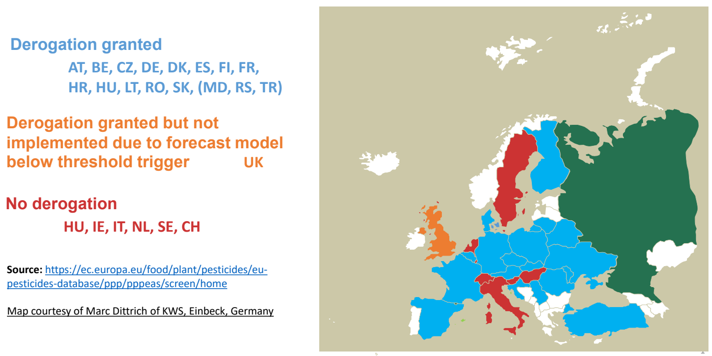


Figure 7. Derogation of neonicotinoids for use in sugar beet in Europe for the 2021 crop.

In the EU at the time, it was expected that every country would abide by this almost unanimous decision, so it came as a surprise to learn at an meeting of the International Institute de la Recherches Betteraves (IIRB) Pests and Diseases study group in Leuven in 2019 that many countries had applied for, and been granted by their respective governments, a derogation to allow neonicotinoid seed treatments in sugar beet, presumably because there were few, if any, reliable alternative methods available to control the target pests. In 2019, ten countries, allowed neonicotinoid seed treatments including Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Lithuania, Poland, Slovakia and Spain. In 2020, nine of these ten countries again allowed use of neonicotinoids in the face of higher risks of pests following a mild winter. Only six countries adhered to the ban in sugar beet, namely France, Germany, Hungary, the Netherlands, Sweden and the UK (Figure 6) (Sugar Industry, 2021). Ironically, all of these countries except Sweden were also more at risk from an epidemic of virus yellows in 2020 due to their maritime climate, having also experienced a mild winter, which allowed many more aphids to overwinter.

In 2021, following substantial yield losses due to virus yellows in 2020, both France and Germany have followed the lead by the other countries and allowed a derogation of use of the neonicotinoid seed treatments, subject to certain conditions (Figure 7) (Sugar Industry, 2021a, b). In Germany, approvals have been granted on only 31% of the total sugar beet acreage (120000 ha), while in Poland, only crops using seed treated in Poland will be allowed to use neonicotinoids, which amounts to 40000 ha of a total 250000 ha crop. In

Table 1. Long-term forecasts of virus yellows incidence based on predictions of global warming model HadGEM2-ES.

Representative Concentration Pathway	Time period	$T_{Jan\text{-}Feb}$	1st Flight	Total Aphids	% VY with neonics	% VY without neonics
Baseline	1980-2010	4.2	17 May	37	0.6	17.6
RCP 2.6	2021-2040	5.2	6 May	94	1.2	34.7
	2041-2060	5.2	5 May	93	1.2	36.7
	2081-2100	5.4	3 May	111	1.4	41.9
RCP 4.5	2021-2040	5.3	4 May	104	1.4	40.5
	2041-2060	5.9	27 April	181	1.7	48.1
	2081-2100	6.5	20 April	297	2.3	62.1
RCP 8.5	2021-2040	5.7	29 April	153	1.7	47.6
	2041-2060	6.2	24 April	224	1.9	51.3
	2081-2100	8.2	30 March	1560	3.1	76.3

Based on data from Broom's Barn met site and suction trap in Suffolk, and the Qi *et al.*, 2004 virus yellows model

France, all growers will be allowed to use neonicotinoids, subject to stringent conditions, particularly on the type and species of following crops – eg no flowering crops for two years after beet. Stringent restrictions also apply to growers in Belgium where flowering crops are prohibited for up to six years after beet, depending on how bee-friendly they are (EU 2021). Only Hungary, Italy, The Netherlands, Sweden, Switzerland and the UK will NOT be using neonicotinoids in sugar beet (Sugar Industry 2021b; EU 2021)).

That decision in the UK was made using a model forecasting the incidence of virus yellows – the first time a national pesticide strategy for a particular crop has been managed this way.

Integrated Pest Management of Virus Yellows

In an era of global warming, whatever the causes of that, it seems likely that epidemics like that which occurred in 2020 will become more frequent in the future. As can be seen in Figures 1 and 3, aphid migrations are occurring earlier, and their numbers are higher than 30–40 years ago, contributing to increasing virus yellows incidence in sugar beet. Table 1 shows likely scenarios that might occur in the future as a result of global warming, with reference to virus yellows epidemics. The scenarios are horrific, with infections rising up to 76% annually by the end of the 21st century.

The current methods of controlling virus yellows in sugar beet will not be able to cope with these mass migrations of virus-carrying aphids, just as they could not contain those that occurred in 2020. The BBRO and other sugar beet research institutes across Europe are at present prioritising aphid and virus yellows research and extension at the very core of their research programmes, but this cannot guarantee that alterative controlling tools can be found in the immediate future, or at all. Therefore, the solution, at least in the short term until new varieties with inbuilt resistance or tolerance to the diseases are developed, is to use seed treatments that are present within plant tissues from the minute the plants emerge above ground, until the most vulnerable stage for infection has passed – the 12-leaf stage, when plants are beginning to meet across the rows. This is what neonicotinoid seed treatments provided. Although virus yellows infection can still cause yield losses after this stage, they are not as drastic as when plants are infected as small seedlings. It would be very useful to have potential recourse to the neonicotinoid seed treatments if and when they are needed, as they have proven yield benefits when virus yellows diseases are rife (Dewar & Cooke, 2006; Dewar, 2009).

In 2021, alone of the countries in Europe where virus yellows is a common problem, and which have reversed the ban on neonicotinoids this year in response to virus yellows epidemics (Figure 6), the UK implemented a decision-making process that took account of the risk of virus yellows. This decision was based on a model, taking account of correlations between overwintering weather, survival of aphids, and likely migration timings in relation to crop growth, similar to the model of Qi *et al.*, 2004, currently being updated at Rothamsted Research (James Bell, pers comm.).

In the event, the forecast for virus yellows for 8% of the UK national crop to be infected (BBRO Advisory Bulletin 1 2020), was just less than the threshold for economic yield loss (9%), and thus below the agreed trigger value for approval of the use of neonicotinoids (BBRO Advisory Bulletin 2, 2021). An emergency approval for use of thiamethoxam had been approved subject to this condition, and certain other restrictions on the way the crop was to be grown, such as maintaining good weed control to prevent flowering weeds that might attract bees, and also choice of subsequent crops in the rotation (no flowering crops within 22 months; no oilseed rape within 42 months; no fallow). Despite these severe restrictions, 80% of growers had still ordered Cruiser SB seed to grow their sugar beet crops this year, but were not allowed to use it. Many will have been disappointed by the final outcome, but, on the plus side, at least there was some science behind the decision to deny the use of neonicotinoids in 2021 in the UK.

Concluding Remarks

It is fervently to be hoped that the decision to continue the ban on neonicotinoids in the UK will not be detrimental to the long-term future of the sugar beet industry here. If yields of sugar beet suffer the same fate as many in 2020, then, such is the marginal profitability of this crop when yields are low, many growers will cease to grow it. Then we shall have the same situation as with oilseed rape, which was grown on 380,000 ha in 2020, about half the area that was grown in 2012 (756,000 ha) (Defra, 2020), with massive changes to the look of the countryside, especially in the East. This was due to adverse consequences of the neonicotinoid ban in oilseed rape, which has resulted in an inability to control infestations of cabbage stem flea beetle (Dewar, 2017).

These changes on cropping practice will have much greater consequences on bees and other pollinators than the neonicotinoids that were banned to protect them. It is the law of unintended consequences, which the green lobby did not predict when promoting their controversial opinions to the politicians of Europe.

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