NIAB TAG

Landmark

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The impact of CSFB in the field this season

IN THIS ISSUE

Jim Godfrey, chair of the NIAB Board

Dr Tina Barsby OBE – a vote of thanks

In this first issue of *Landmark* since Tina announced her intention to retire as chief executive of NIAB later this year, I wanted to take this opportunity – on a personal level but also on behalf of the Board and the entire NIAB community – to say a heartfelt thank you for everything she has done for this remarkable Institution.

I was not closely involved with NIAB when Tina joined as Chief Operating Officer in 2006, but I was certainly aware of how NIAB was perceived more broadly across the industry. A casualty of the ill-fated Barnes Review, NIAB was seen as a rather ailing organisation, a shadow of its former self – hived off from the public sector yet almost wholly dependent on Government contracts and funding for its survival. At the time I think it would be fair to say the culture within NIAB remained that of quasi-Government institute, while the world outside had moved on.

NIAB Board and Executive July 2019

Working against a background of chronic under-funding for applied agricultural research, just consider how dramatically NIAB has changed and evolved in the intervening period. Put simply, 15 years ago the academic and research partnership NIAB recently announced with the University of Cambridge through the Crop Science Centre would have been absolutely unthinkable, but today it is a logical next step in our journey as the UK's premier applied crop science organisation.

The process of transformation began under former chief executive Professor Wayne Powell when the NIAB Board and Trust agreed to use NIAB's own assets and resources to invest in a pre-breeding and genetic research capability in the mid-2000s. This visionary step set the scene for what was to come during Tina's tenure as chief executive from 2008.

Over the past 13 years, under Tina's leadership, NIAB has more than trebled in size through investment in new scientific skills and partnerships, and increasing commercial activity.

I believe three factors have been central to the phenomenal success of this programme of growth. The first is that NIAB's core scientific expertise in assessing the performance and quality of plant varieties and seeds, built up over more than 100 years, has provided the essential foundation on which NIAB has diversified its research and knowledge exchange activities.

In short, NIAB understands better than any other organisation what makes a good crop variety, and that specialist knowledge has underpinned our ability to expand into other activities, such as applied agronomy research through the creation of NIAB TAG in 2009, and into other crop sectors, including potatoes through NIAB CUF in 2013, and fruit crops through NIAB EMR in 2016.

The second key factor is that NIAB occupies a unique position at the interface between discovery science and its practical application. With equally strong links to the academic research base and the input supply industry, and direct interaction with progressive farmer members who account for over 20% of the UK arable area, NIAB is ideally placed to accelerate the transfer of innovative research into farm-level knowledge, advice, products and services.

And thirdly, the diversity of our funding sources today also means that our research and advice is truly independent of government, industry and other interests. NIAB's work is science-based and rooted in our charitable commitment to improve the productivity, sustainability and resilience of agricultural and horticultural crop production at home and overseas.

Tina has embedded these core values and strengths throughout the organisation, underpinning the strategic decisions we have taken, and our interactions with others. That is why NIAB has developed something of a track record in taking on or merging with compatible organisations whose outlook may have been difficult or uncertain, and helping them realise their potential while at the same time strengthening NIAB's scientific and research capabilities as a whole.

One other aspect of Tina's contribution which should be highlighted, and for which she was deservedly recognised with an OBE in 2018, has been her selfless commitment to the wider industry and research community. While these activities have delivered wider industry benefits, I certainly do not underestimate the added value it has brought specifically to NIAB, improving our standing among politicians and policy-makers, making us better connected, more outward-facing and more confident as an organisation.

On a personal level, Tina's management style is calm, thoughtful and compassionate. She listens carefully, and is determined to ensure all of our staff have the opportunity to use their skills and potential to make a significant contribution to NIAB.

All the above go to explain why Tina is universally liked and respected across the sector. And also why she will be greatly missed. As NIAB plans an exciting new chapter in its history, Tina leaves our organisation in a far stronger position than it has ever been. We wish her the very best for the future and her many plans for retirement.

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Cereal Candidates 2021

New varieties continue to flow through the testing system, thanks to the breeders, and hopefully this summer there will be more opportunities to see the current cohort in the field compared to last. There are plenty to look at although some are still caught up in the National List system so data is not always available to discuss.

Winter wheat

This year we see 13 winter wheat candidates across a range of end-use groups. To kick off we will look at three varieties all with potential bread-making quality. **KWS Palladium** (KWS) offers treated yields 2% ahead of those of KWS Siskin and an improved untreated yield. It has short, stiff straw and is relatively early to ripen, which is always useful in a quality variety. It has excellent resistance to yellow rust and is currently sitting a useful 7 for Septoria. **RGT Flintoff** (RAGT) has a treated yield 1% above that of KWS Siskin but its untreated yield is substantially lower, probably partly due to its moderate to poor yellow rust resistance. RGT Flintoff does, however, offer the unusual combination of bread-making quality and orange wheat blossom midge (OWBM) resistance only currently available in Skyfall or LG Detroit. Finally we have **Mayflower** (Elsoms) with a similar treated yield to KWS Siskin and an improved untreated yield. It is relatively early to mature and offers excellent rust resistance combined with an 8 for Septoria as well as a high specific weight and may well prove to be another low risk, easy to manage quality option. All three of these varieties still have plenty of hoops to jump through to prove their quality credentials but they are worth keeping an eye on as they all potentially have something to offer agronomically.

We also have three varieties with biscuit-making potential. **KWS Guium** (KWS) has produced treated yields 3% ahead of KWS Barrel which would put it on par with the current Group 3 leaders. It is a taller variety with stiff straw and OWBM resistance but has a mixed disease profile with excellent resistance to yellow rust offset by a poor rating of 4 for both Septoria and brown rust. **KWS Brium** (KWS) is a similar variety with slightly improved ratings for Septoria and brown rust but does not have the benefit of OWBM resistance.

RGT Rashid (RAGT) demonstrates only a 1% yield increase over KWS Barrel, but offers not only good yellow rust resistance, but also a good Septoria rating of 7 as well as OWBM resistance. Its lateness to mature may be a concern for some but may also be seen as a tool to manage the peak harvest workload. With a good set of new Group 3 varieties added to the most recent AHDB Recommended List, these three varieties will have to perform well this year to make an impact.

Moving onto feed varieties there are two soft feed varieties to take a look at. **RGT Bairstow** (RAGT) offers a competitive treated yield as well as a solid disease profile which includes good resistance to yellow rust as well as a 7 for Septoria. With the added benefit of OWBM resistance it looks a useful package. **RGT Stokes** (RAGT) also offers a good combination of yield and disease resistance which includes an 8 for Septoria and this may well attract interest in the west. On the downside it has suffered some degree of lodging in untreated trials although it does appear to respond well to PGR.

The five hard feed varieties look particularly interesting and we will start off with **Champion** (DSV). Champion offers a very competitive treated yield as well as a good untreated yield. It has good yellow rust resistance and a Septoria rating of 7 as well as OWBM resistance. **LG Farrier** (Limagrain) is alongside Champion in terms of yield and offers excellent rust resistance and a good specific weight. On the downside it has a poorer Septoria rating of 5 and no midge resistance. **KWS Dawsum** (KWS) also has a similar high treated yield but also offers a very high untreated yield. It has stiff straw, excellent yellow rust resistance, a 6 for Septoria and a good specific weight, the only thing missing is midge resistance. **LG Typhoon** (Limagrain) is just 2% behind in treated yield but will offer flexibility in terms of disease and pest management with excellent yellow rust resistance, an 8 for Septoria and OWBM resistance. **KWS Henum** (KWS) also offers the combination of excellent yellow rust and an 8 for Septoria but lacks the midge resistance and has a specific weight towards the lower end.

An interesting set of varieties overall but I suspect the hard feed group will spark the most interest going forward.

Spring wheat

There are three new spring wheats to look at, two with bread-making potential and one feed. **KWS Ladum** (KWS) has bread-making potential and a yield slightly down on KWS Cochise. It offers good mildew resistance as well as moderate rust resistance. The second variety with bread-making potential is **Nissaba** (Blackman Agriculture). Nissaba has a much lower yield, just above that of Mulika and will need Group 1 quality to be of interest. It has a moderate disease profile but benefits from OWBM resistance. Finally we have the feed variety **KWS Fixum** (KWS). The variety has produced exceptionally high yields from a limited set of trials, combined with a good disease profile and this will no doubt attract attention from growers wishing to expand the range of spring cropping on farm.

Winter barley

Eleven winter barley candidates are in trial this year, split between malting and feed. **KWS Feeris** (KWS) tops the malting group and is interesting on several counts. Firstly, it is a conventional six-row variety, with treated yields similar to those of Funky, but remember, it is currently under test for malting. Secondly, it carries tolerance to BYDV, a useful additional trait when chemical options are dwindling as well as becoming less environmentally acceptable. From a disease perspective it is susceptible to mildew but has good levels of resistance to both Rhynchosporium and net blotch. The second malting candidate, **SY Goblet** (Syngenta), is a specialist malting variety which is still awaiting National Listing.

The two-row feed group is topped by **Lightning** (Elsoms Ackermann Barley). It has produced very high yields, up with the best current two and six row varieties, is relatively early to mature and has a good disease profile, boasting 8s for both Rhynchosporium and net blotch. **LG Dracula** (Limagrain) is just 1% behind and also offers a good disease profile and a high untreated yield. **LG Dazzle** (Limagrain) and **LG Prodigy** (Limagrain) fall 1% behind again and also offer good disease resistance. It is encouraging to see that all of these varieties offer improved disease resistance over the current high yielding two row varieties available. There are three other varieties in this group still waiting to be added to the National List, **SU Alia** (Saaten Union), **Endurance** (Elsoms Ackermann Barley) and **LG Caiman** (Limagrain).

Two six row hybrids complete the group. **SY Javelin** (Syngenta) is a high yielding variety that matches the yield of the current top hybrids. It is early to ripen and offers excellent Rhynchosporium resistance. **SY Canyon** (Syngenta) offers a combination of high yields, a solid disease profile and an excellent specific weight.

Spring barley

Despite eight varieties being promoted into RL trials as candidates, only one of them has currently been added to the National List. **Winston** (Elsoms Ackermann Barley) is a malting barley currently under test. It offers good mildew resistance as well as moderate resistance to Rhynchosporium.

Oats

There is one winter oat candidate, **RGT Silver** (RAGT), which is still awaiting National Listing and two spring oat candidates. **Merlin** (Cope Seeds) is a high yielding conventional variety with stiff straw and early maturity as well as excellent resistance to mildew. **Lion** (Saaten Union) is lower yielding but offers a high kernel content. It too has stiff straw and is early to ripen but is very susceptible to mildew.

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Oilseed Rape Candidates 2021

There is a large and exciting mix of new oilseed rape varieties coming forward in the candidate trials in 2021. Thirty-three varieties have been selected as candidates for the AHDB's Recommended List in trial and, at the time of writing, 19 of these have passed their statutory National List tests, allowing data to be published. The remainder are held up, mainly through lack of distinctness from other similar varieties.

This gives us a wide range of varieties to consider and more of them will pass their statutory tests in the future. We would recommend checking on the AHDB website periodically, to see if the candidate table has been updated.

Within the 19 that we have data for, there are three Clearfield® varieties which are really pushing the yield forwards for this type, a semi dwarf and a clubroot resistant variety. We also have one with a breeder's claim of sclerotinia tolerance. The figures stated relate to the East/West or Northern scores on the RL list.

If we look at the Clearfield® varieties first, **Matrix CL** (DSV) heads the current yield league for the three candidates with a UK Gross Output (GO) of 103% but an impressive 108% in the East and West (EW) rankings and a good oil content of 46%. With resistance to TuYV and pod shatter it has excellent scores for resistance to lodging (9) and resistance to stem canker (9) but only scores a 5 for leaf spot resistance. **LG Constructor CL** (Limagrain) has a UK score for GO of 101% with again, an impressive EW score of 105% and also TuYV and pod shatter resistance. It is short and stands very well but is somewhat disease susceptible. **DK Imove CL** (Bayer) scores 94% for GO, is fairly short with pod shatter resistance and has a better disease resistance profile with very good resistance to stem canker and good resistance to light leaf spot.

These results show that there is a determination to bring more of this type of variety forwards and we are rapidly seeing significant improvements. Having the additional herbicide choice is a very useful trait for either controlling unwanted brassicas or for helping with establishment by allowing a wider range of companion crops to help with cabbage stem flea beetle (CSFB) problems.

Moving towards the other varieties put forward for UK listing: **PT303** (Corteva) currently has a score of 111% for the UK. The variety is quite late flowering, but not that late in maturity, therefore has a short flowering window. It has a very good oil content (46.2%), a score of 7 for stem canker and 6 for light leaf spot and is TuYV resistant. We also have a breeder's claim that it is tolerant to Sclerotinia. If this is true, it is the sort of trait that should be encouraged as reducing the need to spray any form of chemistry, especially mid-flowering, is a big benefit.

Next we have **LG Adonis** (Limagrain), GO 109%, excellent oil content at 46.4%, quite short with very good stem canker resistance, a 6 for light leaf spot and is TuYV resistant. **Amarone** (Limagrain) is a conventional variety with TuYV resistance. It has a 107% GO score with an impressive 104% for the North, plus it is short and stands well. **Marvin** (Frontier) is also a conventional with similar characteristics to Amarone and a 104% GO score for the North and 105% for the UK. It has a slightly different disease resistance profile with good resistance to light leaf spot but does not have TuYV resistance.

Although at this stage, we have no varieties with information specifically for the North, we have another 12 that are entered for the East and West region. Topping the yield list of this group is **LG Auckland** (Limagrain) with a GO of 115%. Taller than average but with good standing ability and very good resistance to stem canker, it is also resistant to TuYV and pod shatter. We also have another good conventional, **Annika** (Limagrain), relatively short for a variety from this stable but with a good score of 109% and also good light leaf spot resistance with the bonus of TuYV resistance. It is a little late flowering and maturing but overall matches Amarone and Marvin, and it is good to have three strong conventionals challenging to get on the List.

We have three more hybrids with a good GO of 113%: **PT301** (Corteva), **Dart** (DSV) and **Tennyson** (Elsoms). They are all of average height and stand well, with a good oil content. The standout one from a disease perspective is Tennyson which has an excellent score of 9 for stem canker. Tennyson and Dart also have TuYV resistance whereas PT301 has pod shatter resistance.

We have a further five hybrid varieties trying to get on the List and all look promising, **Duplo** (DSV) (109%), **Flemming** (LSPB) (109%), **LG Areti** (Limagrain) (111%), **PT299** (Corteva) (109%) and **DK Expat** (Bayer) (107%). PT299 has a very high oil content of 47%, and all have good stem canker resistance with Duplo scoring an excellent 9. Duplo and LG Areti have both TuYV and pod shatter resistance, Flemming has TuYV resistance and LG Expat has pod shatter resistance.

We have another good clubroot resistant variety in **Crossfit** (DSV). A hybrid for the East and West region with a GO of 106%, high oil content and a 9 for stem canker resistance, although it is weak on light leaf spot. However, it does have TuYV resistance.

Corteva have brought forward another semi-dwarf in **PX138**, it has scored 99% and has TuYV resistance. This is a useful trait for those who want less growth in the autumn.

Overall it is a great List considering the problems the crop has been having. Whilst as an industry, we continue to look for ways to manage the crop in the presence of CSFB and changing weather patterns, it is pleasing to see the breeders supporting the crop and bringing forward a wide range of genetic traits which are all very useful in protecting the crop and reducing foliar inputs.

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Pulse Candidates 2021

There are two pea candidates, two winter bean and one new spring bean variety for consideration for PGRO's Descriptive Lists in autumn 2021. As always with pulse varieties, we would caution that trial numbers in the early years, before entering Descriptive List trials, are rather low and yields can take three or four years to stabilise. But we can discuss what is known so far and then watch and see how they develop over the coming testing period.

Peas

Rivoli (Senova) is an early maturing yellow/white pea variety with moderate straw length and good standing ability at harvest. There are early indications that it has excellent resistance to downy mildew. In the blue/green category, **Carrington** (LSPB) is an early maturing variety with early indications of high yields. Plants are tall with good standing ability. This variety has good colour retention in the grain and also appears to perform well against downy mildew.

Winter beans

Pantani (LSPB) is an early maturing variety with very short plants that have excellent standing ability. **IB162** (Senova) proved to be a top yielder in National List trials last year, ahead of both new Descriptive List varieties and better-established varieties. Early indications show this to be a late maturing variety with medium-tall plants that have good standing ability.

Spring beans

Casanova (LSPB) is a new medium-late maturing variety in the low vicine/convicine category with tall plants that have good standing ability. Early indications are that yields are low to moderate in comparison to other varieties on the Descriptive List. However, this is observed with caution as it can take a few years for yields of new varieties to stabilise and be fully confirmed.

These new candidates will have their first year of standalone Descriptive List testing in 2021, and we hope to be able to report on them in more detail after harvest when we have another set of data upon which to assess their performance. We will know more about any varieties with improved protein content or seed size after the coming harvest.

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UKCPVS update: early results from 2020

The UKCPVS had an extremely busy year in 2020 – second only to the yellow rust epidemic seen in 2016 – with the Survey receiving more than 300 samples over the season. High levels of yellow rust during the 2019/2020 season posed challenges for wheat growers during March and April after yet another damp and mild winter. Of particular note was a significant increase in reports of yellow rust symptoms observed on the previously resistant variety KWS Firefly. This development became a focus for the UKCPVS during the season, with numerous experiments carried out to confirm virulance reactions on the variety. The UKCPVS also received a number of interesting samples at the end of the season, collected from resistant varieties such as KWS Extase and RGT Gravity.

Despite a high disease pressure season, virulence frequencies for the main yellow rust resistance genes remained stable in 2020, with the red group continuing to dominate the population. Five new pathotypes were identified, the risk of which will be investigated further in 2021 adult plant variety trials.

Current situation: wheat yellow rust

The UKCPVS received a large number of yellow rust samples in 2020, 306 samples compared to 243 received in 2019, with high levels of disease being observed in April. The epidemic peaked in June, when 160 samples were received in that month alone. Samples were collected from 25 counties around the UK with most samples, unsurprisingly, being received from Lincolnshire. However, the UKCPVS also received samples from traditionally lower risk areas for yellow rust, such as Scotland, Northern Ireland, and the south-west.

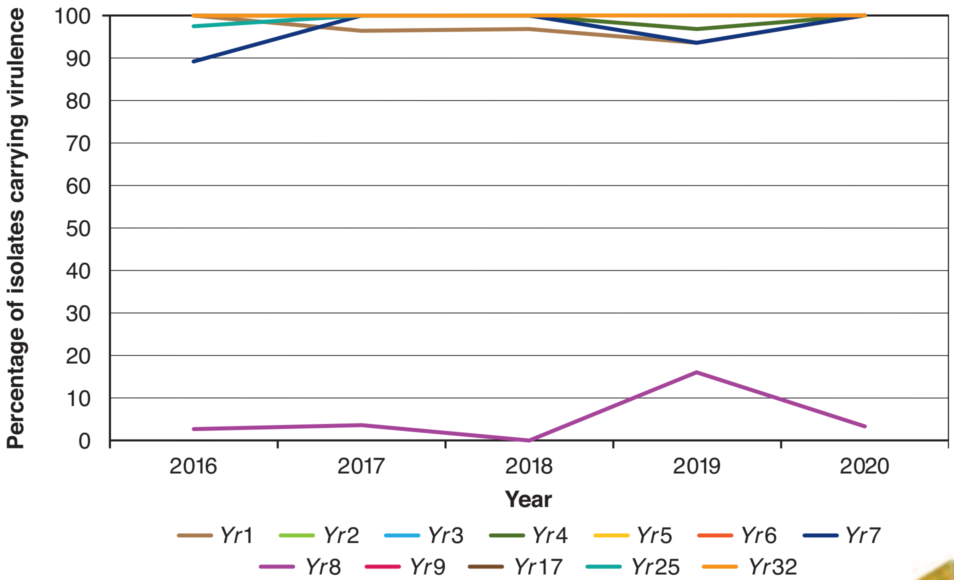
Samples covered 88 different varieties during 2020, with the vast majority not presenting any real surprises. However, the most prominent variety was KWS Firefly – despite a 2019/2020 rating of 9 on the Recommended List – with 25 samples being received by the UKCPVS and numerous reports of sightings around the growing area. In-house testing of the 'Firefly' isolates showed that they were virulent on KWS Firefly. However, virulent reactions appeared environmentally sensitive and were not observed in all growth conditions tested. To understand these host/pathogen reactions further, research will be on-going in 2021.

In addition to KWS Firefly, there were also a small number of samples received from spring wheat varieties Mulika and KWS Cochise and resistant winter varieties such as KWS Siskin and Costello. However, isolates collected from KWS Siskin and Costello did not produce a virulent reaction when re-tested on their respective host and it was therefore concluded that their key resistance genes remained functional.

In isolates collected in 2020, there were no new virulences detected for known *Yr* resistance genes, and virulence frequencies were in line with those seen in previous years for other *Yr* resistance genes (Figure 1). Similar to previous years, the Red Group made up a large proportion of the isolates collected during the 2020 season.

The three most common pathotypes identified in 2020 samples are pathotypes belonging to Red 37 and Red 28, both being found in 17% of the isolates tested and Red 27 which made up 10% of the yellow rust population. Both Red 27 and Red 28 were first identified by the UKCPVS in 2017, with Red 28 being seen every year since. Red 37 had not been identified within the UKCPVS previously but had recently been identified within a separate field pathogenomics project carried out at NIAB. Five new pathotypes were identified during 2020, with one isolate exhibiting virulence for *Yr*8. The

Figure 1. Frequency of detection of isolates carrying virulence to known *Yr* resistance genes over the past five years



risk to UK varieties from these new pathotypes will be investigated further in adult plant trials conducted in 2021.

Looking ahead to the 2021 season, 54 samples have already been received by the UKCPVS at the time of writing, despite the extended cold period this spring, suggesting that we may experience another high-pressure season. Growers are therefore advised to monitor all varieties carefully this season and to report unusual levels of disease to the UKCPVS as soon as possible.

Rustwatch: 2021 update

The NIAB cereal rust group is currently involved in a collaboration of 25 partners from across Europe in a Rust surveillance project called Rustwatch. The aim of the project is to combine the expertise of established virulence surveys from across Europe, rust researchers, agrochemical companies and extension workers to develop an early warning system that will mitigate the risks of future changes in the pathogen populations.

This €5 million project examines many areas of the wheat-rust pathogen interaction and will seek to answer some of the commonly asked questions such as how the new *Pst* populations arrived in Europe from their origins in East Asia and whether these new isolates really are more aggressive than isolates from the old European populations. We also seek to understand how varieties carrying key resistance genes differ in terms of the mechanisms and timing of adult plant resistance development during the season and how these differences could be utilised to improve plant breeding strategies going forward.

In addition, the consortium is investigating the role of sexual reproduction for the cereal rust fungi under UK environmental conditions. To do this, we examine leaves of the common barberry (*Berberis vulgaris*), for the secondary spore structures: the aecia and pycnia. Any sightings of these important plants this season, particularly in hedgerows bordering arable fields, would be very helpful to the project.

Current situation: wheat brown rust

Brown rust was slow to develop during the 2020 season, with moderate to low levels of disease being observed in late June and July. The UKCPVS received 45 samples of brown rust across nine counties, with isolates being identified on 24 different wheat varieties. However, there were no unexpected levels of disease on currently grown varieties during the season.

Seedling differential tests on 30 isolates collected from these samples identified eight new pathotypes. Slight changes in virulence frequencies were observed, with seedling virulence frequencies continuing to increase for Lr28 and decrease for Lr20 in 2020. In 2020 a common pathotype was detected, which represented almost 25% of the isolates tested. The risk to UK varieties from key new pathotypes will be investigated further in adult plant trials conducted in 2021.

We need your help

As always, the UKCPVS relies on samples of interest sent in by growers, agronomists and breeders amongst others. Full sampling details are available on the NIAB website – www.niab.com/research/agricultural-crop-research/research-projects/uk-cereal-pathogen-virulence-survey.

In addition to our usual request for samples NIAB is also keen to survey *Berberis vulgaris* plants as part of the Rustwatch project. We are looking for information on any of these plants that may be in a hedgerow near you.

UKCPVS plant pathologist Amelia Hubbard assessing the seedling tests

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The impact of CSFB in the field this season

A few more fields of flowering oilseed rape are scattered across the countryside this year, a welcome change to the past few seasons where autumn establishment conditions and pest pressure severely curtailed the national area. Nonetheless there are many crops that looked good going into winter, but are now limping slowly towards flowering; this can be attributed to the plethora of pests that are passionate about destroying the crop.

OSR, Wiltshire

Cabbage stem flea beetle (CSFB) adult numbers seemed lower this year, but their legacy lives on in their larvae. NIAB's trapping data from trial sites around the country showed it was well into August before migratory flight numbers began to build. The first real numbers arrived around the third week of August but at relatively low levels and crop damage appeared minimal. Numbers caught in water traps coincided with weather patterns; warmer days meant higher numbers in traps in general. We carried on recording adults into November, but the peak seemed to be the last week of August and into the first half of September, which tallies with the general trend of the beetles arriving at the August Bank Holiday weekend. In the NIAB TAG CSFB Monitoring Bulletins (available on www.niabnetwork.com), we highlighted evidence from Sweden of a 7-8 year boom and bust cycle in population numbers of CSFB, so a bust has to come at some point. We are hoping to build enough data here in the UK to see if our trends are similar.

This year's crops were certainly helped along by the moisture retained in the soil throughout August and September which had been lacking in previous years. The rain at the end of August unquestionably helped out the trial plots at NIAB's regional centre at Cirencester; I have not had such good establishment with so little beetle damage for a few seasons now. Indeed, the tramline trial that has been in place at Cirencester for the past four years got off to a great start with a smattering of rain post-drilling.

This season, the tramline trial has included five different options for establishment. A Clearfield® variety was used as a standard treatment, alongside mustard to help reduce the feeding burden, garlic spray to deter the pest, buckwheat to shield the crop and dairy cow slurry again as a deterrent. The aim of this long running trial is to find which methods, if any, are viable to use during those difficult early stages of crop establishment. All the crops were sown on the same day, with the expectation that the fast growing mustard would germinate slightly ahead of the OSR crop as it has in past years and which it did this year. Being slightly faster to grow means the mustard shields the young OSR plants coming through and alleviates the adult damage.

Plant counts from the trial show the relative ease in establishing the crop this year, as all treatments gave a reasonable plant stand at cotyledon stage (Figure 1). It was almost two weeks later when the beetles arrived into the crop, with numbers building in the second week of September. The garlic spray and slurry treatments were applied to the crops at this point. The logic behind this is that CSFB are deterred by pungent smells; the garlic spray would be an easy option for growers without access to slurry applications. Figure 1 shows the plant counts before and after CSFB arrived in the crop, with traps collecting in excess of 20 beetles in some treatments. The difference between the treatments and plant population are hard to tell apart looking at the field itself, due to

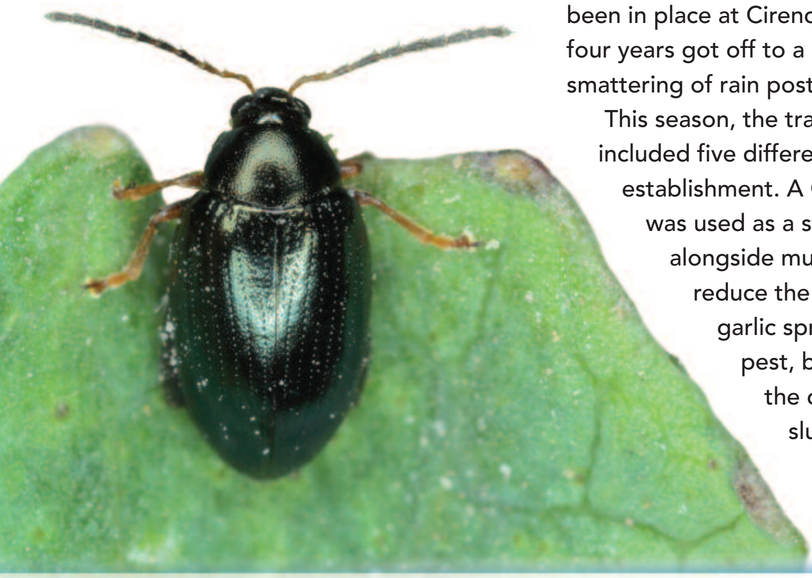


Figure 1. NIAB TAG tramline trial data (plants/m²)

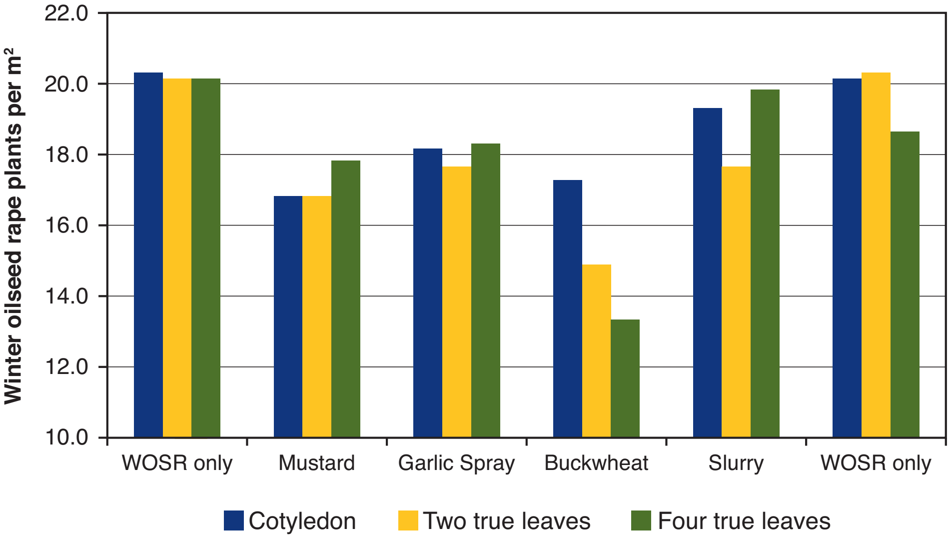


Figure 2. CSFB larvae in the stems of flowering plants

Figure 3. Wilted WOSR plants ready for a larval count

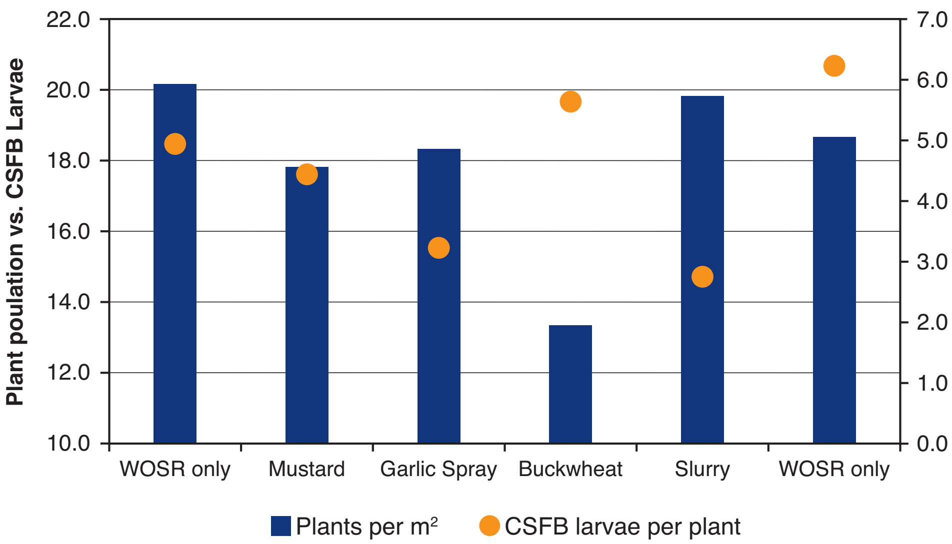
the low adult grazing damage but do show in the data slightly. The two treatments with a second crop have slightly lower populations, perhaps due to population competition.

In reality, the weather has allowed all treatment plots to perform well. The trial becomes more interesting with the March assessments for CSFB larvae and it seems this year, more so than previous years, they are a bigger problem. As mentioned before, good-looking crops are now struggling to extend, and indeed flower, as the larvae move into the stems of plants and severely knock back their growth (Figure 2). Even a strong looking crop can have infested plants within. I am hopeful that these plants will survive and make it to harvest but the reality is we are not sure what will happen. Side branches will likely pick up the yield.

In March we collected 15 plants per treatment (or field) to examine the numbers of larvae within each plant and to see if the autumn treatments had a secondary effect on larval development. In the past this has been carried out the old-fashioned way: diligently pulling apart the leaves and stems bit by bit. This year we adopted the Syngenta water method – faster, less muddy and more accurate, and far fewer squished larvae. We would definitely recommend trying it next season so you can see what the crop is hiding. Use a bucket of water and a squirt of washing-up liquid, so the larvae cannot crawl out and escape their fate, plus some chicken wire. Place the collected plants on the wire above the water-filled buckets and leave to wilt (Figure 3). The larvae will drop out of the plant and into a watery grave. Depending on the weather it took around two weeks for a good wilt and then, instead of dissecting many plants, it is just one bucket of water to sieve through and count.

The results on the tramline trial treatments (Figure 4) showed an interesting decrease in larvae per plant from both the garlic and slurry treatments even though in the autumn there seemed to be no visible benefit. The smell clearly did not encourage too many beetles to stick around for mating season, with preliminary evidence suggesting they provide a secondary effect against larval damage in the spring. This effect has been seen for the past two years with slurry.

Figure 4. Plant population versus larvae per plant



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NIAB research and climate change

Climate change is at the forefront of much of the research carried out at NIAB. We use the knowledge of how genetics, environment and management interact to increase crop production and quality and cope with a more variable and changing climate. Biodiversity protection and enhancement are also key goals, alongside increasing the efficiency of resource use, resulting in less waste across the food system. We believe that sustainable and efficient crop production can go hand-in-hand with action to reduce greenhouse gas emissions, to store carbon, and to adapt crop varieties and cropping systems to a changing climate.

Farming occupies a unique position as both a significant contributor to climate change and a major source of solutions to mitigate and reduce its impact. A major driving force in agriculture is the globally increasing demand for food, driven largely by a growing world population and a wealthier population with a higher proportion of meat in their diet. As a consequence of this global food production system, greenhouse gas emissions are increasing at around 1% per annum. The challenge of reducing agricultural emissions is acute because the reductions achievable by changing farming practices are limited and are often in conflict with the increasing demand for food.

Greenhouse gas emissions from agriculture constitute a relatively low percentage (c.10%) of total GHG emissions. In the process of crop production for food, some carbon is fixed in plant tissues and a proportion of that makes its way into the roots/soil and may be stored. When crops are harvested and consumed, they release much of the CO_2 back into the atmosphere, but it is possible to breed or select crop plants which could store greater amounts of carbon in deeper roots and soil for longer periods. Methane and nitrous oxide, both very potent GHGs, are released in higher quantities by farming-related activities, and are much harder to reduce, offset, or counterbalance. The complexity of these issues, and the urgency of the climate change threat, underline the importance of research into carbon-neutral farming.

Many schemes, which include measures to improve on-farm efficiency, also double up as GHG mitigation measures. For example, increasing soil carbon stocks through incorporation of cover crops, integrating grass and herbal leys in rotation, switching to low input forage crops, and reducing soil compaction all help to maintain good soil health, and are also effective methods of reducing GHGs produced.

NIAB research areas focused on climate change:

Designing Future Wheat

For many years now, NIAB has run ground-breaking wheat pre-breeding programmes, applying extensive phenotyping expertise to maximise output from experimental wheat lines developed at NIAB. These include lines derived from re-synthesised hexaploid and tetraploid wheats for a range of important traits including environmental adaptation, drought tolerance and hybrid breeding potential as well as processing characteristics and digestibility.

Drought-tolerance and early flowering are the focus of ongoing research projects conducted by NIAB in collaboration with other research institutes and breeding companies. NIAB is currently assessing wheat varieties and pre-breeding lines for agronomic performance under water-stressed and irrigated conditions as part of the BBSRC-funded Designing Future Wheat project.

Crop diseases

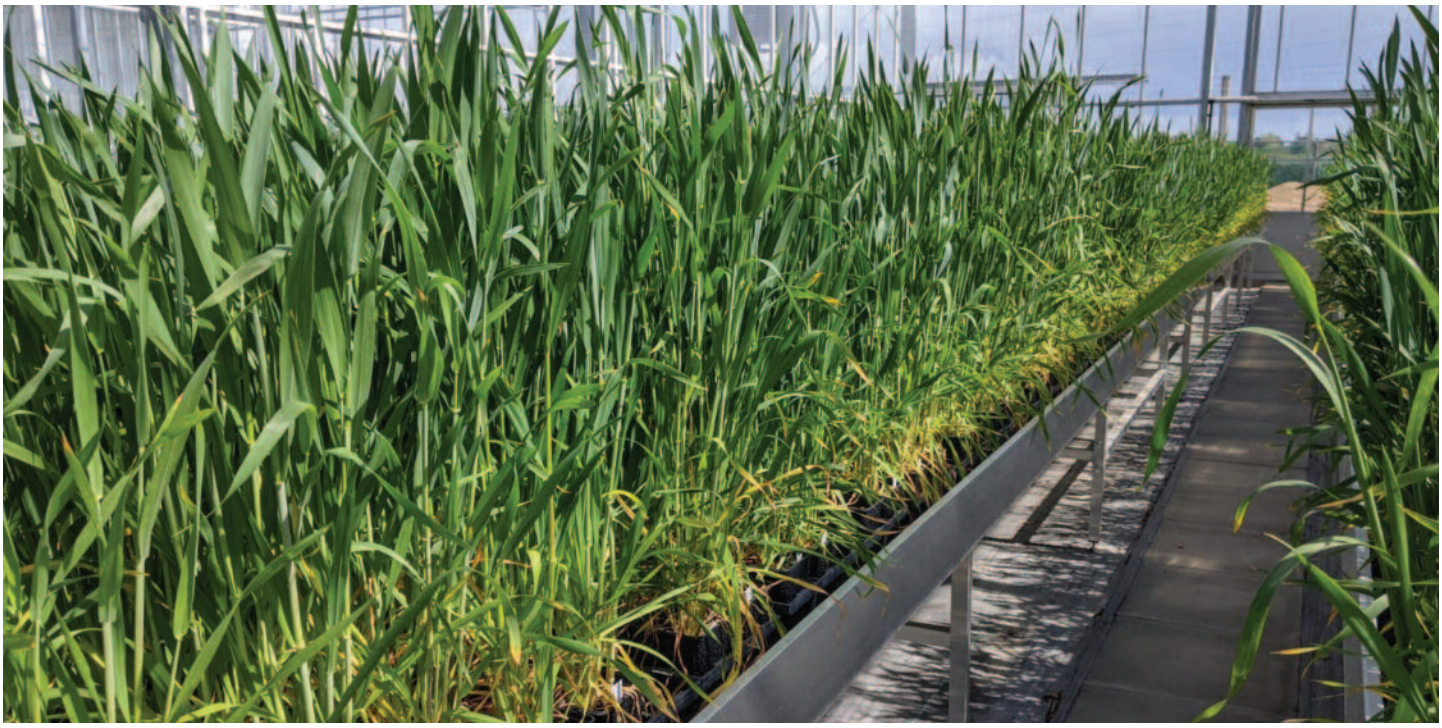
Changing climatic conditions will undoubtedly lead to the adaptation of fungal pathogens, such as high-temperature tolerant yellow rust in wheat. We will also see the introduction of new pathogens and the increase of currently rare diseases such as wheat stem rust (*Puccinia graminis* f sp. *tritici*), which is devastating to wheat crops in southern Europe, but is rare in the UK. NIAB continues to monitor and predict new and existing pest and disease threats to build resilience in UK crop production.

Flowering time

Flowering time and its timing relative to local environmental conditions is a major determinant of grain yield in wheat. Winter wheat varieties in the UK are typically later flowering than varieties in other regions of northern Europe, and in the past decade there has been a shift to predominantly later flowering varieties. However, under most climate change scenarios, warmer summers are expected to increase in frequency in the UK, accompanied by a reduction in summer rainfall, leading to an increased risk of drought. Varieties with earlier flowering times may help to avoid this risk during warmer summers.

Soils and greenhouse gas emissions

The Intergovernmental Panel on Climate Change (IPCC) reported that GHG emissions resulted from a combination of CO_2 and N_2O emissions during fertiliser manufacture and N_2O emissions, direct and indirect, from fertiliser



use. At the same time, there is a large quantity of carbon held in the organic matter within the world's soils. The disruption of soil aggregates during tillage usually increases the rate of decomposition; hence reducing tillage intensity can lead to more stabilisation of soil organic carbon. In general, we see bigger changes where there is a change in land use or major rotational changes, rather than changes in management (e.g. reduced tillage, use of cover crops).

NIAB leads in the measurement and maintenance of soil health, monitoring the effects of cropping systems and management practices, and gives practical guidelines on how to enhance soil health.

Nitrogen fertilisers

The easiest soil management step to implement, that will help mitigate climate change, is an increased focus on nutrient management, in particular, steps to improve nitrogen use efficiency. Any benefits of N fertiliser for crop productivity (and increased root and residue returns that increase carbon inputs to soil) can be confounded by higher emissions of CO_2 from fertiliser manufacture and losses of N_2O from soils.

Practices that improve N use efficiency include:

- adjusting application rates based on more precise estimation of crop needs (e.g. precision farming);
- removing any other constraints to growth whether pH, other limiting nutrients or disease, or planning N applications to take account of the change in yield potential (e.g. due to drought/pest attack);
- avoiding time delays between N application and plant N uptake (improved timing);
- using slow-release fertiliser forms or nitrification inhibitors;
- avoiding excess N applications by calculating crop need more accurately;
- improving soil structure to improve both rooting and water holding capacity.

NIAB continues to lead the UK in providing independent crop management R&D, information, and services, based on practical crop and agronomy research. This includes nutrient management information and independent agronomy advice.

Selecting wheat varieties

Together with agronomic practices, the choice of varieties can also affect GHG emissions. Simply choosing the right variety can have a significant impact on resource use efficiency. The yield potential of modern UK wheat varieties continues to increase by about 0.5% per year. This increase is largely due to genetic gains in yield, but they are also undergoing selection in times of climate change; those that are well-adapted to current climatic conditions will tend to be selected by the trialling system. Those that are more resilient (i.e. perform well in good and poor seasons) will also be favoured.

We need to turn our minds to figuring out policy mechanisms that can deliver sustainable high yield farming, as well as safeguarding and restoring habitats. If we are serious about saving the planet for anything more than food production, then the focus has to be on increasing yields and sparing land for the climate. We estimate that by actively increasing farm yields, the UK can reduce the amount of land that is a source of greenhouse gases, increase the 'sink', and sequester enough carbon to hit national emission reduction targets for the agriculture industry by 2050.

An extract from the study by *Bamford et al* published in *Nature Climate Change, March 2019*

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Carbon costing apple orchards

The UK Government set a new target earlier this year to reduce greenhouse gas (GHG) emissions by 78% (relative to 1990 levels) by 2035. Perennial horticultural crops, such as apple trees, represent a potential carbon sink since they lock-up carbon in their woody biomass and roots for the duration of their lifetime (approximately 15 years in the case of dessert apple orchards). However, the GHG emissions balance of apple orchards is highly sensitive to the management practices used by the farmer. In particular, their effect on soil health can be pivotal in determining the overall GHG emissions.

Compacted soils

Conventional dessert apple production systems rely on the regular use of heavy machinery throughout the orchard's lifetime, from ground preparation and spraying of agrochemicals through to pruning and harvesting of fruit. This results in soil compaction in the alleyways (inter-rows) which can be highly detrimental to soil health. Compacted soils have poor soil structure with fewer pore spaces and a higher bulk density. This leads to reduced infiltration rates that can make the soil prone to waterlogging. Compaction can also increase the risk of soil erosion, and subsequently a loss of soil organic carbon (SOC), since the fine soil particles that are more susceptible to erosion have a high sorption capacity for carbon. Soil respiration rates may actually decline in compacted conditions since the soil is less aerated, causing a reduction in microbial activity and thereby lower CO_2 emissions. However, emissions of the far more potent GHG nitrous oxide (N_2O) can increase up to seven times. Furthermore, reductions in crop yield in compacted soils are often reported, which would increase the relative GHG emissions on a product basis (e.g. per kilogram of apples).

There are practices that can ameliorate the effects of soil compaction. These include cover cropping and the application of organic amendments, such as mulches. Direct methods for reducing compaction include the use of low pressure tyres and subsoiling. The latter is not always desirable, however, since it will cause a temporary burst of CO_2 and may

disrupt mycorrhizal networks and soil aggregate stability which can increase erosion risk.

Cover crops to boost soil health

Typically, dessert apple orchards in the UK tend to have grass-covered alleyways. Although grass acts as a good carbon store and is certainly preferable to the bare, herbicide-treated alleyways that are more common in orchards elsewhere in the world, there are further benefits to be gained by using cover crops. In addition to alleviating soil compaction, cover crops can help to increase soil fertility (particularly if using legumes in the mix), improve soil structure and reduce erosion. As explained earlier, erosion can result in substantial losses of SOC, so the benefits of cover crops are greater in locations, such as the Mediterranean, where soil erosion is a more prevalent issue. Indeed, research shows that the implementation of cover crops in Spanish Mediterranean woody cropping systems could boost annual soil carbon sequestration rates by almost half a tonne of carbon per hectare. Another notable finding in the literature was that topography strongly affects the level of erosion, with steeper slopes exhibiting greater benefits of cover crops in protecting SOC relative to flatter areas.

Irrigation

Irrigation, or fertigation, is a major source of orchard GHG emissions. This is primarily due to the energy required to power these systems and, in the case of fertigation, the GHG emissions produced during the fertiliser manufacturing process. However, the irrigation regime can also have significant implications for soil GHG emissions from orchards. Research shows that by either using regulated deficit irrigation (reducing the irrigation volume in non-critical periods), or having less frequent irrigation events (but delivering the same overall volume of water), soil N_2O emissions can be greatly reduced – by as much as 27% in the case of an apple orchard in Canada. This occurs because under higher/more frequent irrigation there are more water-filled pore spaces, and this anoxic environment favours the microbial process of denitrification which generates N_2O. Given that N_2O has a global warming potential almost 300 times higher than that of CO_2, such dramatic reductions in its emission rates could be highly beneficial.

What to do with grubbed trees?

After grubbing an orchard, the usual practice in the UK is to burn the trees in the field, which releases various GHGs into the atmosphere. In doing so, any carbon that was stored in the tree biomass is released. However, elsewhere in Europe, processing the grubbed trees and pruning residues for the production of either biofuel or soil amendment products is becoming increasingly common. These alternative management options include chipping, biochar production and anaerobic digestion.

Chipped apple wood can be either used as a soil amendment to increase SOC, as a fuel for bioenergy production, or as a main material in the manufacture of particleboards. If all the pruning residues from dessert apple orchards in the UK were chipped and used for bioenergy, they could potentially produce almost 9,000 MWh yr-1 – enough to power 2,363 households in the UK annually (based on recent government statistics). However, it is advised that the apple wood is mixed with other types before burning as it has a high waste (ash) production.

Biochar is produced via the process of pyrolysis which involves the controlled combustion of plant biomass at very high temperatures. It can then be used as a soil amendment which has been reported to result in increased soil carbon stocks and reduced nitrate leaching. Increases in yield following biochar applications have also been reported for some crops, although this has not yet been shown in apple. There are also reports that biochar can help to reduce soil N_2O emissions by as much as 38%, although there are contradictory findings in other studies possibly partially due to difference in soil physicochemical properties and pyrolysis conditions. In terms of the total GHG emissions incurred by biochar production, the key determinant is the efficiency of the pyrolysis process.

Another alternative use for orchard plant residues is as a feedstock for anaerobic digesters. The resulting biogas can be used for energy production, and the digestate can be used as a biofertiliser. Thus it offers the opportunity to both produce a renewable energy source that could offset some of the energy used during the orchard's lifetime, and reduce the need for chemical fertilisers which are among the greatest contributing sources to the GHG emissions associated with apple production. However, it is important to note that the overall GHG balance of anaerobic digesters is highly dependent on the efficiency of the system, as inefficient anaerobic digesters can actually result in a net increase in emissions.

It is important to note, however, that not all of the tree roots are removed during the grubbing process. Although there is a lack of data quantifying the portion of roots that remain below the grubbed zone, it is possible that they could serve as a significant carbon store, particularly given the limited microbial activity that occurs in deeper soil horizons.

Top tips for cutting emissions and enhancing soil C stocks

End of life practices and pruning residue management are evidently areas of opportunity with regards to cutting GHG emissions from UK apple orchards. Through their use as either a soil amendment or as a biofuel, converting the woody biomass of prunings and grubbed trees into either chippings, biochar, or anaerobic digestate can substantially reduce the overall emissions balance of an orchard. Cover cropping is another avenue through which apple growers could enhance soil C sequestration while also potentially boosting yield. In adopting these measures, growers could reduce their carbon footprint, standing them in good stead for future carbon auditing policies.

For more information on this topic, please contact flora.obrien@niab.com for a copy of the report *Carbon sequestration in modern dessert apple orchards* co-authored with Dr Alicia Ledo for the AHDB.

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Adriana Gallego

The sustainable production of protein-rich crops in a net-zero carbon economy

Food systems account for one-third of all anthropogenic greenhouse gas emissions (GHG). The majority of carbon emissions are the consequence of land use change and the loss of natural habitats, the manufacturing of fertilisers, the emissions from soil after fertiliser application and emissions from livestock. Even in a scenario where all fossil fuel emissions immediately ceased, food system emissions under business as usual would prevent attempts to limit average global warming to 1.5°C and could threaten a 2°C climate target.

Opportunities for reducing food system emissions include improved farming practices, conserving natural habitats and reducing waste. The single most impactful intervention, on a global basis, is to decrease the proportion of animal-based protein in our diets. Meat and dairy are responsible for 60% of world-wide agricultural GHG and 14.5% of total anthropogenic GHGs, despite providing only 18% of calories and 37% of protein globally.

A range of scenario-based studies imply that even modest increases in the proportion of protein derived from plant-based sources in the average diet could make a significant contribution to the target of net-zero emissions by 2050. If land previously used for grazing or feed crop production were ecologically restored, the benefits of meat and dairy reduction would be further increased through increased carbon sequestration. However, in order to avoid unintended consequences associated with the gaps in our understanding of the sustainability credentials of alternative protein sources, safeguarding policies would have to be put in place to ensure that newly available land is ecologically restored and that agricultural production becomes highly sustainable. Thus, future protein supply cannot be merely a matter of producing more of the same in the same proportions. Factors that influence the potential of various current and future protein supply sources are to be considered. Plant-based protein sources often lack one or more amino acids in sufficient quantity to meet human nutritional needs. Combinations of different proteins, including cereal-pulse combinations, and supplementation, can help to overcome this in strict vegan or vegetarian diets.

Popular plant-based protein sources: Legumes and pulses

Currently vegetal sources of protein dominate protein supply globally (57%), with other animal products making up the remainder.

Soybean is the most popular source of plant-based protein, a large body of knowledge has been generated throughout the many years soybeans have been used as alternative to animal-based proteins. Soybean's high levels of protein and essential amino acids content, and favourable gelling properties make it an excellent alternative to animal-based proteins. In 2017, 123.6 million hectares were used to grow 352.6 million tonnes of soybeans, of which 70-75% was used as animal feed, 18% was used as biodiesel and the remainder was used for other by-products, including human consumption. The large amount of land used to

cultivate soybeans merely as animal feed makes the growing practice, but not the crop itself, unsustainable. Looking closely, soybean cultivation brings other benefits to the food system: they are excellent at fixing nitrogen, they rely on minimal fertilisers and pesticides, and they help farmers to control grass-weeds. In other words, soybean cultivation is not the problem, our over-reliance on using it to produce animal products is.

Pulses are excellent at fixing nitrogen; they are usually low input crops and are considered an important source of dietary protein and other nutrients. They are the major source of protein and often represent a necessary supplement to other protein sources. For example, cowpea is an important pulse grown and consumed in east and west African countries. Nutritionally pulses contain approximately 10% moisture, 21-25% crude protein, 1-1.5% lipids, 60-65% carbohydrates, and 2.5-4% ash. Chickpea is an exception as it contains about 4-5% lipids, and some pulses such as lupins have been reported as having up to 45-50% protein.

Cereals

Cereal proteins account for the major portion of dietary protein intake globally. Wheat accounts for the largest group of plant protein sources in the western diet. Maize is eaten across the world, with 61% of global production consumed in Mexico and neighbouring central American countries, 45% in eastern and southern Africa, 29% in the Andean region, 21% in west and central Africa, to 4% in south Asia. Millet is consumed extensively in west Africa, its protein content is similar to maize.

Rice does not contain large quantities of protein but research has been conducted to prepare rice protein isolates from rice flours using different techniques. In southern India where protein malnutrition of infants is common, rice and millet are consumed regularly and, in Ethiopia, teff, with an amino acid profile similar to egg protein, is preferred. Protein from oats are of high quality, amino acid content and quality is comparable to soybean (Table 1). Oats have higher content of the essential amino acid lysine compared to other cereals and a lower proline and glutamic acid content.

The case for using models

While it is clear our current food system is unsustainable, the challenge is to develop strategies that together make it healthier, sustainable, and more resilient. Models can help, they are useful tools to simulate crop development under a multitude of scenarios such as environmental footprints, biotic constraints, trait and gene effects. Models can be incorporated into tools for decision support to help farmers to manage crops more sustainably. Models can also assist national decision-making in determining strategies that achieve net-zero GHGs.

Some challenges need to be addressed to fully embrace the utility of models. First, is the need to collect high-quality agronomical data that makes models more reliable. Second, is connectivity. In several regions particularly in developing countries, high-rich protein crops are located in remote areas that makes the functioning of 'Internet of things' (IoT) and crop modelling forecasts hard to implement in real time. Third, is concern with how models are applied for policy analyses. Priorities include the need for expanding scenario thinking to incorporate a wider range of uncertainty factors, providing insights on target setting, alignment with broader policy objectives, and improving engagement and transparency of approaches with different stakeholders. Once these challenges are addressed, models acquire critical relevance to support the short- and long-term strategies in providing effective decision support. Through crop modelling, more and better protein-rich crops can be systematically and sustainably managed.

Table 1. Protein concentration (P %), Limiting Amino Acid (LAA) score. Other functional and environmental scores (1 Highly favourable, 0.5 Somewhat favourable, 0 Not favourable)

	P %	LAA score	Supply	Nutritional value	Env impact	Protein functionality	Taste and appearance	Allergies
Soya	36.5	100	1	1	1	1	1	0.5
Oats	16.9	72	1	1	0.5	0.5	1	1
Wheat	10.3	38	1	0.5	0.5	0.5	1	0
Maize	9.4	49	1	0.5	0.5	0.5	1	0
Millet	11.0	33	0.5	0.5	1	1	0.5	1
Rice	7.1	62	1	0	1	0.5	1	0
Mungbean	23.9	83	0.5	1	1	1	1	1
Chickpea	19.3	100	1	0.5	0.5	0.5	0	1
Cowpea	23.5	100	0.5	1	1	1	1	1
Lupins	36.2	78	0.5	1	1	1	0.5	0.5
Peas	5.4	85	1	0.5	1	1	1	1

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The economic cost of achieving Net Zero

Had I been asked the question – what is the economic cost of achieving Net Zero carbon? – a few years ago, I would have probably gone away to calculate how many hundreds of billions of pounds I thought this ambition might cost. However, more recently with all the government policy announcements that have been and are still being made the answer is "probably not that much really".

Although, the current frenzy of activity on 'net zero' is part of the lead-up to the much talked about COP26 meeting in Glasgow later this year, it is fair to say the UK has always been one of the lead countries trying to implement practical plans to achieve cuts in greenhouse gas emissions.

Much of the information in this article comes from either reports produced for, or published in, the *December 2020 Committee on Climate Change (CCC) 6th Carbon Budget Report (2033-2037), The UK's path to Net Zero*.

The economics of change

In 2006 *The Stern Report, The Economics of Climate Change* set the initial benchmark modelling the likely economic impact of changing the way society operates to stabilise greenhouse gas (GHG) emissions and mitigate climate change versus carrying on with 'business as usual'. The summary conclusion was it was not going to be free, but the sooner a serious start was made, the less it would ultimately cost and the sooner the longer-term benefits would come. Overall, the costs were estimated to be around 1% of global GDP if practical steps to limit GHG emissions were adopted quickly.

The Government took note and in 2008 the UK implemented the Climate Change Act, which puts in place statutory targets along with structures and procedures to enable a planned approach to reducing the amount of GHGs emitted.

So, here we are in the 2020s and we are now starting to hear the word 'cost' be replaced by phrases like 'opportunity', 'job creation', 'green accounting' and 'ecosystem services'. There are now a number of reports such as: Natural Capital Committee reports and recommendations (2012-2020), Green Finance Taskforce (2018), BEIS Green Finance Strategy (2019), Defra Enabling a Natural Capital Approach (2020) and The Economics of Biodiversity: The Dasgupta Review (2021) which all seek to embed these into the way we talk and think about the economy. The way things are accounted for and valued is changing.

Achieving Net Zero

Progress made to date in reducing GHG emissions is now regarded as not sufficient to have a realistic chance of limiting average global temperature rise to less than 2°C, as agreed at COP21 in Paris, 2015. So, the revised ambition is net zero emissions by 2050.

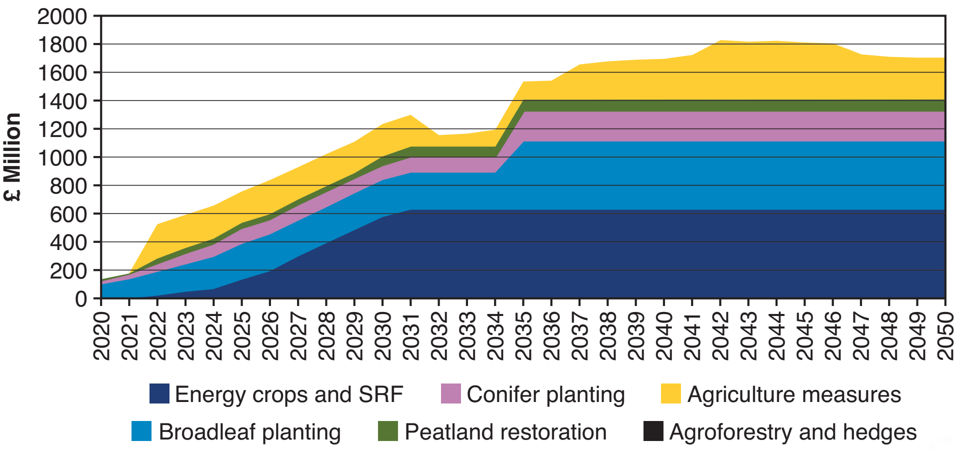
Lots of very clever people have had large inputs into the research and reporting – so although not perfect, the data and policy are well thought through. There is no doubt that the UK Government is highly committed to following through on many policies to transition rapidly to an economy that is not dependant on fossil fuels.

According to the Advisory Group on Finance (AGF) 2020 report for the CCC, *The Road to Net Zero Finance*; although overall, investments of up to £50 billion/year by 2030-2035 are estimated to be required, cost savings are also predicted to increase to largely off-set this investment and more by 2050 and further into the future. The investment is anticipated to be partly from government and partly from private sources. The cost savings are expected to come from tangible things like not having to produce and transport fossil fuels, a fall in prices of renewable power and technology v increasing prices for non-renewables – driven by a combination of political policy, market forces and changes in social acceptability; along with less tangible things, such as better health and wellbeing from easier access to semi-natural environments, such as woods (on land that was previously farmed!).

A similar but even more optimistic conclusion is reached by the Cambridge Econometrics 2020 report for the CCC, *The Economic Impact of The Sixth Carbon Budget*, using the E3ME economic model. This predicts an increase in UK GDP of 2-3%, supporting the creation of around 300,000 new jobs by 2050.

Focusing down to the agricultural and land use sector within the CCC 2020 report, projected net costs are estimated to rise from around £0.2 billion/year

Figure 1. Net investment costs in the balanced Net Zero Pathway



Source: CCC analysis

currently to around £1.8 billion/year by the 2040s (Figure 1).

It is estimated that social benefits such as recreational use of woodlands, reductions in flood risk and better health from having cleaner air and a more pleasant living environment will off-set some of these costs from around 2035. These types of benefit are estimated to be worth around £0.6 billion by 2050. This would reduce projected net costs to around £1 billion by 2050.

Both the CCC and the NFU's net zero policy projections conclude that to achieve net zero, changes in agricultural production methods will also need to be linked to land use change (Figures 2 and 3) hence the large shares for such investments in Figure 1. 'The Balanced Pathway' on Figure 2 is when somethings go well and others not so well. 'Headwinds' is when things do not go according to plan, and 'Tailwinds' are when things go better than expected. Figure 3 shows the reliance being placed on peatland and woodland being managed for carbon capture and storage. All the graphical figures taken from *CCC The Sixth Carbon Budget, Dec 2020, the UK's path to Net Zero: Agriculture and land use, land use change and forestry*.

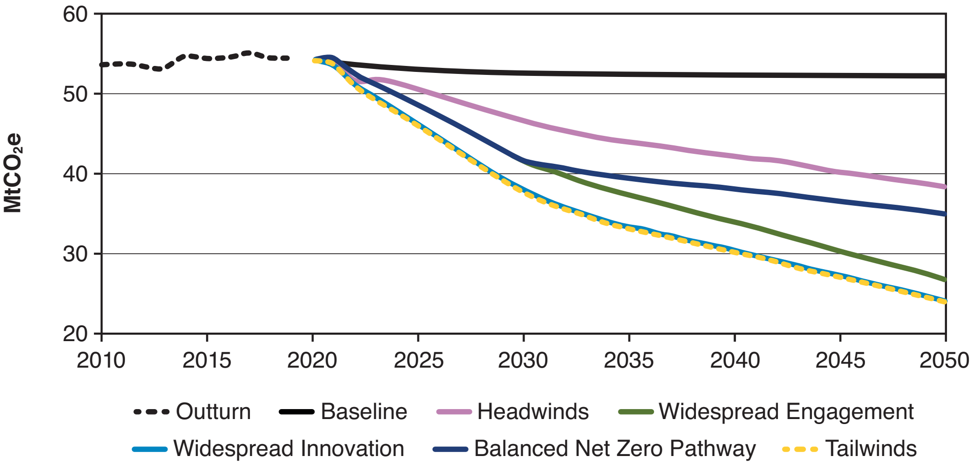
Impacts on individual businesses

All this high-level stuff is all very well, but how might this impact individual farm businesses?

From an individual farm business point of view, it is a question of keeping an open mind and being prepared to adapt in a timely manner, most likely linked to the availability of grant funds or other incentives. Many reading this may have already bought themselves new technical gadgets from the various capital grant schemes offered so far or be involved with changes to agricultural support projects such as the Sustainable Farming Incentive (SFI).

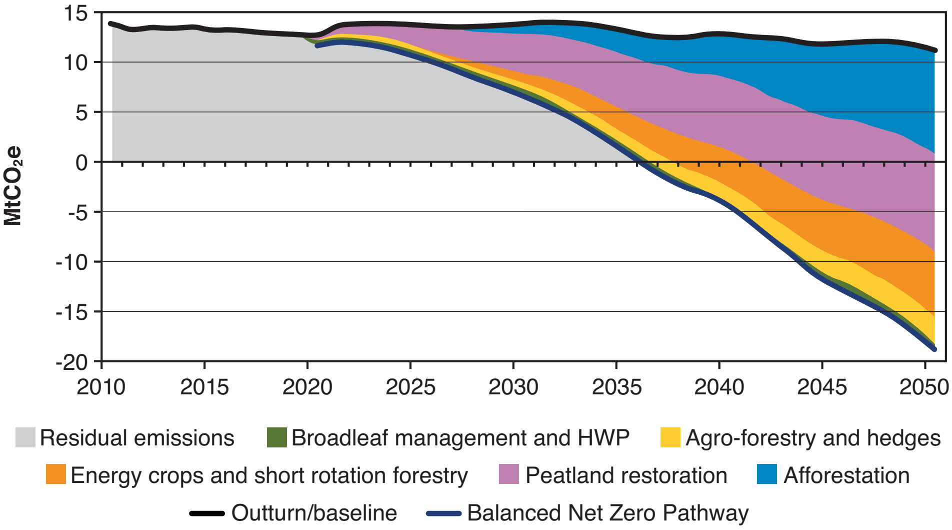
The fact that the key period for investment is predicted to be in the next 10-15 years is important. There are already new incentive schemes starting up, such as projects linked to the £640 million Nature for Climate Fund and other 'green priority measures' announced in the March 2020 budget, along with projects

Figure 2. Emissions pathways for the agriculture sector



Source: BEIS (2020) Provisional UK greenhouse gas emissions national statistic 2019; SRUC (2020); CCC analysis

Figure 3. Sources of abatement in the balanced Net Zero Pathway for the LULUCF sector



Source: BEIS (2020) Provisional UK greenhouse gas emissions national statistic 2019; SRUC (2020); Centre for Ecology and Hydrology; CCC analysis

linked to Defra's November 2020 Agricultural Transition Plan such as the Farming Investment Fund from 2022, and the Sustainable Farming Incentive scheme (SFI) as the first step towards the much talked about Environmental Land Management (ELM) scheme.

Machinery that is powered by clean fuels, such as hydrogen or renewable electricity, is quite likely to become 'the norm', maybe as soon as in 15-20 years time. Businesses should be considering this and adapting machinery replacement plans so that as far as possible, capital spending is balanced between buying replacements that use current technology and new choices as they become available, either via purchase or leasing.

Some businesses will already be doing some form of carbon footprint calculations. It will be a good idea to look at expanding this type of activity and seek to establish a carbon accounting system alongside or within the traditional farm accounts. This will help identify the key areas of GHG emission and sequestration and their potential financial value, which will help businesses be better prepared to pick and choose the most appropriate incentive options as they appear.

It is already obvious that many younger family members, and employees are of this mindset and are prepared to adapt enterprises and land use in a 'towards Net Zero' way.

Yes, whatever individuals or the UK do will not change the world; but aspiring to live in a truly more sustainable way and demonstrating how is no bad thing. The future is bright, it is not orange – it is green!. . . so long as the rest of world is very close behind us!

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Counting carbon on NIAB's trial grounds

With Government targets of the UK reaching net zero, or becoming carbon neutral, by 2050, and the NFU setting its net zero target for a decade earlier, NIAB needs to start acting now. But before we can act to cut our emissions, we need to work out just how much carbon our farming operations are emitting. NIAB's Mark Leaman and Keith Truett have been doing just that for our Cambridge farm. Here they talk about what they have done and how they worked it out alongside some advice for members looking to start the same process.

The farm

The Cambridge arable farming operation is around 600 ha but at the time of doing the assessment it was based on 400 ha, but what makes it unique from other similar-sized farms are the trial plots. To accommodate our wide range of crop trials, we set a rotation that is very different to most commercial farms – there is little first wheat or oilseed rape. However, when we assessed our carbon emissions, we tried using a standard farm blueprint to make it more comparable but included our trials work.

We investigated a few of the online calculators and with little obvious difference between them went with the Cool Farm Tool (https://coolfarmtool.org), deciding that as long as we continued to use it, and not swap to another, we could judge NIAB's performance against this base level.

The tool was run first as a fairly standard farm and indicated a carbon footprint of roughly 500 t CO_2e/year. The extra vehicles, machinery and staff required for our trials operations were then added in and the carbon footprint went up to 640 t CO_2e/year – an extra 140 t CO_2e/year onto our carbon emissions.

The next step

So, we know what NIAB is producing, but what can be done to reduce our footprint and how do we rank against other farms? Our carbon footprint of 500 t CO_2e/year, over a 400 ha farm, means that we are producing roughly 1.25 t/ha of carbon. Benchmarking against other farms would help us work out how NIAB can move forward.

The trials work is adding a further 0.75 t/ha, but we also need to determine if our variety and agronomy research into better crop practices and management is actually generating a saving of more than 0.75 t/ha. The calculation may not be sufficiently covering the carbon we are already offsetting, i.e. that absorbed by growing crops, margins and other environmental additions, alongside the production and agronomy advancements being made by these trials, which has considerable value. It also fails to build in services such as electricity supplier. So there is room for improvement, but it is a good start.

Reducing emissions

Whichever variable was inputted the amount of carbon NIAB produces is driven by the amount of nitrogen fertiliser we are using on farm. If the amount of nitrogen used is halved, the carbon footprint is halved – it is that simple! This would suggest that we need to look at ways of reducing this. For example, at three of our trial sites we are under-sowing combinable crops with clover. The aim is to show whether a 'living mulch' at the bottom of the crop, that reduces weed competition and provides nitrogen, is a realistic option and cuts our carbon production. Options like using electric vehicles would go someway to reducing our footprint, but reducing the amount of nitrogen fertiliser we apply will have the greatest impact.

Future advice

NIAB has just begun its carbon footprint checking journey, including looking at the whole NIAB business, but it is making us think about it across our farm operations and raising a lot of questions including:

- Improving our benchmarking;
- Reducing or offsetting our carbon footprint;
- Understanding the impact of our wide and varying business and farm operations;
- What is the offset from our trees, hedges and grass field corners/margins.

The take home message for farmers looking to check their farm business carbon footprint is find a tool that is easy to use and understand that it not only allows you to monitor your own carbon, but also your own natural capital or offsetting. Set your own benchmark as a reference point and carry on using the chosen system to better see the value of any improvements made. Then take a look at other farms and business for ideas and advice on how they are reducing their carbon footprint.

The bottom line is if you are carbon efficient, your farm is more efficient.

Vital for those involved in pesticide use decisions and applications.

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