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Wildflowers enhance beneficial insects in crops, supporting pest control and pollination

In this Issue

Mario Caccamo, Chief Executive, NIAB

Opening the door to new breeding technologies

Prospects for the future of plant genetic research and innovation in England received a boost recently when, following a public consultation earlier in the year, Defra announced plans to free up field trial research on gene edited plants, and to bring forward legislation to take most gene edited crops out of the scope of GMO controls.

It was especially fitting that the Government's announcement took place on the last day of Professor Tina Barsby's almost 14-year tenure as CEO of NIAB, since Tina has been at the forefront of efforts to persuade Ministers to use their post-Brexit powers to move away from the EU's restrictive regulatory approach. Last year, for example, Tina brought together a group of leading scientists to urge the Government to support an amendment to the Agriculture Bill designed to bring our rules into line with other countries around the world that do not regulate simple gene edited plants or animals as GMOs.

This call from the scientific community was supported by cross-party politicians, farmers, plant breeders, food processors and other agri-food organisations, and during the passage of the Agriculture Bill last summer, the Government agreed to consult on plans to take simple gene edited products out of the scope of GMO regulation.

The proposed approach would allow a revised definition of GMO, consistent with the Cartagena Protocol, that would align England with the regulatory position of other countries such as Canada, Japan, Argentina and Australia. According to the Cartagena Protocol, the use of a new biotechnology tool only merits the implementation of a more restrictive oversight if it results in a novel combination of genetic material that could not occur naturally or through the use of traditional breeding.

Experience from the countries that have embraced gene editing is that, compared to GMOs, the products generated by these technologies follow a much faster rate from laboratory to market, involve a greater diversity of crops and traits, and include a broader range of developers, from public sector research institutes to SMEs and multinationals.

As a first step, Defra has announced that it will use existing powers within the Environmental Protection Act (1990) to reduce the regulatory burdens on plant scientists and breeders seeking to carry out field trial research for gene edited crops in England. The next step will be to bring forward new primary legislation to change the legal definition of GMO and so enable the development and commercialisation of gene edited crops through the existing, proven system of variety registration and seed marketing controls.

We very much hope that a new Bill to do this will be part of the Government's next legislative programme.

I am taking on the role of CEO of NIAB at an unprecedented time: food production must undergo a transformation in which we need to grow enough nutritious crops for an increasing population while reducing use of synthetic fertilisers and pesticides, increasing the land available for green infrastructure and biodiversity, achieving net-zero greenhouse gas emissions from agriculture, and adapting to climate change. All these goals must be achieved without offshoring the associated climate and environmental impacts to other territories.

It is right for the UK to take the lead in addressing what is one of the grand challenges facing humanity. Evidence-based decisions will need to play a central role to ensure the necessary transformation supports a viable and innovative farming sector.

While the climate pact secured at COP26 may have been comprehensive in terms of international commitment, it has barely done enough to keep the 1.5°C target alive, and one can only wonder whether we are doing enough to address the challenge in hand. To paraphrase Henry Dimbleby in the National Food Strategy, our food systems have taken their current forms over many years, and it will take time and effort to reshape them to protect both our health and our planet.

At NIAB we have developed a scientific strategy that puts these challenges at the centre of what we do, and relies on accessing all the tools at our disposal. That is why we welcome this open door to accelerate the adoption of new breeding technologies.

I joined NIAB in 2015 from The Genome Analysis Centre (TGAC, renamed Earlham Institute) in Norwich. At TGAC, initially as Head of Bioinformatics and later as Institute Director, I helped lead the UK contribution to the international consortium that released the first high-quality bread wheat genome dataset in 2013.

Conquering the wheat genome, an inter-specific hybrid that brings together the genomes of three grass species, was for many years considered a task too complex to achieve. It was a milestone that has facilitated the development of molecular tools to unveil the genetic mechanisms underlying key traits, providing the key to eventually support the delivery of gene editing. Following that achievement, it was a natural step for me to focus my career on deploying some of these new tools in practice.

NIAB leads the way in the translation of science into practice to benefit growers and supply chains in the UK arable and horticulture sectors. We also have the scientific breadth and track record to respond rapidly to the challenges imposed by climate change. Our core values are shaped by our commitment to independence and integrity. It is my aim to cement NIAB's leadership role as the 'go-to' place for agriculture and horticulture innovation.

There are exciting times ahead!

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New cereal varieties for 2022

With the 2022/23 AHDB Recommended Lists (RL) released in early December 2021 it is time to start assessing the new additions and weighing up what, if anything, they can add to our farms over the next few years. After a difficult couple of seasons, as well as changing chemistry, the issues you want to address may well have changed and these new varieties may have different questions to answer than their predecessors. With new varieties across a wide range of crops this article will aim to sum up what will be on offer going forward.

Wheat

A massive ten varieties were added to the Winter Wheat Recommended List, spread across all end uses with the exception of Group 1, where the choice will remain unchanged. Group 2 sees two varieties added with **KWS Palladium** (KWS) being the highest yielding of the pair, offering a treated yield just 1% below that of KWS Extase. It has delivered a good protein content when grown for milling and a high Hagberg Falling Number which it has held onto at sites that experienced a wet harvest. It has excellent resistance to yellow rust and a good septoria rating, which all adds up to a safe, low risk variety. **Mayflower** (Elsoms) has a treated yield 4% below that of KWS Extase and is slightly weaker strawed. It has a good set of quality characteristics and excellent yellow rust resistance combined with very good septoria resistance, again leading to a relatively low risk variety. The millers are positive about both these new additions and, for them, take up of these

two varieties will lessen the risk of their reliance on KWS Extase. Of course, for any new quality variety there is still much to be learnt as larger tonnages make their way through mills and bakeries.

Group 3 sees three varieties added, increasing the choice even further. **KWS Guium** (KWS) is now the highest yielding Group 3 variety. It is a late maturing variety with excellent resistance to yellow rust as well as orange wheat blossom midge (OWBM) resistance but it is very susceptible to brown rust and has below average septoria resistance. **KWS Brium** (KWS) is 2% lower yielding, is slightly earlier to mature, and has slightly improved disease resistance but no OWBM resistance. **RGT Rashid** (RAGT) has a similar yield but again is later maturing. It has excellent straw strength and a much better disease profile with much improved brown rust and septoria resistance as well as OWBM resistance.

RGT Bairstow (RAGT) joins the soft feed section on a high yield, level with both Skyscraper and RGT Saki. It has similar straw strength and its maturity falls between the two. It has relatively good yellow rust resistance and a moderate to good septoria rating as well as OWBM resistance. All in all it looks like it could be useful. **RGT Stokes** (RAGT) is just 1% lower yielding and boasts slightly better septoria resistance. However it is naturally weak strawed and although it does respond well to growth regulators this does represent a risk, it also does not offer OWBM resistance. Both varieties are usefully rated as 'good' for distilling.

The hard feed sector is possibly the most interesting with three new additions. **Champion** (DSV) comes on with a top yield, 3% ahead of previous top yielder SY Insitor. It also offers a good untreated yield and an excellent range of disease resistance with good resistance to yellow rust, and very good resistance to septoria, as well as OWBM resistance. Its straw will need some management and the moderate specific weight must not be forgotten but, grown in the right place, it has a lot to offer. **KWS Dawsum** (KWS) is just 2% lower yielding and has a slightly higher untreated yield with excellent yellow rust resistance and moderate to good septoria resistance. Its excellent specific weight will be attractive to many, alongside a flexibility in drill timing. The only downside is the lack of OWBM resistance. As a pair these two varieties are a strong offering and would work well together to maintain high yields whilst managing risk.

Finally, we have **LG Typhoon** (Limagrain) which offers good yield potential combined with good disease resistance, especially for yellow rust and septoria. It looks suitable for early drilling and as a second wheat, and will offer another option to manage risk without giving yield away.

The spring wheat list has seen greater changes this year than we have seen for some time, with two new Group 1 varieties added, plus a high yielding feed variety. **KWS Ladum** (KWS) is the highest yielding of the new Group 1s with a treated yield 8% higher than that of Mulika. It has shown good grain quality as well as a good disease resistance spectrum. **Nissaba** (Blackman Agriculture) is just 1% higher yielding than Mulika and slightly later to mature, but also offers OWBM resistance. Nissaba has been bred for sowing from October onwards and yields are more competitive from these earlier drillings. **KWS Fixum** (KWS) is the new feed variety, with a huge yield, 3% higher than the previous highest yielder. It is a later maturing variety but has a good disease resistance spectrum and a good specific weight. All three varieties warrant consideration for the specific benefits they can offer.

Barley

The Winter Barley Recommended List sees two new two-row feed varieties as well as two new six-rows. **Lightning** (Elsoms Ackermann) is a two-row feed offering a high treated and untreated yield combined with good disease resistance, although its straw will require good management. The other two-row feed variety is **LG Dazzle** (Limagrain), which also offers high yields, both treated and untreated, good disease resistance and slightly stiffer straw.

SY Canyon (Syngenta) is a six-row hybrid offering a similar treated yield to SY Kingsbarn but with an improved untreated yield and disease spectrum as well as a high specific weight. **KWS Feeris** (KWS) is a conventional six-row which offers genetic tolerance to BYDV. It has a sound agronomic profile with yields on par with the two-row varieties and will be particularly useful for growers in higher risk aphid zones. Another useful genetic tool available for growers to use to their advantage and minimise risk.

The Spring Barley RL sees three new varieties with brewing potential added. **Jensen** (Limagrain) is a high yielding variety with good disease resistance but a low specific weight. **SY Bronte** (Syngenta) and **Spinner** (Agrii) both have treated yields just 2% behind and offer better specific weights. **Malvern** (Agrovista) is a feed variety recommended for the west. Limited data however suggests it is very susceptible to *Rhynchosporium*.

CB Score (ADM) is a described variety bred by Carlsberg. It is a specialist Null-Lox malting variety which offers the end user improved beer quality. It produces a high yield and has a reasonable agronomic package.

Oats

No new winter oats were added to the Recommended List this year leaving the choice for 2022 sowing unchanged.

Two new spring oats grace that List. **Merlin** (Cope Seeds) is a very high yielding variety that is early to mature. It offers good grain quality and excellent resistance to mildew although it is susceptible to crown rust. **Lion** (Saaten Union) is a lower yielding variety with very good grain quality although it is very susceptible to mildew. Both varieties are currently being assessed by millers. Finally we have **Lennon** (Senova) naked oat, which has returned to the 'described' section of the list. It has a competitive yield and has proved a popular choice.

In summary, we have a wide selection of new varieties to familiarise ourselves with. The value of some is immediately obvious while others are likely to struggle to achieve market share. For growers, identifying the characteristics useful to your situation and employing them to work for you on farm should be a priority.

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New oilseed varieties

It is another exciting year for new varieties of winter and spring oilseed rape appearing on the AHDB 2022/23 Recommended (RL) and Descriptive Lists (DL) with 11 new varieties appearing on the full List plus one described variety and three new varieties on the spring List.

The 2020/21 season was easier for oilseed rape trials operators. In recent years, many growers have become more used to drilling earlier to combat the problems of establishment and cabbage stem flea beetle (CSFB). With oilseed rape variety trials, the seed is rarely available before the last third of August so we can face problems getting even establishment. In the late summer of 2020, we were blessed with a few showers and the adult CSFB numbers were much lower than the previous year. This has meant that there was a good set of 18 winter OSR Recommended List trials, spread geographically across the country. For those who have not seen RL trials – they are large – and a lot of effort is put into measuring, assessing and counting all the variables that help make decisions on which varieties succeed in getting onto the List. The information also helps farmers, growers and agronomists understand how best the individual varieties might fit into our own farming systems.

Winter oilseed rape

PT303 (Corteva) has come straight to joint top of the RL with a UK-wide recommendation of 107% of the controls (UK controls averaged 5.1 t/ha). This hybrid variety has performed well in both national ADHB trials as well as NIAB's own trials and has been generally stable across the regions, joint top in the East/West region and only one point from the top in the North. It is a fairly tall variety but has good stem stiffness and very good resistance to lodging (this trait has limited data). It flowers fairly late and but does not mature very late. The breeder claims a level of sclerotinia tolerance based on genetics and anything that helps reduce spraying when the crop is in full flower is a good benefit. It has good resistance to both light leaf spot and stem canker, is resistant to turnip yellows virus (TuYV) and has an excellent oil content of 46% and very low glucosinolates.

LG Auckland (Limagrain) has entered the List, joint top with PT303. This hybrid also scores an impressive 107% for the UK and again is consistent across the regions, and was second in NIAB variety trials this year. Shorter than PT303 but still a little on the tall side with good stem stiffness and very good resistance to lodging (limited data for this trait). LG Auckland is early flowering and relatively early to mature, it has good resistance to both light leaf spot and stem canker and is resistant to TuYV as well as resistance to pod shatter and a high oil content of 45.4%

The conventional variety **Annika** (Limagrain) almost mirrors Acacia yield wise, both East/West and North and is in front of Aspire in both. It is good to have another conventional variety join the List and this one also has the benefit of TuYV resistance. It is a medium height variety with good stem stiffness and very good resistance to lodging (limited data for this trait) and a good oil content at 45.4%. It has an average flowering time but is a little late to mature. It has good resistance to light leaf spot and slightly less resistance to stem canker.

The hybrid **Matrix CL** (DSV) is a

herbicide tolerant variety with a UK-wide recommendation and an impressive 99% for gross output showing how fast the breeders have worked to get these varieties up to the yield levels of the non Clearfield® (CL) varieties. The herbicide tolerant trait is extremely useful for those situations where it is needed. Matrix CL has performed slightly better in the East/West than the North and has a very good oil content of 45.8%. It is a relatively tall variety with good stem stiffness and very good resistance to lodging (limited data for this trait), and is middle of the road for flowering and maturity timings. It has average resistance to light leaf spot but very good resistance to stem canker and has both pod shatter and TuYV resistance.

LG Constructor CL (Limagrain) is another herbicide tolerant hybrid variety that has performed very well to get onto the List with consistent yields in the East/West and North. With a gross output of 96%, it is another variety that will help those with weed or volunteer issues. It is of average height with good stem stiffness and very good resistance to lodging (limited data for this trait) with a good oil content of 45.2%. Neither early or late to flower and mature, LG Constructor CL, like Matrix CL has both pod shatter and TuYV resistance and average levels of resistance to light leaf spot and stem canker.

New varieties for the East/West region

LG Adonis (Limagrain) has joined for the East/West with an excellent 108% gross output figure for this region. It is of average height with good stem stiffness and very good resistance to lodging (limited data for this trait). It is fairly early flowering but can be a little late to mature. It has good light leaf spot resistance and very good stem canker resistance as well as TuYV resistance, an excellent oil content of 46.4% and low glucosinolates.

Dart (DSV) is a hybrid with an impressive gross output score for this region of 106%. It is of average height with excellent stem stiffness and very good resistance to lodging (limited data for this trait). It flowers a little early but has a score of 5 for maturity

showing that it is slightly later. It has good resistance to both light leaf spot and stem canker and is resistant to TuYV with a very good oil content of 45.5% and low glucosinolates.

Tennyson (Elsoms) is a hybrid which has an excellent score of 9 for stem canker resistance which the breeder claims is not solely based on the Rlm7 gene and therefore this resistance is robust. Tennyson also has good light leaf spot control. It has a good gross output score of 103% for the region, a good oil content (45.2%) and has TuYV resistance. It is of average height with good stem stiffness and very good resistance to lodging (limited data for this trait). The variety has an average score for earliness of flowering but does not mature early.

Flemming (LSPB) is another hybrid with a very good gross output score of 104% for the region. It has good light leaf spot resistance and very good stem canker resistance which the breeder claims is based on RlmS (+ quantitative resistance), rather than just Rlm7 making the resistance more reliable. Although a slightly taller variety, Flemming does have excellent stem stiffness and very good resistance to lodging (limited data for this trait). It has a 6 for earliness of flowering meaning that it is not early but does mature quite late, with a moderate oil content of 44.8% and TuYV resistance.

Amarone (Limagrain) is a conventional variety that has joined the List, recommended for the North, scoring a very good 105% for gross output for the East/West. It is quite short and very stiff with very good resistance to lodging (limited data for this trait). It flowers fairly early but does not mature very quickly. It has average stem canker but good light leaf spot resistance, TuYV resistance and a good oil content of 45.1%

Varieties with special traits

Crossfit (DSV) has joined the List for the East/West region and is believed to be resistant to common forms of clubroot. It also has excellent resistance to stem canker but is a little susceptible to light leaf spot. It has both TuYV and pod shatter resistance, an excellent oil content of 46.4% and a solid gross output score of 99% for the East/West. It is of average height with good stem stiffness and very good resistance to lodging (limited data for this trait), it flowers a little early but does not mature early. Resistance to clubroot is an excellent trait that is very useful where required, but we do need to make sure that these varieties are not over-used to protect the resistance.

PX138 (Corteva) is a described semi-dwarf variety for the East/West region. It is very short and stiff, slightly late to flower, but has average maturity times. It has average stem canker and light leaf spot resistance, TuYV resistance and a good oil content of 45.4%.

Spring oilseed rape

There are three new varieties on the AHDB 2022 Spring Oilseed Rape Descriptive List. This crop does provide a good break option with a decent margin and helps with difficult weed control issues. Just note that all the DL data is from a limited number of trials and should therefore be treated cautiously.

Lavina (DSV) arrives on the List with a good yield performance of 104%. It has a short stem and does flower early but has a moderate maturity date similar to the other higher yielding varieties. The oil content is 44.4%. **Fergus** (Senova) is a conventional slightly lower yielding variety with a slightly higher oil content at 45.2%. It has a short stem, flowers early but like many of the varieties on the List, does mature a little late. **Caramino CL** (DSV) is a hybrid herbicide tolerant variety. It has a moderate yield at 92% but a good oil content at 45%.

Spring linseed

There is only one new spring linseed variety this year on the AHDB 2022 Descriptive List. **Sarah** (DSV) has an average yield and oil content and flowers and matures late.

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New pea and bean varieties on the PGRO Descriptive List 2022

In 2021, the Processors and Growers Research Organisation (PGRO) changed to a Descriptive List format, moving away from the long-standing Recommended List system. This has provided a more flexible and adaptable approach. Varieties coming through from National List can be viewed in terms of consistency of performance, helping growers to make informed decisions when it comes to making decisions on seed for the next season.

Growers are now getting used to the change of terms to align the UK with the international recognition of blue and white peas; blue now being green peas and white now being yellow peas. Within the blue category, small and large will be combined together, eliminating any confusion as in the past the division has been a little blurred.

The new 2022 PGRO Descriptive Lists feature two new spring peas but no new spring bean varieties.

Combining peas

Carrington (LSPB) joins the List as the highest yielding variety at 117%. This green pea is a tall variety with good standing ability which is medium early maturing. It has good resistance to downy mildew and is also resistant to pea wilt (Race 1). The pea is small to medium size with below average protein.

Rivoli (Senova) is a yellow pea with a yield of 103%. The plants are moderately tall with good standing ability and medium early maturity. It has good resistance to downy mildew (8) with the highest resistance in this group but is susceptible to pea wilt (Race 1). It has a medium grain size with an average protein content.

Elsewhere, **Kameleon** (Senova) and **Orchestra** (LSPB) maintain a very high yield potential with 115% and 111% respectively. Both have now been on the list for five years during which Kameleon has been consistently high yielding in each year and Orchestra four out of five years.

There are now a number of varieties on the List with good downy mildew resistance which is great news for growers; **Bluetime**, **Mikka**, **Greenway**, **Kactus**, **Blueman** and **LG Aviator** all have a resistance score of 8. Maple peas **Mantara** and **Rose** came back into the trials matrix in 2021 and both varieties also have a downy mildew resistance score of 8. Resistance to powdery mildew, a new trait considered under the disease resistance category for 2021, has been an increasing problem, both in trials and for growers, with a challenging 2020 season. In the new List, breeders' information suggests that Blueman and LG Aviator are highly resistant as is **Greenwood**, although this variety is more susceptible to downy mildew. **Manager** (KWS) has moderate resistance to powdery mildew and still has a good level of resistance to downy mildew.

Spring beans

There are no new spring beans added to the List this year. **Lynx** now tops the list at 106% followed closely by **Ghengis** and **Stella** at 105% and **Capri** and **Macho** at 103%.

Lynx shows good resistance to downy mildew with a score of 7 which is slightly below that of **Maris Bead** which has been around since 1964.

Winter beans

Pantini (LSPB) has been added to the 2022 Descriptive List. It has a moderate yield of 93% but is short strawed and fairly early maturing. **Vespa** currently tops the list with 108% followed by **Vincent** at 106%.

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The role of mixed species forage in climate change mitigation and resilience

In a recent NIAB and SRUC study of the opportunities and barriers to forages for UK livestock productivity and sustainability, a wide range of currently underused forage crops and major challenges to forage production were reviewed. Some of the key themes that came through our investigations were the need to improve nitrogen use efficiency in grass and forage cropping, along with a growing interest in the use and value of mixed species swards.

Weather

Some of the greatest challenges to forage production identified were the prolonged wet and dry weather spells that have been experienced more frequently in recent years. The Met Office projects that UK winters will continue to become warmer and wetter with hotter, drier summers. Summer rainfall will be less frequent but more intense, with more droughts expected. Prolonged wet weather leads to waterlogged soils which restricts root function, whilst hot, dry summers increase drought and temperature stress and stunt or stop plant growth. Baked soils have slower water infiltration rates and increased surface run off. Increased temperatures and increased CO_2 content in the atmosphere mean crops will need to adapt to the new climatic conditions with greater tolerance to stressful conditions needed.

In prolonged wet weather, permanent pasture with well-developed sward bases cope best with carrying livestock. Shorter term, young leys will benefit from keeping stock off, where possible, to avoid longer term damage to soil structure and ongoing sward productivity. Prolonged dry weather will require resting grazing as much as possible, grazing swards less hard before moving on and rotating around fields or grazing blocks within larger fields. Leaving higher residues will aid better sward survival and recovery.

Whilst perennial ryegrass continues to be the most productive, relatively hardy and widespread grassland species, other species may have more of a role in the drive for climate resilience. Cocksfoot is a grass species that can become dormant in dry summers, especially useful for plant survival under severe drought on land where this is a particular risk. Tall fescue has high water-use efficiency and a deeper, more extensive root system for endurance to summer drought with good spring yields in average rainfall levels.

Swards including deep rooting legumes such as sainfoin, lucerne and red clover, rigorous rooting permanent pasture grasses such as meadow fescue, cocksfoot and smooth-stalked meadow grass as well as ley grass species timothy, Festuloliums and herbs chicory and ribwort plantain (ribgrass) will be most resilient to prolonged dry weather as well as providing the nutritional benefits of legumes, including higher mineral levels whilst also reducing worm burdens.

Legumes

Ruminant livestock production systems face the challenge of producing more meat and milk to meet increasing world demands whilst reducing use of inputs.

On the continent, forage crops are often grown in simple or complex mixtures, annual legumes with cereals and perennial legumes with grasses. Grass–legume mixtures can produce 40% higher yields than monocultures of each species, depending on the species combination and usually provide improved nutrition than grass alone.

Using forage legumes that are able to fix their own nitrogen can reduce overall GHG emissions due to decreased fertiliser use (and the emissions associated with its production).

Each kg of ammonium nitrate produced by the Haber–Bosch process consumes 58 MJ of energy and emits 86 kg CO_2 equivalents in the form of nitrous oxide. The IPCC suggest that for every 100 kg of N-fertiliser added to the soil, 10 kg of N is emitted as nitrous oxide (N_2O) which is 300 times more potent than CO_2.

Legumes offer great potential for sustainable intensification at many different stages with the soil-plant-animal-atmosphere system, most effective at 30-50% inclusion in mixed swards. Voluntary intakes of forage legumes are 10-15% greater than that of grasses of similar digestibility.

As well as the reduced use of mineral

White clover

Lucerne

Red clover

nitrogen fertiliser, other benefits of including forage legumes in swards and mixtures include lower emissions of carbon dioxide, nitrous oxide and methane both from the farm as a whole and per unit of milk or meat production, lower production costs, reducing bought-in protein feeds, increased forage production, increased nitrogen use efficiency, higher forage nutritional value, improved feed conversion efficiency and improved livestock health and performance.

The inclusion of legumes into short-term grass leys could increase the sequestration of carbon into the soil organic matter. Legumes can also enhance biodiversity and support soil organic carbon by reducing decomposition by producing decay resistant substrates.

In addition, legumes may benefit and adapt to higher atmospheric CO_2 concentrations and to changing climatic conditions.

Condensed tannins

Methane production decreases with inclusion of the condensed tannin forages such as the legumes sainfoin and birdsfoot trefoil and the herb chicory in ruminant diets. Condensed tannin activity has been found to reduce nitrogen excretion by protecting dietary protein from degradation in the rumen for more efficient digestion and absorption further down the digestive tract. The tannins also shift nitrogen excretion from urine to faeces, reducing the rate of volatilisation and leaching. Reducing methane production will also improve the efficiency of productive ruminants and decrease their carbon footprint.

Sainfoin produces high quality forage at reasonably high yields in alkaline and drought-prone soils. Inclusion of 20% sainfoin within a lucerne stand has been found to prevent bloat and improve digestibility in sheep. Increased digestibility has also been found where sainfoin is included in grass mixtures including cocksfoot.

Sainfoin can also be particularly beneficial via its anthelmintic effect when fed before and after lambing when immunity of the mother and newborn is low. The condensed tannins in sainfoin can also stimulate the immune response to produce more T-cells, particularly important as parasites are inherently immune-suppressive. Condensed tannins are also effective against flystrike in sheep, as they produce drier faeces, preventing flies from laying their eggs.

Further development

Breeding focus on forage crops across Europe is on increasing genetic diversity, crossing in species to increase variation for key traits that aid adaptability in changing climatic conditions such as the resistance to fungal diseases where temperature and rainfall shifts increase their range and viability.

Increased, more precise, use of organic fertiliser and decreasing losses and leaching of applied nutrients is essential to increase nutrient use efficiency in grassland systems. Plant communities with higher species diversity are expected to use resources more efficiently making mixed cropping a promising strategy for sustainable intensification. Further work is needed to assess species compatibility within a wide range of mixtures.

Developing species and breeding varieties more tolerant to climate stresses are expected to play a crucial role in climate change adaptation and mitigation strategies. The increased role of legumes in ruminant systems will support more sustainable and competitive ruminant production systems and along with grass leys in arable rotations, their importance and value are expected to become more widely embraced in the future.

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Wildflowers enhance beneficial insects in crops, supporting pest control and pollination

We all know that wildflowers are a good resource for pollinating insects, but do we fully understand the interaction between wildflower areas, insect abundance and diversity, and crop production?

Celine Silva

Fruit crops are grown in increasingly intensive systems with the aim of achieving high quality and more productive yields. However, these production systems have a greater abundance of blossom per hectare which rely on insects to vector the pollen from flower to flower. Intensively grown crops also exacerbate the prevalence of pests, some of which can be controlled by naturally occurring predators and parasitoids. An additional, but equally important, aim is to avoid waste. Unmarketable fruit is a waste of input costs, and fruit left in cropping areas can be a source of further pests and diseases, which might further impact economic return.

The use of plant protection products is often associated with immediate prevention or reduction in pest and disease prevalence below an economic threshold. However, the fruit industry faces challenges associated with the declining availability of chemical products and a gradually rising accessibility of new, often physically or biologically acting products which take longer to take effect. Consequently, their use potentially increases the risk to the crop and requires much better scouting, forecasting, and even setting new economic thresholds.

Instead of repeatedly relying on short-term fixes, there is an opportunity to provision landscapes with a more resilient ecosystem – ecological intensification. This strategy ensures that in seasons when some pollinators or natural biological control agents are less abundant, other species step in, reducing the need to import managed pollinators or apply unnecessary plant protection products. This strategy, which can include conservation biocontrol, is also complementary to augmented releases of biologicals made in most fruit crops, e.g. predatory mites in strawberries and anthocorids in pear orchards.

Part of this approach can be the establishment of wildflower areas. Areas of land less productive for crops can be utilised, and in fruit crops, understories of alleyways between the fruit rows can be sown. With good monitoring and maintenance, wildflowers can be preserved with minimal intervention for the life of the crop.

Perennial wildflowers for perennial crops and semi-permanent tunnel structures make sense as floral areas can be a significant investment to set up. However, maintenance is much reduced after the first two years compared to preparing soil and resowing annual wildflowers or cover crops.

Researchers at NIAB EMR and collaborators (including the Universities of Reading, and Worcester, CEH, Avalon Produce Ltd, Worldwide Fruit Ltd, Syngenta and a host of European partners) have worked on a range of projects in recent years to understand the benefits and costs of sowing wildflower areas. In a BBSRC funded project, it was demonstrated that perennial wildflowers on the margins of fruit orchards increased the numbers of Andrenid – ground nesting bees, which are important pollinators of apple crops. In AHDB and Waitrose-funded research, perennial wildflowers sown in the alleyways of orchards increased the abundance of natural enemies in fruit trees, including spiders, lacewings, ladybirds etc., not only in outdoor-grown apple but also in polytunnel protected cherry orchards.

An Interreg and AHDB-funded literature review on the benefits of wildflowers to fruit crops is currently being drafted and already providing evidence that wildflower resources should not be more than 50-100 m, at most, from the cropping area they will service. This is important for long distance dispersing pollinators and natural enemies including bumblebees and hoverflies. For insects with a shorter dispersal ability, the floral resource needs to be much closer to the target crop, e.g. parasitoids of aphids and caterpillars often disperse only tens of meters at most. Hence, the most comprehensive benefit comes from integrating wildflower areas as part of the cropping area.

In the AHDB funded project, NIAB EMR researchers showed that wildflower alleyways in apple orchards reduced the number of fruits damaged by codling moth and, in some years, reduced the abundance of rosy apple aphid. Control of both these pests has had plant protection product approvals withdrawn in the last few years. Additionally, changes in natural enemy abundance in response to floral interventions takes at least two to three years from sowing.

The most important aspect of establishing perennial wildflower areas is ground preparation, including a stale seedbed to a fine tilth and ensuring pernicious weeds are not present. This preparation stage is time-intensive and can take months to get right, but without which efforts will be wasted. In addition, wildflower seeds are tiny and often wind dispersed in nature and need to be broadcast onto the surface of the soil followed by rolling and then a good helping of predictable rain – which is not too difficult in UK situations.

As part of an Interreg North Sea Region Programme, the BEESPOKE-NSR project is designing crop-specific perennial wildflower mixes and tools that growers and farmers can use to establish wildflowers near to a range of fruits, beans and oil seed rape. Other tools include how to monitor the progress of these interventions over time with, for example, crop pollinator surveys. The BEESPOKE-NSR project brings together a wide range of partners from policymakers, research institutes, advisory and end users from six different North Sea Region countries. Demonstration sites in the UK include NIAB EMR. Much of the downloadable information is available to growers on the BEESPOKE-NSR web page [https://northsearegion.eu/beespoke/] and the dedicated Facebook page [www.facebook.com/BeespokeNSR/], where 'how to' videos can be accessed.

Research linked to this project is also looking at changes in soil, including water infiltration from polytunnel runoff (Rivers Trust-funded). Additionally, the percentage grass to wildflower mix needed to maximise establishment is under investigation (Marks and Spencer-funded). Currently, most perennial wildflower mixes are a 20:80, forb: non-competitive grass ratio.

The aim of any sown floral mix should be to incorporate a mixture of flower types from legumes, which provision a range of wild species of bumblebees, to open umbellifer structured flowers which are easily accessible to parasitoids and hoverflies. The seed mix should be tailored to the soil type as species that do well on chalk grasslands do not fare so well on highly fertile soils. Mixes for flower types are available from seed specialists who are usually willing to tailor mixes to your preference. Ideally the seed mix should contain a sequential flowering throughout the season to enable continuity in food sources for beneficial insects of different species. Hence, mixes including early flowering types, such as red campion, to later and longer-lived species, such as hawkbit, are encouraged.

Celine Silva at NIAB EMR has spent the last few months taxonomically identifying species of thrips in wildflowers at the NIAB EMR, WET CENTRE and on growers wildflower areas. Certain species of thrips are important pests of strawberry causing significant stunting and bronzing of fruit, rendering it unmarketable. Although small numbers of adult pest thrips are found in some wildflowers it is not clear if they use this resource for breeding and, as always, there is more work to do.

Wildflower areas are not just an important source of food in the form of nectar and pollen, but they attract a wide range of herbivorous insects that natural enemies, including predators and parasitoids, can build up on early in the spring to then spill over into crops. They also provide structures for spiders to spin webs and ground beetles to shelter. Although the final cut of wildflower areas tends to be in the autumn or just after harvest, they also provide an area for a range of natural enemies to overwinter ensuring an early start to local natural enemy build-up the following year.

In short, perennial wildflower areas should be encouraged on farms looking to deliver sustainable crop yields, crop protection, and improved farmland biodiversity. Although we have begun to understand some of the benefits that these resources bring to a crop and the wider landscape, more work is needed on the interaction of these resources with the crop. For example, it is not determined whether wildflowers act as a sink, drawing pests away from crops, or a source where, over time, pest numbers can build up to become a future problem.

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The challenge of combating climate change – plant by plant

Following the 26th UN Climate Change Conference of the Parties (COP26) that took place in Glasgow in November 2021, it is obvious that fresh, long-term thinking in agricultural scientific research will be needed to help reduce carbon emissions in the food system, increase biodiversity and ensure the crops we grow are resilient to a warming world.

Our agricultural system provides affordable food for many and is underpinned by scientific progress in genetics, agronomy, and mechanisation with skills and techniques that we have incrementally built throughout the 20th century.

With populations projected to grow beyond 2050, as with almost all areas of society, in our farming systems we now face some hard choices. How do we ensure that our food system eliminates the use of fossil fuel and reduces greenhouse gas emissions from livestock? How do we make our farming systems resilient to the in-train effects of a warming world and simultaneously enable ecological restoration of some of the most important environmental services, protecting both humanity and the billions of other species that we share the planet with? And how do we do this fast enough to limit warming to the agreed 1.5°C, which currently we are predicted to reach by 2034?

At NIAB, over the past two years our scientific research strategy has fundamentally shifted to put these challenges at the heart of everything that we do.

Collectively, we need to think both about what solutions we need for the next thirty years to take us to an overall position of net zero globally, and then looking beyond that to design a world where we have net negative emissions, while simultaneously reversing the damage that we have already done to our wider planetary ecosystem. As the custodians of so much of the land, agriculture must play its part. Ensuring that much of agriculture remains highly productive, and that maximum efficiency is gained per unit of food produced ensures that more land can be taken out of production and used to provide environmental services.

Reducing emissions from our food system

Our immediate actions should focus on steps to reduce fossil fuel consumption and the reduction of greenhouse gases released from soils, as these will both reduce emissions and wider environmental pollution. Precision applications of fertiliser, reducing tillage or moving completely to no-till systems dramatically reduces greenhouse gas emissions from soil and wider runoff from agricultural soils into natural environments. The science behind these actions is well established and much of the job rests in the hands of advisors and technologists. NIAB's farming systems team led by Dr Elizabeth Stockdale is at the forefront of delivering these solutions to farmers.

Whatever innovation occurs in agriculture, it is clear that demand-side changes are required, as agriculture produces what the market demands. While meat will always be an important part of the diet and there is much that can be done to decrease greenhouse gas per unit of production, reducing the overall amount of meat we consume, and increasing the efficiency of conversion of plants into palatable protein products with consumer pull, could really shift land use patterns in the short term and decrease total emissions from farming.

The discovery and subsequent commercialisation of mycoprotein is worthy of its own article, but a key message is that although still dependent upon fossil fuel, for production at present, it has a far lower environmental footprint than all farmed animals. At NIAB, my own research group has been working for some time with Marlow Foods to understand more about the biology of the fungus used to make Quorn, currently produced using glucose sources derived from wheat. Improving our understanding of how fungi respond to different sources of carbohydrate will allow us to utilise a more diverse range of crops and opportunities from the circular bioeconomy to supply the fungus with its nutritional needs.

Looking ahead to the crops we grow, there are significant opportunities to enhance current arable rotations, to improve upon the diversity of crops but also the way in which we farm with, rather than against, nature, but without reducing productivity. When thinking about the joint challenge of reducing the amount of fertiliser used and increasing the amount of protein from plants faba beans, soy, chickpea and other legumes could all have increased prominence in climate-friendly farming solutions.

At NIAB we are growing our capabilities in the area of legume genetics and biotechnology, in particular gene editing and genomic-assisted breeding building upon a strong base of research, development and germplasm resources stretching back many years. We are looking at how we can increase both the amount and diversity of legumes in the rotation, while maintaining productivity per unit of input.

Many of the legumes produced globally are not yet desirable either from a productivity or a sustainability perspective in Northern European production. However, we have the plant science skills to rapidly adapt them to our climate and our farming systems and a very encouraging regulatory landscape to enable the use of modern breeding tools to do so and to ensure that we are simply not 'onshoring' a wider sustainability problem. Our team of legume scientists is rapidly growing and in addition to the work that Tom Wood and team has been carrying out in the area of legume

pathology, the recent appointment of Dr Abhimanyu Sarkar, working with Dr Phil Howell has expanded our capabilities. Similarly, in Dr Emma Wallington's biotechnology team, we have recently brought in Dr Subramanian Kondeti who has experience with soy transformation.

Thinking still further ahead about reducing fertiliser usage, through NIAB's work at the Crop Science Centre, as part of a programme led by Professor Giles Oldroyd and funded by the Bill & Melinda Gates Foundation, we are working to understand how some plants can associate with bacteria that take nitrogen from the air and convert it into bioavailable nitrogen. As part of the symbiosis process this nitrogen is then transferred to the plant in exchange for carbohydrates. The ENSA programme (Engineering Nitrogen Symbiosis for sub-Saharan Africa) is working to transfer this capability into other crops such as cereals. Unleashing this ability has long been the dream of many in this field of research, recapitulating the innovations that evolution has brought about. This represents the next frontier of scientific discovery; while it is relatively straightforward to move 'simple' single gene traits between closely related species, the ability to take whole modules of traits that have evolved over millions of years and move them between crops, represents one of the great scientific challenges of our generation.

Improving crop resilience

As our weather becomes more extreme as a result of a warming world, we need to build in crucial resilience traits to our crops. Perhaps familiar to many is NIAB's work in charting and then harnessing the diversity from crop wild relatives. We have been able to introduce novel variation into wheat, by bringing together new genetic diversity, reconstituting wheat from its ancestral progenitors. This is now providing plant breeders with the with the raw material that they need to reduce losses and boost yield per unit of input and enhance pest and disease resistance.

We are only just beginning to explore this new genetic diversity, brought in from wild relatives. This work is led by the Designing Future Wheat team, championed by Dr Sigrid Heuer. Advances in our understanding in the genetic control of complex traits means that in addition to the diversity that exists at this current window in time, new genetic diversity can be introduced with a precision that was only dreamt of a decade ago and knowledge can be translated more effectively between crops and the model plants that have been the focus of intensive research study for the past forty years. At the heart of this more 'rational design' of crops the use of machine learning technologies is critical, as the 'old' model of generating and testing hypotheses without the assistance of a computer model is becoming ever more strained by our own abilities to handle the vast supply of information that the global engine of scientific research is generating.

Here, regardless of the source of genetic variation, we need to ensure that our regulatory systems keep pace with crop science innovations. The National and Recommended Listing systems have the opportunity for reform and could capture and rank varieties with efficiency, resilience and resistance traits, in addition to the core productivity traits that have been prioritised for the last fifty years. Were these systems to change though, it must be done in such a way that still makes the UK a desirable marketplace for entry by breeders into any listing system, statutory or recommended. Here the vast power of precision measurement and remote sensing could be harnessed in tandem with genomic technologies to measure across multisite trials and onto the farm how closely predicted genetic performance matches to actual real-world performance. NIAB has invested heavily in recruiting some of the key skills in mathematics, computer science and data science needed to underpin this transition.

Enhancing biodiversity

It has been known for many years that where cropping systems are diversified, there is the potential to lower inputs without decreasing productivity. Pinning down the reasons for these observations is less well understood and likely includes soil nutritional balance, differing microbial dynamics both above and below ground and potentially greater support of beneficial insects and represents an exciting frontier of research, which will need to be carried out in partnership with the farming community.

In addition to the key challenge of producing healthy soil communities, innovations farming practice for the crops we currently grow must continue to be deployed. Insect pollination is worth €15 billion in the EU, but the number of wild pollinators is decreasing due to loss of flower-rich habitats. Dr Michelle Fountain's team at NIAB EMR participated in The BEESPOKE Project. This has designed bespoke seed mixes and habitat management guidelines to support the suite of pollinators required for 14 crop types on 72 demonstration sites around the EU.

This project has showcased best management practices, and there are now training materials for biodiversity monitoring and for measuring pollination. This places solutions that boost biodiversity in farmed areas into the hands of growers and farmers, ensuring that the reversal of biodiversity decline happens across all land use types, but not at the expense of productive farming.

These are just a few current examples how NIAB continues to play a key role in the research and innovation landscape, helping to rapidly scale the outputs of scientific research and provide effective knowledge exchange and training. An extremely large part of NIAB is the work that it carries out in partnership with the farming and horticultural sectors and the extensive links built up over a century of service. Now, at this critical juncture, we must all play our part in the mission to tackle the toughest problems of the 21st Century and put plant science into practice.

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Learning to live with cabbage stem flea beetle

In the autumn of 2020, NIAB began a Defra-funded project, csfbSMART – Sharing Management and Agronomy Research Tools, to look at options for managing winter oilseed rape in the presence of cabbage stem flea beetle. Initially we spoke to many growers and built a long list of subjects, mainly revolving around establishment for which growers wanted a better understanding. These included:

- drilling dates
- varieties
- seed rates
- nutrition
- companion crops
- drilling methods
- organic amendments
- defoliation.

On top of this, we are now seeing the increasing concern of larval numbers in the plants that in the spring of 2020 severely damaged crops that had established satisfactorily.

There was already a significant amount of work being carried out on a wide range of interventions, mainly looking at establishment. It is clear that there is no blueprint. Geography, and the weather in that particular year, play a large role in understanding what works best in each region. Those growers, who have developed their own successes, tweak their systems each year to make sure they take best advantage of the situation. With such a range of establishment methods, we are aiming to capture the thoughts of these growers and make this information available so others can add more options and ideas when planning their own crop management.

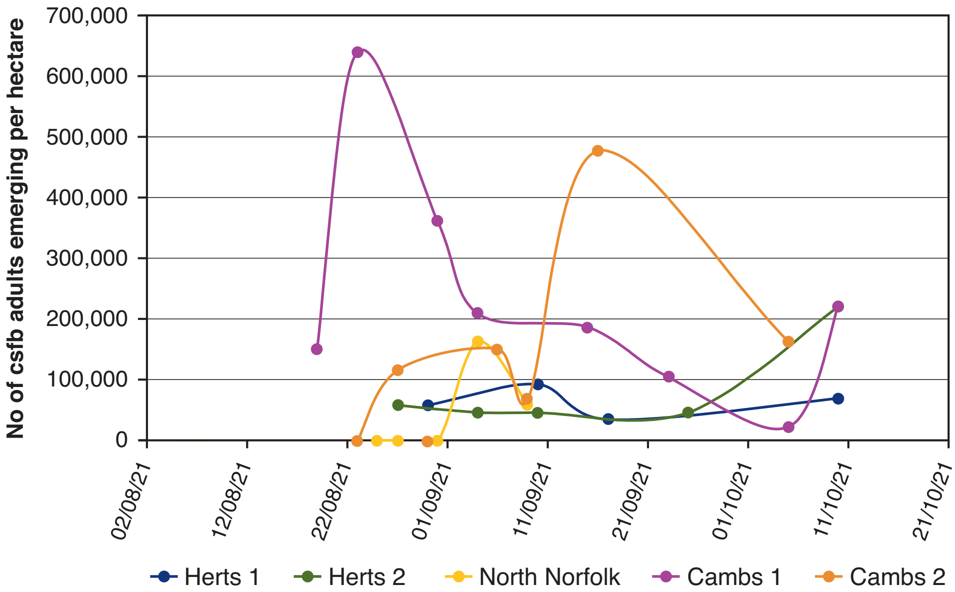
Monitoring

One of the project's main targets is to understand more about how the pest operates in the wider landscape. For many years, growers have been told to leave the volunteer crop to act as a catch crop. This all makes sense but there is a need to follow up with monitoring of these catch crops. The literature states that the adults hatch in June/July, but this information is now quite old so it is time to take another look. So emergence traps, borrowed from Rothamsted Research, have been placed in a range of volunteer crops across different regions (Figure 1). Emergence traps are designed to catch anything surfacing from the soil. As can be seen, they are basically a small tent, dug into the soil, so insects that emerge are trapped in a small water bath on the top.

Figure 2 shows adult emergence from the soil at five locations across Hertfordshire, Cambridgeshire and Norfolk. Needless to say, there would have been a hatch earlier in the summer which will be the ones seen at harvest. However, the graph shows large numbers emerging through late August and well into October when the traps were removed as the weather cooled. The nets struggled with windy conditions so more robust ones will be sourced for the future. The largest hatch came from the 'Cambridgeshire 1' site; the total caught

Figure 1. Emergence traps

Figure 2. CSFB adults emerging from the soil at different locations late summer 2021



was equivalent to just under 2,000,000/hectare.

This is fresh information but it is only one year of data. Emergence traps will be used again in first wheats following oilseed rape to check for a spring hatch. What we know is that, after a while feeding, adults go through a physiological change which means that they are unable to fly. But anecdotally, reports indicate adult beetles flying in the spring, damaging salad crops and spring brassicas, so the aim is to identify these and find out where they come from.

If this hatching pattern does happen in the same manner in the coming summer/autumn, it may mean that there is a different way of monitoring adult movements. But, we need to explore the possibility of disrupting hatch at the crucial time as the new crop is establishing, so a range of cultivation trials are planned with oilseed rape volunteers.

Ways are being explored to gather simple information from a geographically wide range of growers so we can understand the adult levels at various stages. Using a simple phone app, we were able to get an impression of adult numbers at harvest from a wide area by simply asking growers what they could see at harvest using a simple drop-down menu on their phone which only took seconds. With better knowledge of the beetle's life cycle, the next step is to understand the pest pressure in different areas of the UK at different times. To do this, growers and agronomists need to get involved.

Figure 3 shows that beetle numbers were low at that time, indicating that early drilled crops would be safe in those areas in the short term. It was followed-up with water-based trap monitoring, which allowed the production of maps showing the levels around the country in a green, amber and red scenario (Figure 4). After this point, there was further beetle emergence from the soils, but it all contributes to a better understanding of how the pest operates and, how by simple monitoring, a bigger picture can be built. In the future, we hope to be able to forecast levels suggesting high or low populations, which would help with decision-making before drilling oilseed rape.

Call for plant samples

With so many different crop establishment interventions used, we often hear the phrase "we're not sure how much difference it is making". It is difficult to measure as geographically the situation can be very different across the UK, and as the pest is so mobile it is challenging to measure accurately in trial plots.

Therefore, the aim this winter is to take a proper look at the UK picture by carrying out a stem larval assessment of as many different crops as possible. This includes normal monocrops, as much as those with companions etc, as well as varieties and drilling dates to ensure a full comparison of as many aspects as possible. The more samples gathered, the better chance our chance of seeing differences and we will report back directly to all those who help.

It is totally free. All that is required is ten plants from a field crop using a representative area of about 5m². If you have different varieties or drilling dates or a range of interventions, we would like a sample from each. There is a simple video 'csfbSMART: Assessing stem larvae numbers 2021' at www.niab.com/csfbsmart showing how to take samples. Contact Colin Peters (colin.peters@niab.com) for postage paid bags and further information.

Figure 3. Growers perception of adult numbers at harvest in trailers and grain stores

59 responses

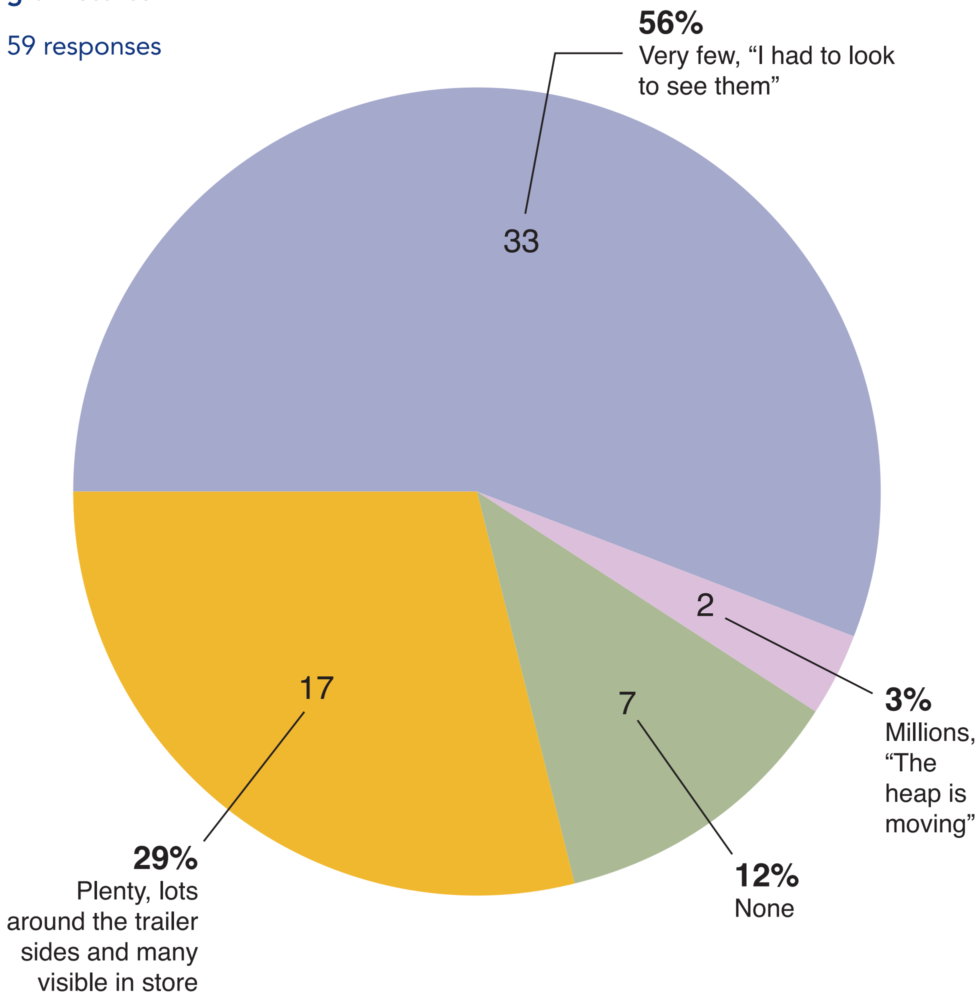


Figure 4. Adult numbers found by growers and agronomists in traps late August. Green = low, Amber = medium

ARTIS NIAB

Technical training courses

Classroom Courses

19 January	**Exploring winter and spring barley** • Trained by Bryce Rham • Wiltshire
20 January	**Exploring winter and spring wheat agronomy** • Trained by Bryce Rham • Wiltshire
1 February	**Optimising nutrient management for combinable crops** • Trained by Andrew Watson • NIAB HQ
9 February	**Advanced nutrient management for combinable crops** • Trained by Stuart Knight • NIAB HQ
16 February	**Gross margin budgeting and management** • Trained by Christopher Winney • NIAB Park Farm, Cambridge
24 February	**Better control and avoidance of disease in wheat** • Trained by Aoife O'Driscoll • NIAB Park Farm, Cambridge

Virtual Courses

18 January	**Best practices in water management and crop irrigation** • Trained by Mark Stalham
26 January	**Exploring regenerative agriculture** • Trained by Elizabeth Stockdale and Richard Harding
8 & 9 February	**Benefits of cover crops in arable systems** • Trained by Nathan Morris Course split over two 3 hour morning sessions
15 February	**Improving soil organic matter and farm carbon management** • Trained by Elizabeth Stockdale and Becky Willson
17 February	**Using an integrated approach to weed management in arable crops** • Trained by John Cussans

e-learning

Nematicide Stewardship Programme (NSP) • The NSP Protocol is now an audited part of the Red Tractor Standard for potatoes, carrots, parsnips and sugar beet. Complete the FREE online training modules to obtain your certificate and prove your compliance.

Register your interest

We are still in the process of organising some of our courses. Please visit www.artistraining.com to register your interest for a course or join our mailing list for regular updates.

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Discovering Agritech

A new, regular feature in Landmark, **Discovering Agritech** will shine a spotlight on the projects and businesses working with NIAB to offer innovative and sustainable solutions to the food and farming sector, both in the UK and globally. We will introduce two enterprises in each feature, giving them an opportunity to outline their vision and plans for new products and services.

Our first two businesses **Piatrika Biosystems** and **Geotree** are both members of Barn4, NIAB's agritech business incubator based at the Park Farm site near Cambridge (www.barn4.com).

Through initiatives such as Barn4, the Eastern Agri-Tech Innovation Hub, Growing Kent and Medway and Cambridge AgriTech, NIAB is committed to creating, developing and supporting new commercial activity across the agricultural or horticultural sectors. Delivery is through licenses, consultancy, access to facilities, training and agritech products or services and across our activities we are able to reach into NIAB's global industry networks, its science, and its talent pool to access the resources and skills we need.

Developing mutually beneficial relationships with small and medium-sized enterprises (SMEs) and their investors in the agritech sector is an important focus for NIAB, working closely with the sector to explore new business models and support delivery of innovation for the industry.

Environmental monitoring

Launched in November 2021 Geotree offers global-scale carbon sequestration monitoring of all nature-based solutions. It is a joint venture between Barn4 member Mantle Labs, a leading remote sensing company that provides digital agricultural solutions, and Hartree, a global merchant commodities firm.

The fact that soils can sequester atmospheric CO_2 in the form of soil organic carbon (SOC) offers a cost-efficient means to mitigate climate change. This has attracted the attention of environmental research and policy agendas. SOC is also crucial to preserving soil quality and health and assuring food security. For example, maintaining or increasing SOC concentration improves other chemical and physical soil properties, such as nutrient storage, water holding capacity, aggregation and aggregate stability, and sorption of organic and/or inorganic pollutants. Increased carbon stocks also go hand-in-hand with increased microbiological diversity and activity. Together, this underpins the growing need to spatially estimate and monitor SOC and other soil properties. Continuous monitoring at different spatial and temporal scales provides invaluable support and guidance for soil and land management as well as decision and policymakers.

Unfortunately, high-resolution maps that indicate areas where SOC levels are critically low, and where improved management options could be most effective, are scarce. Current SOC maps at regional to global scale consist of coarse grid cells and are based on legacy data. Updating this data through collection and analysis of new soil cores is expensive. To date, little effort has been put into extracting soil's inherent optical properties, unaffected by remnants of crops and stubbles, changes in soil water content and roughness etc., that permit a robust SOC mapping across large areas.

With the launch of the European Copernicus programme and other complementary space activities, the availability and quality of remote sensing data has dramatically changed the paradigm. Together with the upcoming imaging spectrometers, remote sensing of (top) soils becomes feasible in a coherent manner from local to global scales – the use of high spatial and spectral resolution optical images from orbital platforms enables the development of soil monitoring and mapping techniques from the local to the regional, continental and global scales in an effective, fast, frequent and economical way. Only satellite remote sensing offers the necessary high revisit cycles, to permit comprehensive monitoring of large areas at fine spatial resolution.

SOC shows a close relationship with reflected electromagnetic radiation both in the visible, near-infrared and short wave-infrared regions. Several recent studies and scientific papers demonstrated the capability of satellite images, including the Copernicus Sentinel-2 multi-spectral instrument and NASA's Landsat-8 operational land imager (OLI), for SOC content prediction and mapping results have been encouraging.

The spectral models can be further improved by including auxiliary predictor variables such as vegetation, topography, climate, and geology, which are also highly correlated with SOC. The acquired data and retrieved information can be combined using physically-based, statistical, geostatistical, machine learning, and hybrid techniques to predict and monitor SOC at a fine spatial resolution with a consistent specification and uncertainty, for sustainable soil management and decision-making.

Based on the Geotree team's deep understanding of the physical interaction of electromagnetic radiation with matter, we have developed a robust SOC modelling approach based on time series of high-resolution Sentinel-2 data. The developed approach is robust against changes in soil wetness and roughness whilst also detecting and removing spectral effects of residual vegetation cover and stubble. In this way, Geotree obtains from the Sentinel-2 time series soil inherent optical properties (SIOP) that are closely related to SOC as well as other soil parameters. This revolutionary approach allows scalable and regular global soil carbon monitoring.

Geotree/Mantle Labs

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Cloud-based bioinfomatics

Inspired by improving the sustainability of agriculture and the pressures of feeding a growing population Piatrika Biosystems has developed a cloud-based data platform to help researchers and businesses bring crop varieties and agrochemicals to market faster whilst also developing the underlying science in collaboration with international academic research partners.

Sustainable agriculture has moved during the last decade from being an aspiration to an essential element of the world's solution to feeding a rapidly growing population without destroying the environment that population will inhabit. Social, environmental, and economic issues must all be considered if a truly sustainable approach to global food production and land management is going to be realised. Agritech is developing at an ever-increasing pace to support the transition to sustainable farming but the discovery, design and development of new crop varieties and agrochemical products is still limited by the time it takes to field-test.

Agricultural testing, unlike many other experimental regimes has a vast array of variables over which the technical team have little if any control. Factors such as climate, location, operational practices, and environmental effects can have as large an impact on the traditional measurements of yield and efficacy as any changes in genetics or chemical composition.

One of the tenets of precision agriculture is that data will help unlock the gains that are waiting to be made that will in turn enable sustainable approaches. What is clear is that a combination of data collection and robust data science to monitor and deliver crop intelligence can be used as a part of a loop that enriches the discovery phase for new products. In the case of developing new crop varieties infusing this loop with genomic data can dramatically reduce the length and cost of breeding programmes. The techniques have been developed to a point where they are mature but are only relatively recently being applied at scale to crops.

Piatrika Biosystems is building a platform that will help researchers and seed companies to bring more sustainable varieties and agrochemicals to market faster. This is being done by creating an innovative cloud platform to link genomic discoveries to plant breeding decisions, programme design and monitoring. While the discovery platform is supported by novel technologies in computational biology and data science, integrating this with autonomous phenotypic, temporal and spatial data capture for more accurate analysis helps enhance the discovery process. The integration of instrumentation; in-field data collection and satellite data is used to drive field operations and enrich the data matrix for targeted genomic-phenomic studies. Genomic selection and analysis is backed by an Artificial Intelligence approach implemented in the platform. This can perform analysis on multidimensional data sets and support real-time decision making.

Piatrika Biosystems

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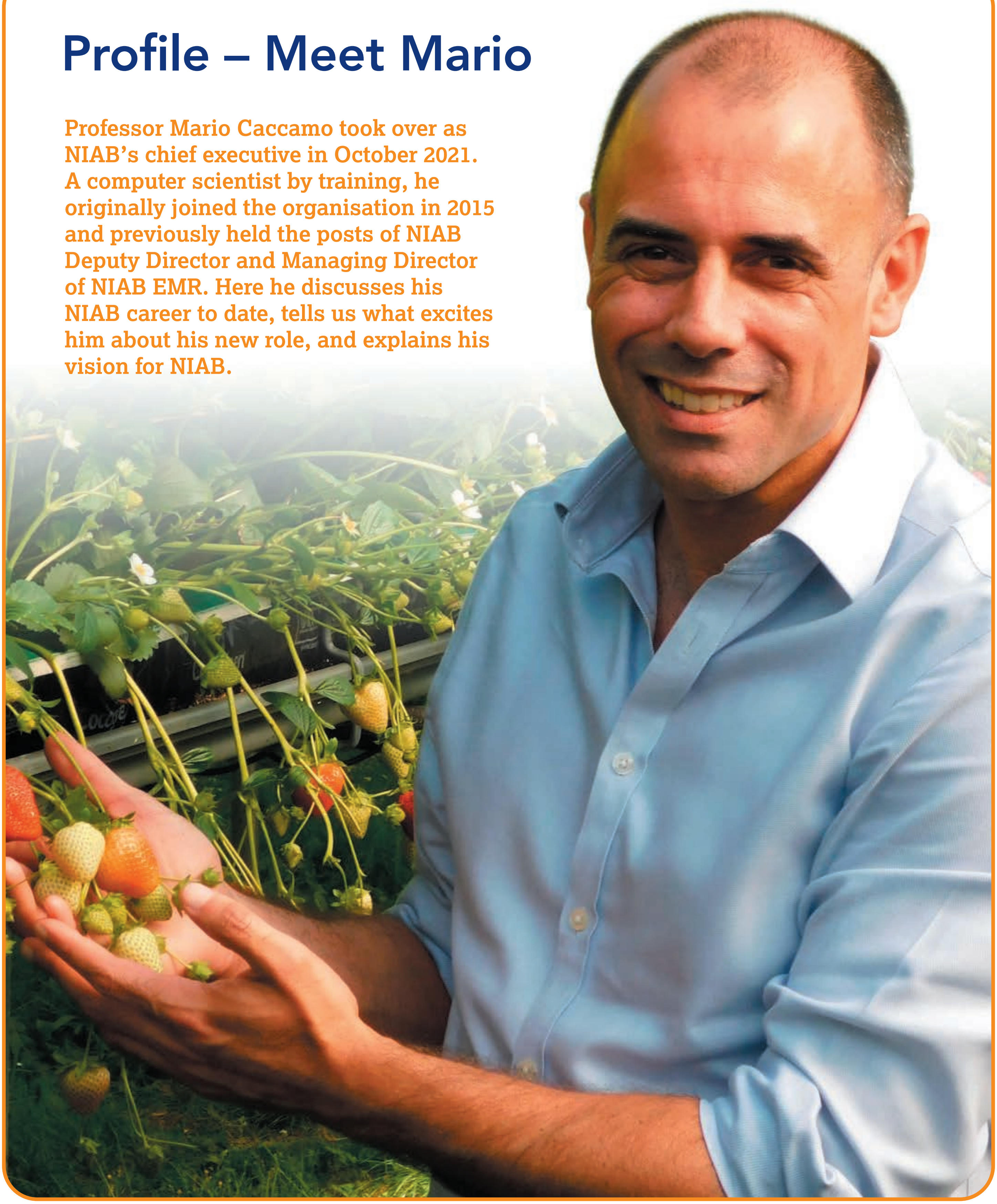
Profile – Meet Mario

Professor Mario Caccamo took over as NIAB's chief executive in October 2021. A computer scientist by training, he originally joined the organisation in 2015 and previously held the posts of NIAB Deputy Director and Managing Director of NIAB EMR. Here he discusses his NIAB career to date, tells us what excites him about his new role, and explains his vision for NIAB.



Can you tell us a little more of your background?

I grew up in Argentina's Patagonia region, but I have been privileged to be able to travel across the globe, following my studies, making the UK my home over 20 years ago. My PhD is in computer science at Aarhus University in Denmark was followed by a four-year stint at the Wellcome Trust Sanger Institute, two years at the European Bioinformatics Institute and six at the Genome Analysis Centre, now the Earlham Institute, the latter two as Director.

I joined NIAB in 2015 originally to develop the data sciences section, but was quickly given the opportunity to lead NIAB EMR in Kent. There I've overseen a successful programme of growth in the organisation's research and commercial activity, realising the opportunities offered by its acquisition by NIAB in 2016, alongside a multi-million pound redevelopment programme implemented in partnership with the East Malling Trust.

As a computer scientist, how did you get into plant science?

I have over 20 years' experience in life science research and big data, but with a passion for food production. I was originally drawn to the challenge of making sense of the genetic data for a very complex genome such as the one for wheat. Until only a few years ago the aim of sequencing and managing large crop genomes was considered unreachable. I can think of many similar problems in other fields of science but the unique opportunity to work on an area of research that has a large impact on our daily lives, such as food, was the other great incentive for me. Which is why I'm now at NIAB.

What excites you about your new role?

Working in innovation is always exciting. Every day I get up and work with a great team of people, who will come to you with incredibly innovative solutions for real problems that our society faces. Plus the independence to be able to follow what we believe has always been one of the extraordinary things about NIAB; we have this unique role of being trusted by our partners and being able to tell them what we believe are the right things for them in terms of the solutions we offer.

What do you think are the biggest challenges facing NIAB?

The pressure to deliver novel crops on ever shorter timelines brings undoubtedly a huge challenges for breeders and therefore for NIAB. The advent of new data-driven technologies will help but interestingly brings other challenges such as the access to the skills to manage and model the data. And then the need to train the new generation of crop researchers and breeders in these technologies is increasingly becoming more important. That we are aware of these challenges and working to find solutions is a huge positive for NIAB, for example projects such as Designing Future Wheat through to the recently launched Collaborative Training Partnership for Sustainable Agricultural Innovation.

NIAB leads in providing independent crop management R&D, information and services, which we need to maintain and even improve upon in the future. This includes extending our on-farm presence and ensuring our strategic agronomy services that bridge research, trials and consultancy, support decisions to achieve crop improvement.

The challenge when you are working in innovation is to make sure you are looking at a technology in a way that you can support a sector, where we can 'de-risk' that innovation. This is something that has always a part of what we do at NIAB – we are a 'go to' place for agricultural innovation.

What are you looking like to achieve with NIAB?

NIAB is a 100 year old organisation. It has made its name by working with farmers and growers to always make sure that we can develop products or a strategy that is good for them, good for consumers and good for the environment. That remains our over-riding vision.

The next step is to establish NIAB as the recognised innovator in crop science and production for combating climate change and decarbonisation for agriculture. Of course, we are already well-known for delivering practical solutions for growers and we need to continue and stay ahead of our competitors with this, for example, in the uptake of protein crops, working towards a net-zero agenda, the effective adoption of automation and data science, and the development of modern breeding technologies. NIAB has the track record to credibly convey a commitment to translate science into practice to benefit growers and supply chains.

And I would like to see NIAB's partnership with the University of Cambridge, through the Crop Science Centre, as being fruitful, and successful. A measure of that would be to see that we have delivered on a number of products that can be used by UK growers, and potentially internationally, that will give us this global presence.

Getting to know you

What was the last book you read?

Non-fiction was 'The case against education' by Bryan Caplan and fiction 'Catch-22' by Joseph Heller – a bit late in life but I wouldn't have enjoyed it as much without a few years under my belt.

Which are your favourite sports?

Faithful to my roots it has to be football, but I also like watching and playing volleyball (and I don't even know the rules for polo).

Where's your favourite holiday destination?

I love deserts, especially Sonora in North America (south-west US and Mexico), Eastern Patagonia in Argentina and Puna in the Andes of Chile and Argentina.

Tell us something about you that would surprise people?

I think this is remarkable – on my Mum's side of the family I am the first boy after two generations of all girls: my grandmother was one of six girls, and all of those girls went to have only girls. I am the first boy but then I have four sisters and no brothers, and I went myself to have five children: four girls and one boy.

If you hadn't worked in the science sector, what else would you have done?

I think I would have been in the education sector.

NIAB

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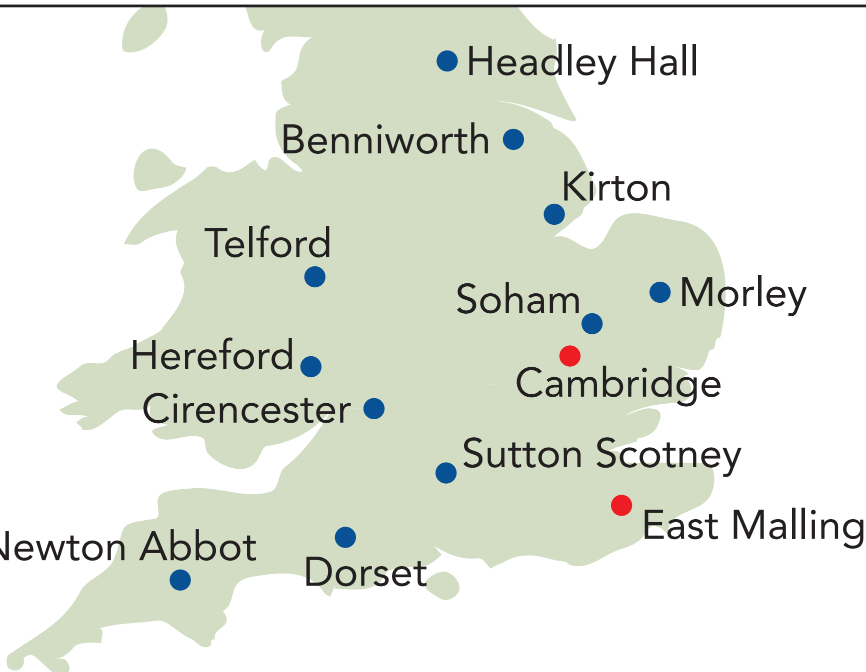

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