NIAB TAG

Landmark

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Wildfire plant recovery research highlights role of smoke detection in improving crop roots and nutrition

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Tina Barsby, Chief Executive, NIAB

Time for bold Government action on crop genetic innovation

NIAB recently joined other leading players including the British Society of Plant Breeders, the John Innes Centre, Rothamsted Research, The Sainsbury Laboratory and leading plant scientists at Britain's top universities, in urging the Government to take action on two fronts – regulation and R&D – to help unlock the enormous potential of crop genetic innovation in securing a more sustainable food future.

Our joint statement welcomed the recent publication of Henry Dimbleby's plan for a National Food Strategy, and in particular its recognition of the importance of crop genetics in delivering the productivity, resource use efficiency and nutritional quality gains needed to support a healthier, more resilient food system.

Specifically, the National Food Strategy highlighted the need to invest in new breeding techniques "to improve productivity without polluting the land," and discussed the potential to increase crop yields by up to 30% through advances in crop breeding.

The Strategy also set out the need for a Challenge Fund aimed at practical innovation that would shift the nation towards sustainable and healthy eating. Achievable innovations would provide alternative sources of protein, including plants, and improved production of fruit and vegetables.

Our joint statement urged Government to ensure these innovations can take place by providing a proportionate and enabling regulatory framework for genetic innovation, alongside a more coherent R&D strategy for crop genetic improvement.

The need for bold action by Government on these issues has been underlined by a series of recent high-level reviews undertaken on behalf of UKRI and the EU plant breeding and seeds sector.

In March 2021, a new plant science strategy, *UK plant science research strategy: a green roadmap for the next 10 years*, led and authored by Professor Jane Langdale of the University of Oxford, reached similar conclusions in relation to the need for a more enabling regulatory framework and a joined-up R&D pipeline for crop genetic innovation.

Of particular concern is the hiatus in research funding between early-stage genetic research and its application in commercial breeding programmes. This was first identified as a problem 17 years ago in a 2004 BBSRC review of crop science led by Professor Chris Gilligan of the University of Cambridge – I was a member of that review panel. According to Professor Langdale's 2021 review, a fragmented R&D pipeline in plant genetics remains a significant barrier to innovation.

"The modest and relatively inelastic income from seed royalties limits commercial plant breeders' ability to invest in more speculative or long-term targets. Because of this, and the lengthy timescales involved, the expectations of the current system for financing near-market and applied R&D is not working, and opportunities to exploit major advances in our understanding of plant science are being lost," she said.

Such advances will be critical to meeting future food security, climate change and sustainable development goals, as evidenced by a major report into the socio-economic contribution of EU and UK plant breeding, published in May 2021.

The study, by independent scientific consultancy HFFA Research GmbH, concluded that, since 2000, progress in plant breeding has accounted for two-thirds of the productivity gains in UK arable crops. Without plant breeding over the past 20 years, the study found that crop yields would be 19.1% lower, and 1.8 million hectares of additional land would be needed in other parts of the world to meet the UK's food needs, placing additional pressure on scarce global resources and causing more than 300 million tonnes of additional GHG emissions.

The HFFA study highlighted the challenges of maintaining the rate of yield improvement in the face of further pressure to reduce pesticide and fertiliser inputs. It underlined the critical importance of access to new breeding

techniques, such as gene editing, with the potential to accelerate the rate of progress in crop innovation.

Against this background, the importance of a positive outcome to the Defra consultation on gene editing cannot be over-stated, not only in freeing up access to crop research and innovation but also, given the UK's strengths in plant science, boosting prospects for inward investment and international research collaboration.

The Government's support for a joined-up R&D pipeline will be critical to realising these opportunities. And here there remains cause for concern.

Reiterating our joint statement's call to action, Julian Sturdy MP also wrote to Defra Ministers in his capacity as chair of the All-Party Parliamentary Group on Science and Technology in Agriculture, of which NIAB is a founding stakeholder.

The response he received from farming minister Victoria Prentis MP suggests that the UK's primary vehicle for bridging the long-recognised gap between early-stage discovery research and its translation into relevant crop backgrounds for use in commercial breeding programmes are the Genetic Improvement Networks (GINs).

While valuable as a mechanism for bringing together key players along the crop improvement pipeline – from early-stage academic research to commercial plant breeding – the GINs are under-resourced. Defra is currently funding four GINs addressing our major crops to the tune of £5.5 million over five years from 2018 to 2023.

To set that in context, the Government's flagship Transforming Food Production R&D programme is set to invest £90 million over four years in digital and precision farming projects such as robotic harvesters, vertical farms, AI and sensor technology.

These agri-tech innovations are incredibly important in driving efficiency improvements and squeezing more out of what is already there. But they cannot in and of themselves alter the genetic potential of what goes in the ground.

Independent studies such as the HFFA report referred to above have repeatedly shown that genetic innovation is the main driver of productivity gains in agriculture. Policy development and the allocation of research funding must reflect that.

As I sign off as chief executive of NIAB, I urge the Government to be bold, to listen to the science and the scientists, and to establish a properly resourced and strategically directed Crop Genetic Innovation Research Fund, with long-term funding commitments, engagement along the length of the crop improvement pipeline, as well as clear targets and measures of success in terms of productive, sustainable and climate-resilient crop production.

The opportunities and challenges ahead are too great to ignore.

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Understanding smoke detection can lead to better crop roots and nutrition

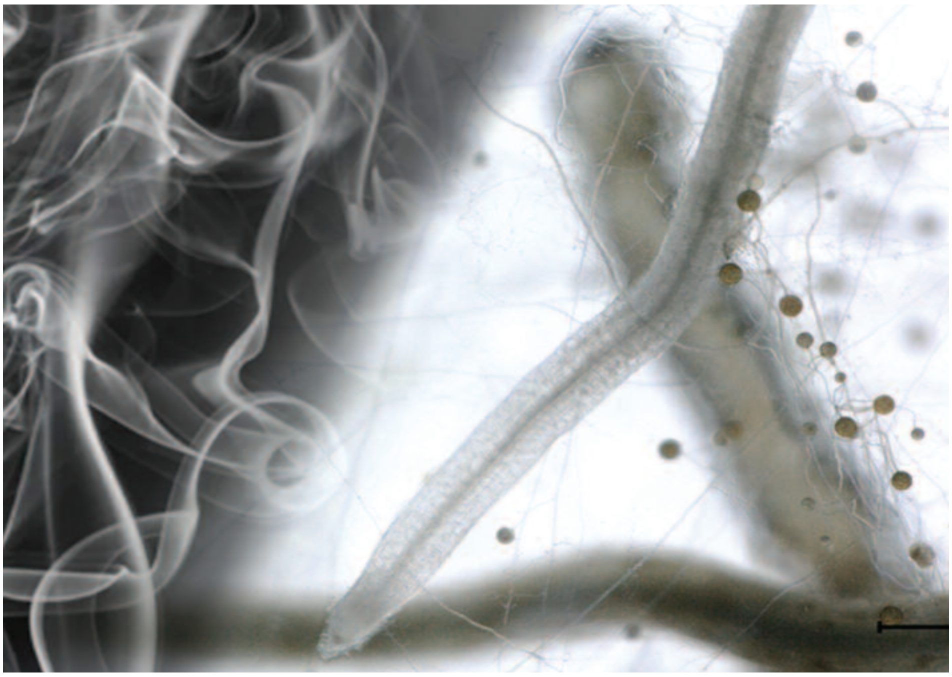
Knowledge of how plants work is paramount to ensure sustainable crop production. However, in some cases, an understanding of plants relevant to cropping systems in the UK comes via a long and convoluted way.

It has been known for a long time that some plant species are fire-followers. They germinate after a fire, benefiting from increased light and nutrient availability due to the clearing of the vegetation, and their seeds' germination is induced by either the heat of the fire or the resulting smoke. This is particularly relevant to ecosystems in Australia, where bush fires are widespread and a major contributor impacting the ecosystem dynamics.

Interestingly, smoke can induce the germination of a wide range of species beyond specific fire-follower species. This knowledge has already been exploited in commercial horticulture and restoration industries with a routine application of smoke to promote the germination of a broad range of plant seeds. More recently, researchers at the University of Western Australia identified specific compounds (out of more than 4,000) present in smoke that can induce germination. These are small water-soluble compounds that can promote germination and seedling vigour, at concentrations as low as parts per billion. They are now named karrikins, after the aboriginal Australian word for smoke, 'karrik'.

The relevance of these compounds to improve crops only came to light when researchers started to identify which genes and proteins are involved in sensing karrikins. This knowledge allowed researchers to switch on and off the karrikin responses without the smoke and discover other hidden aspects of karrikin signalling. For example, the way that plants sense karrikins is intricately linked to the perception of strigolactones. These are endogenous root-borne hormones involved in shoot branching, and some are secreted in the soil. Parasitic weeds, including *Striga*, *Phelipanche* and *Orobanche* species, detect strigolactones from the host roots and germinate for infection. In Africa, parasitic weeds are highly prevalent in soil (40% of all agricultural land is affected) and cause severe yield loss in sorghum, millet, maize and upland rice. So naturally, the strigolactones are at the heart of a parasitic weed control programme.

On the other hand, the knowledge of these compounds and how plants perceive them becomes relevant for sustainable crop production because of their critical role in root biology. Researchers at NIAB and the Crop Science Centre discovered that these compounds regulate root architecture, root growth patterns and the establishment of root and fungal symbiosis to maximise nutrient and mineral uptake.



Source: Jeongmin Choi, Honeywell©

The mechanism of smoke perception in plants can also regulate root growth and establishment of symbiosis with beneficial fungi

Improvement in crop root architecture is an active area of research with a high potential for yield gains. Below-ground traits tend to have been neglected by breeders as they are challenging to study in soil. Roots serve many purposes to the crops, such as anchorage to the soil to prevent lodging and acquiring nutrients and water. The root system architecture includes root number, length and diameter. High root branching, which can be broadly defined as the number of total roots, including primaries, laterals and adventitious (emerging from the base of the shoot) is particularly valuable as this trait would enable plants to access nutrients unevenly distributed throughout the heterogeneous soil matrix.

Plants from the model species, *Arabidopsis thaliana*, that are deficient in the perception pathway for both strigolactones and karrikins, show greater root branching (both in terms of increased lateral root densities and adventitious numbers). In addition to root architecture, root growth patterns are also relevant to the plant's ability to grow well. Root growth patterns represent where the roots are positioned in the soil and how their growth is influenced by many environmental factors (e.g. gravity or water availability). Our work has shown that the perception pathway for karrikins, but not strigolactones, is important in regulating root growth patterns. We are interested in, and working towards, translating this knowledge from the model species to agriculturally relevant crops such as wheat.

Another prevalent but unnoticeable way plants obtain minerals and water is through symbiosis with beneficial fungi called arbuscular mycorrhizae. Approximately 80% of plants, including major cereal crops, operate a 'fungal farm' in nutrient-poor soils. Plants feed arbuscular mycorrhizae with carbon fixed by photosynthesis (often in the form of lipids). One end of fungal filament extracts valuable minerals, such as phosphorus and nitrogen, in the soil. The other end unloads them inside plant roots to be transported throughout the plants.

The first essential step to successful symbiosis is distinguishing friendly fungi from pathogens through biochemical communication. Karrikins and strigolactones are critical for this initial step. For example, plants secrete strigolactones in the soil to attract and activate the mycorrhizal fungi for infection. It was discovered that activating the karrikin signalling pathway makes plants a better host by boosting the strigolactones release and ability to recognise the fungi. In the past, it was considered that arbuscular mycorrhizal symbiosis occurs by default. The discovery of karrikin and strigolactone signalling pathways demonstrates that plants have the means to regulate symbiosis.

So what regulates the symbiosis? One example is soil nutrient level. When soil is rich with ample nutrients, such as after fertiliser input, plants shut down mycorrhizal symbiosis to save carbon costs to feed the fungi. Therefore, modern agriculture with heavy fertiliser input failed to harness the benefits of mycorrhizal symbiosis. It is time to implement arbuscular mycorrhizal fungi to improve crop mineral use efficiency and reduce environmental costs. To this end, our current research project aims to understand how nutrient levels, such as phosphorus and nitrogen, alter arbuscular mycorrhizal symbiosis.

In summary, the story of karrikin demonstrates the importance of basic science and its unexpected contribution to crop improvement. The partnership and close collaboration between NIAB and the Department of Plant Sciences of the University of Cambridge at the new Crop Science Centre will continue to accelerate this translation to improve nutrient and water uptake in crops through this 'smoky' signalling pathway.

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Stocking up on carbon in agricultural soils

There is a large quantity of carbon (C) held in the organic matter within the world's soils; it is estimated that the global stock of soil organic C (SOC) is in the range 684-724 billion metric tonnes in topsoils (assumed to be to a depth of 30 cm). This quantity of SOC in topsoil is about twice the amount of C in atmospheric CO_2 and three times that in global above-ground vegetation. The C stock in soils actively exchanges with the atmosphere via the processes of photosynthesis (taking C up) and respiration by soil organisms (releasing C). Changes in soil C can contribute significantly to GHG emissions so, for example, the IPCC estimated that the annual release of CO_2 from deforestation (coming from both vegetation and soil) was about 25% of that from burning fossil fuels. No wonder then that there has been significant interest in maintaining the soil C stock we have and, where possible, increasing it to help reduce atmospheric CO_2.

Measuring the soil C stock

Accurate direct measurement of soil C requires destructive sampling – soils are taken from the field and then sent to a laboratory for processing and analysis. Soil organic matter is usually measured using the loss-on-ignition method, essentially the organic matter is burnt off. It is also possible to measure the total carbon content of the soil (after removing any mineral carbonates) by dry combustion.

The measures of soil organic matter and soil C are closely correlated, but are not the same. Soil organic matter contains 58% C on average; but there is some variation about this typical number, so where measures of C stock are required, it is better to ask for C to be measured directly. There is active research that is trying to reduce the need for sampling and/or use quicker indirect spectroscopic techniques (NIRS and MIRS) and proximal data from on-the-go sensors in the field. However, such technologies are still at an early stage of development and all the methods require very careful calibration for different geographic areas and soil types using the laboratory direct combustion methods as a reference. Any mineral carbonates in the soil also need to be accounted for – this is not just a problem for chalk or limestone soils. So, for a measure of C stock, send soil samples to a laboratory for measurement of soil organic C; the combustion method used is usually known as the Dumas method. But this is the easy bit!

A major challenge is that there is a high degree of spatial variability – even in seemingly uniform fields. Robertson *et al.* (1997, Ecological Applications 7: 158-170) showed that SOC content may vary by as much as 5-fold, or more, even in a field of the same soil type, ploughed and cropped uniformly for over 100 years. So, for a accurate estimation of SOC content across a field of tens of hectares up to a hundred samples would be required. SOC also changes with depth (Figure 1); in most UK arable soils, SOC content is fairly homogenous in the topsoil, but in uncultivated soils such as pastures and long-term no-till sites, SOC declines continuously from the surface.

The IPCC has specified the 0-30 cm layer for soil C inventories; this may include the upper subsoil (or rock) in some UK soils. Measuring the topsoil only will capture the impacts of most changes in SOC stock occurring due to land-use or management change. However, some practices e.g. inclusion of leys with deep-rooted species in arable rotations, may lead to small but significant changes in the SOC stock in the subsoil. It is also important to compare sites/practices appropriately; increased stratification of organic matter in no-till systems means that comparing samples from no-till and plough-based systems collected at 0-10 cm are very likely to give bigger differences that those collected over the whole topsoil, 0-25 cm. Differences at 0-10 cm are often real and may help increase soil surface stability and biological functioning, but they do not necessarily mean that soil C stocks in the whole topsoil are higher.

The calculation of soil C stock requires the collection of soil samples of known volume so that bulk density and stoniness can be determined and the soil weight

Figure 1. Estimating soil C stock means taking measures of SOC content for known depths, together with stoniness and bulk density

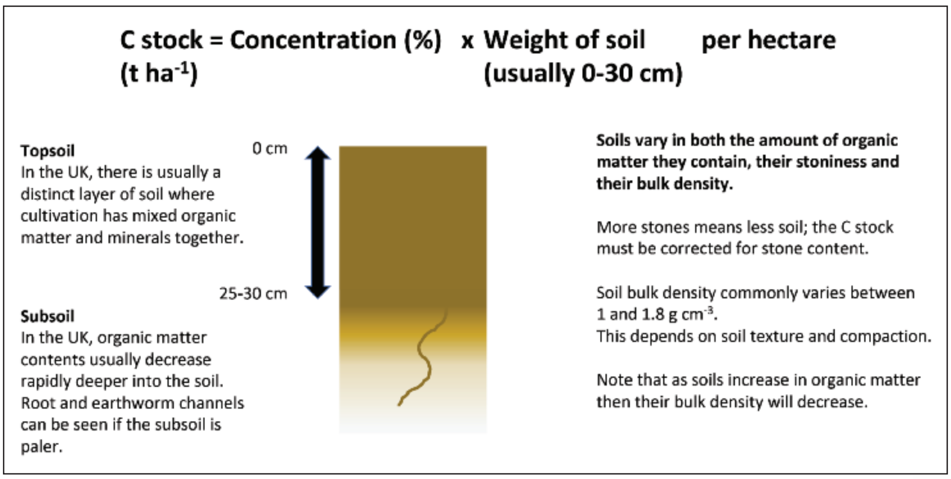


Figure 2. Estimates of soil C stock are affected by soil depth, stoniness and bulk density as well as SOC contents

Organic matter (%)	Topsoil organic C (%)	Depth of topsoil (cm)	Stoniness (%)	Bulk density (g/cm)	Soil weight (t/ha)	C stock (t/ha)	
3	1.74	10	10	1.25	1125	19.6	**Increasing topsoil depth increases C stock**
		20			2250	39.2	
		30			3375	58.7	
3	1.74	30	0	1.25	3750	65.3	**Increasing stoniness reduces C stock**
			10		3375	58.7	
			20		3000	52.2	
			40		2250	39.2	
3	1.74	30	10	1.7	4590	79.9	**Reducing bulk density reduces C stock (measured over the same soil depth)**
				1.4	3780	65.8	
				1.25	3375	58.7	
				1.1	2970	51.7	
2	1.16	30	10	1.25	3375	39.2	**Increasing C amount (%) increases C stock**
3	1.74				3375	58.7	
4	2.32				3375	78.3	
4.2	2.44				3375	82.2	

per hectare can calculated. Collection of such samples is much more laborious than the collection of soil samples for routine nutrient analysis. Currently this service is available from specialist soil sampling companies at a cost. The impacts of soil depth, stoniness and bulk density on soil weight per hectare and hence on the soil C stock are shown in Figure 2. Variation in stoniness can be as large as that for SOC content in many soils.

The amount of SOC in soil is relatively large compared with the changes that result from management over a short period of time; this gives a problem in detecting change – the signal-to-noise problem. As can be seen from the C stocks shown in Figure 2, a 5% change in the SOC, c. 4 t/ha in a pool of c. 80 t/ha, gives a SOC concentration change from 4% to 4.2%; with most management changes this change would occur over a 3-5 year timescale and would be just about detectable. Hence, sampling to monitor changes in soil organic matter should take place regularly and, ideally, always at the same point in the rotation, it is usually not useful to measure organic matter every year. Trends can usually be detected using samples collected in the same way at 3 to 5-year intervals over a decade or more. The most effective way to measure changes is to measure at precisely located benchmark sites over time. But note that detecting changes in the total soil organic matter in the field is often a slow process.

The measurement of soil C stocks is a matter of focus because of the attempt to value and reward enhanced levels of SOC as result of agricultural practice change; C accreditation schemes require feasible, credible and creditable assessment of soil C stocks. However, such direct field measurements are costly and so for many of the developing schemes a hybrid approach is being taken where C models are used together with a smaller number of benchmarking or monitoring measurements.

Modelling the C stock

Models can provide a way to predict soil C stock changes, taking into account the integrated effects of different management practices as well as impacts of changes climate or soil conditions. Such models, bring together the best theories and check them against the results of monitoring and of long-term experiments. Process-based models have potential for broad applicability across gradients of soil, climate and management – but they need to be used with care, as they have often only been validated for a limited range of conditions. The ROTH-C model developed at Rothamsted Research can be integrated within a full ecosystem-scale model framework for soil C accounting. This approach is used in Australia to underpin the voluntary scheme to provide payments to farmers who participate in emissions reduction and carbon sequestration known as the Emissions Reduction Fund (https://www.agriculture.gov.au/ag-farm-food/climatechange/cfi).

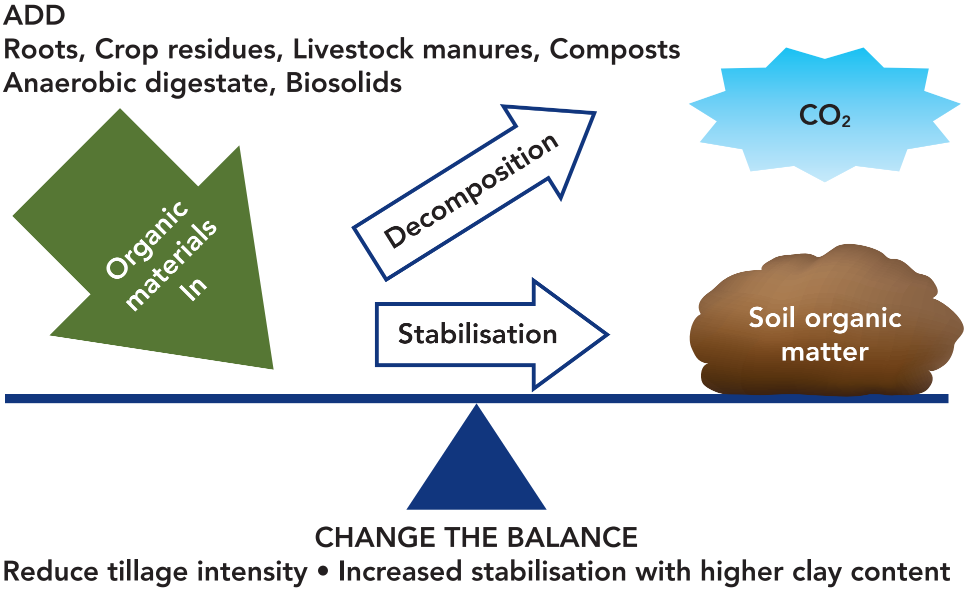
But what is really possible – can agricultural soils increase C stocks?

Bellamy *et al.* (2005; Nature 437: 245-248) analysed changes in SOC content in soils of England and Wales by using data from surveys conducted on two occasions (approximately 1978 and 2003). Overall there was a decline in the soil C stock but in soils with the smallest C content at the time of the first survey (mainly long-term arable soils) C stock had increased by the time of the second survey. This increase was probably caused by increased organic C inputs resulting from additional returns of stubble (and perhaps also straw) following the cessation of straw burning in the UK. NIAB has seen the same small increase in the long-term straw incorporation experiment at Morley in

Norfolk.

For areas with a low SOC level (relative to the potential of that soil to hold C) there may be potential to increase the soil C stock through altered management (e.g. including cover crops or leys in rotations) or land use (arable to woodland or grassland), thus creating a sink. However, in some cases, a low C content reflects a small potential for SOC accumulation, either because of soil type (for example, the sandy soils of the Breckland have less capacity to stabilise C than heavier soils around Cambridge) or through limited plant growth resulting from climatic factors. Benchmarking soil organic matter content against levels typical for soil type can help to understand whether soils have much capacity to increase C. The general principle that applies to all soils is that if more carbon is added to the soil, then more organic matter is built. The levels of SOC in any soil are a result of the equilibrium between the inputs of organic matter and the decomposition of the organic matter by soil organisms (Figure 3). The disruption of soil aggregates during tillage changes the distribution and accessibility of SOC in soil and usually increase rates of decomposition; hence reducing tillage intensity can lead to more stabilisation of SOC.

Figure 3. Levels of soil organic matter are a result of a balance between C inputs and outputs. A range of factors affect the processes of decomposition and stabilisation in different climates/soil types so the same inputs can lead to different amounts of SOC



In general, bigger changes are seen with a change in land use or major rotational changes, rather than changes in management (e.g. reduced tillage, use of cover crops). But it is important to note that there are some general limitations to the effectiveness of C sequestration in soil or vegetation:

- The amount of C locked up is finite: the increase in SOC content ceases as a new equilibrium value is approached. The period of transition is often 25-40 years and is usually slower when SOC is increasing than when it is being lost. Long-term studies clearly show that SOC does not accumulate indefinitely;
- The process is reversible: the change in land management leading to increased C in soil or vegetation must be continued indefinitely to maintain the increased C stock. For example, if a grass or legume ley is included in an arable cropping system at least part of the SOC accumulated during the ley period is lost after ploughing for the next arable phase, though there will often be some overall increase in SOC in the long-term compared with continuous arable cropping if the ley-arable rotation is continued;
- Land management changes leading to increased soil C may either increase or decrease fluxes of the other more potent greenhouse gases: N_2O or methane. Hence it is essential to consider the full GHG budget not just the impacts on SOC.

Even with these limitations, sequestering additional SOC will make some contribution to climate change mitigation in the medium-term, depending on the options available for changes in management practices or land use. Practices leading to SOC accumulation can also start immediately without the need for development of new technologies. Even where there is no net additional transfer of C from the atmosphere to soil, and thus no climate change mitigation, increasing or maintaining the SOC is almost always beneficial for soil health and function, especially in agricultural soils. However, experience has shown that improvement in productivity in arable systems after improved organic matter management takes some time to appear.

Defra research has shown measurable benefits of improved organic matter management, in addition to any nutrient supply benefits, but these are often only realised after at least six years of implementation. Increased SOC has positive impacts on soil physical properties, including increased stable aggregates, decreased risk of run-off, erosion or surface capping, increased rate of water infiltration and increased water retention. It has been shown that even small increases in SOC can have disproportionately large impacts on aggregate stability, infiltration and the energy required for tillage. To deliver these benefits for production, ensuring that there are regular additions of organic matter to "feed" the soil is more important than achieving any particular measured value of SOC.

In UK arable farms, practices with positive benefits on SOC include:

- reduced intensity of cultivation;
- reducing periods of bare soil – continuous green-cover cropping systems;
- targeted steps to increase soil organic matter through managed additions of organic materials.

These measures, together with the monitoring of soil organic matter levels, are the focus of the new Sustainable Farming Incentive – Arable and Horticultural Soils Standard. Land-use change e.g. increasing woodland or rewetting peatland under arable cultivation can also have major impacts on the C stock in soils.

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Forage maize variety selection for the 2022 growing season

The British Society of Plant Breeders' 2022 Forage Maize Descriptive Lists (DL) provide a range of parameters that growers can use to select suitable varieties within the appropriate maturity range for their growing conditions. Parameters include dry matter yield and ME yield per hectare as well as, starch % and cell wall digestibility. Scores for early vigour, standing power and eyespot resistance can be useful for selecting varieties where sites have higher risk of poor establishment, lodging or eyespot incidence. The *Favourable* DL uses trial data from sites with the longest potential growing season, with warmer spring soils for early establishment. Trials data from *Less Favourable* sites show performance of varieties in shorter, cooler growing seasons.

Varieties on the *Very Favourable* DL, a stand-alone List, may be suitable for producers growing to maximise yield as a feedstock for anaerobic digesters where sites have a long growing season and very favourable conditions. ME yield is also an important factor for achieving high biogas yields so should be taken into consideration.

The last few years have tested the Descriptive List varieties with a range of challenges such as cold springs delaying sowing and testing varieties' early vigour, prolonged drought conditions and high temperatures challenging growth with some high levels of lodging and some very wet conditions delaying harvest. Nutrient and spray applications are in accordance with the commercial crop surrounding the variety trials, providing best practice, commercial agronomy, ensuring relevant growing and assessment conditions. Once established, trials are protected from pests and ongoing development is monitored by the trials teams with guidance provided by the trials coordinator (NIAB) and BSPB's maize technical specialist.

Trials are inspected by NIAB and BSPB inspectors to assess the establishment of each plot, plant populations are standardised and any plots with significant issues may be excluded from the trial, whilst data is scrutinised to identify potential varietal

or seed lot issues. Trials are also inspected prior to harvest to ensure harvest data are valid and reliable. Trials are assessed for disease incidence, lodging and brackling and must be harvested at a dry matter of between 28% and 35% to be included in the data matrix. Reserve sites are included in the trial programme in case of trial losses.

Maize breeders, through the BSPB, are invited to tour some of the trial sites each year to view their own varieties under test and also observe the trial conditions. The BSPB Maize Crop Group meets three times a year to review the trials programme, data, statistics and ongoing development for the trial year ahead. The DL panel determines which varieties make the first choice DLs and consists of breeders, growers and independent industry representatives. The Descriptive List trial procedures reflect the national list VCU (value for cultivation and use) trials procedures held by the Plant Varieties and Seeds section of APHA, which also has a procedure development group consisting of technical experts from across industry.

Since exiting the EU, all maize varieties sold in the UK must now be included on the UK National List, which requires two years of VCU trials. The data produced from the Descriptive List trials programme includes a minimum of four growing seasons data for each variety, through rigorous, independent evaluation of the varieties across up to thirteen sites across the country, providing robust information to support the resilience of forage systems within the changeable UK climate.

New varieties

Two new varieties, Gema from Limagrain and KWS Exelon, have been added to the 2022 Descriptive List for *Favourable* sites. Gema also makes the List for *Less Favourable* growing conditions.

Favourable sites

On the *Favourable* DL, KWS Exelon is one of the highest yielding at 18.9 t/ha, with an ME yield of 222 k MJ/ha, starch yield of 6.45 t/ha and excellent eyespot resistance. Gema has the highest starch yield of the list at 6.55 t/ha with good standing power and eyespot resistance. The highest yielding variety on the List is the Limagrain variety Resolute from 2020, achieving 19 t DM/ha at 32.9% dry matter, with the highest ME yield of 224 k MJ/ha and very good early vigour.

Less Favourable sites

Data from the *Less Favourable* trials sites show Gema has high starch at 36.7% and good resistance to eyespot. Resolute has the highest dry matter yield per hectare and highest ME yield on the *Less Favourable* DL, as well as good early vigour.

Growers looking for highly digestible, good quality silage in more challenging growing conditions should look for early maturing varieties with good early vigour to make best use of a shorter growing season.

Very Favourable sites

Four varieties have been added to the *Very Favourable* DL; Mantilla from Limagrain, Neutrino from Saaten Union/Elsoms, RGT BIXX from RAGT and SPYCI CS from Caussade. Each are high yielding with good ME yield per hectare, good early vigour and good standing power.

The standalone, *Very Favourable* DL includes some varieties that are also found on the *Favourable* and *Less Favourable* Forage Maize DLs as well as some unique to this List.

The BSPB 2022 Forage Maize Descriptive Lists are available to download from the BSPB (www.bspb.co.uk) and NIAB (www.niab.com) websites. The Descriptive List trials programme is also supported by the Maize Growers' Association on behalf of their members.

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Emerging agritech

In 2016 the McKinsey Global Institute ranked agriculture as the slowest of all sectors to adopt digital technologies. No-one needs to spend long on a farm to realise that the world has changed. The array of technologies, both digital and otherwise, available to a grower is huge. Most people think of robots, drones, vertical farms and precision agriculture techniques as agritech. Technologies such as farm management software and tractor guidance systems have become so embedded in the industry that they are often overlooked. Others, including advanced pesticide formulations and improved plant genetics, are hidden from view but the effects are significant. What is clear is that agritech is going to make a step change in the productivity and sustainability of the agricultural sector.

It is difficult in a single article to scratch the surface of the range of emerging agritech technologies, but this item aims to provide an overview of how NIAB interacts with the companies producing these innovations and how we are helping bring them onto farm.

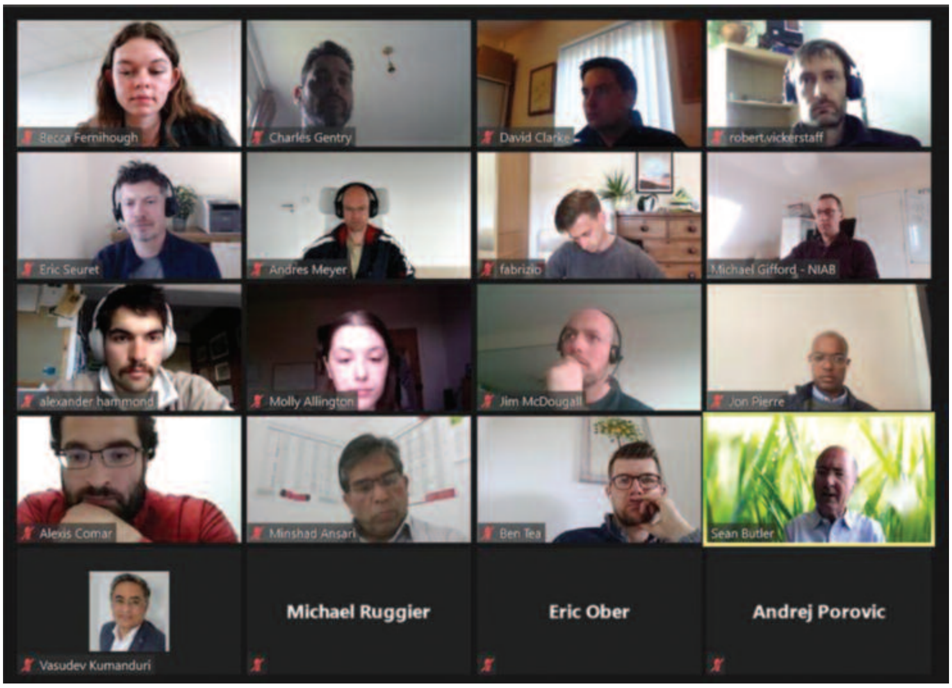
Tests and trials

For over a century NIAB has led the UK in testing and trialling new developments in agriculture. One of the main services offered to agritech companies is the inclusion of products in our trials programmes. In the past this was largely comparative assessments of varieties or treatment regimes. More recently the scope has extended to evaluating technologies as diverse as robot weeders, novel growing systems, AI powered identification algorithms and plasma seed treatments.

The benefit to the companies in question is an unbiased, scientifically robust approach to evaluating their technology. The results of the trials then inform the company with regards future development of their products as well as providing valuable data to support both marketing and fundraising activity.

Collaborative development

Largely driven by the availability of funding from Innovate UK (and its forerunner the Technology Strategy Board), NIAB regularly collaborates with agritech businesses in the development of their technology. While this often includes an element of testing and trialling as outlined above, collaborative development adds a level of engagement from NIAB in creating or advancing the technology development. The range of skills and expertise within NIAB that can be brought to bear on problems or opportunities is wide. Depending on the nature of the funding, NIAB may end up with a stake in the future of the technologies developed. This provides an income stream to fund further development and creates a strong virtuous cycle.



Barn4 virtual member seminar

Barn4 opened at Park Farm in March 2021

Barn4

Barn4 is NIAB's agritech incubator, built with the support of the Cambridgeshire and Peterborough Combined Authority, and opened in early 2021. Barn4's remit is to provide support to agritech start-ups and SMEs through the provision of facilities and the linking of companies to the wider NIAB organisation.

Despite opening during the depths of the pandemic demand for memberships has been strong and 13 companies have joined since March. While some have access to the physical space within the Barn4 building on Park Farm, others have taken advantage of the virtual option which allows them to gain a range of benefits including training, virtual networking invitations, free tickets to external events and most importantly the support of the Barn4 team in developing connections both within NIAB and its wider network. While most members are UK-based this has also provided a useful landing point for Weedbot (robotic weeding) and Quicktrials (trials management software) who hail from Lithuania and Switzerland respectively.

Germination Programme

Developed as a part of Barn4's activities, the Germination Programme is a very specific level of support available to individuals, teams or very early-stage companies to help them develop concepts for new agritech businesses. The support varies depending on the ambition and level of development of the concept. It includes a free period of Barn4 membership and help developing both the technology but often more importantly the underlying business plan.

To date we have worked with an aeroponic system developer, a grower of vegetables for use in South-Asian cuisine and two companies looking at variety development for different purposes. The application process is very straight-forward, quick and always open. For entry to the Germination Programme the only real requirements are imagination, energy and a passion for agriculture.

Meeting of minds

The Meeting of Minds initiative has been running for a number of years. In its basic form it is a 90-minute workshop attended by the agritech company and a team of experts from NIAB. The company presents their technology and business for 20-30 minutes before questions and suggestions from the NIAB panel. The resulting discussions are insightful and direct and provide the agritech company with real insight into the industry, its challenges and what the impact of its technology could be.

Feedback from participants shows that Meeting of Minds sessions are always useful for companies and they often lead to further interaction either in the form of collaboration, trials programmes or Barn4 membership.

Grower panel

While it is great for NIAB to be directly engaging with and supporting emergent agritech, one of the most common difficulties these companies face whilst developing their technologies is access to growers, agronomists and their advisors.

The Barn4 team has started a Grower Panel to provide this link. To prevent this being used for direct marketing, the Barn4 team does not provide Grower Panel member contact details to agritech companies but will instead let Panel members know where there is an opportunity to get involved. This may be through on-farm trials, providing advice on "real" industry challenges, or attending events at Barn4. Panel members are free to take part in as much or as little of this as they want.

If you are a grower, agronomist or farm advisor and have an interest in engaging directly with developing agritech companies then please email contact@barn4.com and one of the team will be in touch about Grower Panel membership.

Case Study – Outfield

Founded by Oli Hilbourne and Jim McDougall in 2016, Outfield was initially focused on providing survey services to farmers. While the team managed to secure a number of contracts to map field boundaries it rapidly became clear that there were issues with the business model. Through a chance meeting with Michael Gifford (long before he joined NIAB) Outfield was introduced to NIAB's Sean Butler who organised a Meeting of Minds.

Oli's presentation provoked an interesting discussion which made it clear that the economics of arable farming was unlikely to sustain contract drone flying at any kind of scale. The meeting went on to explore how Outfield and NIAB might collaborate on an opportunity to pivot their business into the top-fruit sector through drone-enabled blossom counting. A successful proposal to Innovate UK led to a three-year project with NIAB EMR. Outfield counted the blossom from its drone imagery and NIAB provided the ground truthing.

The outcome of the project has formed the basis of a commercial product and an agreement is in place for revenue sharing between the consortium partners. NIAB and Outfield continue to work together and engage at a number of levels both technically and commercially.

Outfield now provides a suite of commercial services to apple growers, including blossom maps, fruit and tree sizing, yield estimation and thinning prescriptions. Still based in Cambridge, it operates across a number of countries around the world.

Oli Hilbourne, Outfield's Founder, comments that "the engagement and collaboration with NIAB has made a huge difference to Outfield's development and we see them as a key partner going forwards."

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Integrated weed management – implementation and solutions

IWMPRAISE

As weeds become increasingly challenging to manage as a result of diversifying systems, climate change and herbicide resistance, adopting a strategy that follows the principles of Integrated Weed Management (IWM) will be vital in maintaining sustainable levels of control. IWM is the integration of multiple control options which take account of weed biology, mechanical control and chemical control to reduce the reliance upon herbicides. Research into IWM techniques has been on-going for over 50 years, however adoption of these practices at a broad scale is currently limited. Practical Implementation and Solutions for Europe (IWMPRAISE) is an EU-funded Horizon 2020 project of which NIAB is one of 37 partners across eight European countries, with a key aim of supporting and promoting IWM practices leading to greater uptake by growers.

Cultural control across a range of species

Reflective of the key crops in Northern Europe, there has been substantial focus on combinable narrow-row crops. From a weed management perspective, the focus of UK growers for the last twenty years has been black-grass, and this species is often dictating farming practices. The backbone of cultural advice for this species has been to use delayed autumn drilling, or spring drilling to exploit the biology of this weed species – reducing the populations in-crop. As uptake of these techniques has been a win for weed science, it is important to consider other weed species, and characterise the effect of these techniques on them.

Cultivation strategy is an equally important consideration when dealing with future threats. As part of the IWMPRAISE study a footprint of cultural weed control has been applied to black-grass, Italian rye-grass and a mixed population of broad-leaved species to demonstrate the relative strengths and weaknesses of common advice. This combines the effect of ploughing, deep non-inversion and direct drilling with early autumn, late autumn and spring establishment.

The use of spring cereals, such as spring barley or spring wheat, as a rotational tool at sites with high density can be very effective, as this trial demonstrates (Figure 1), with incredibly low levels of seed return recorded – a

Figure 1. Population of rye-grass heads in untreated plots from 2019

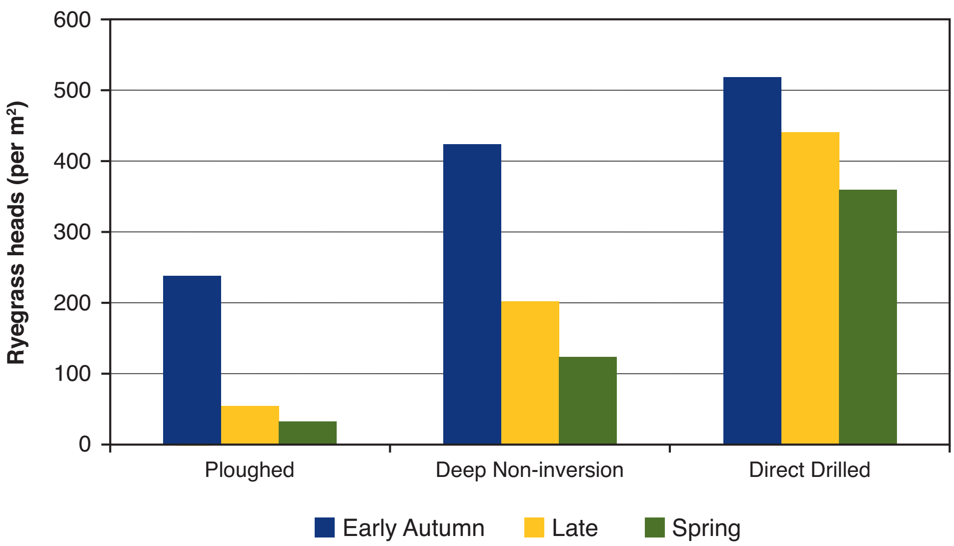
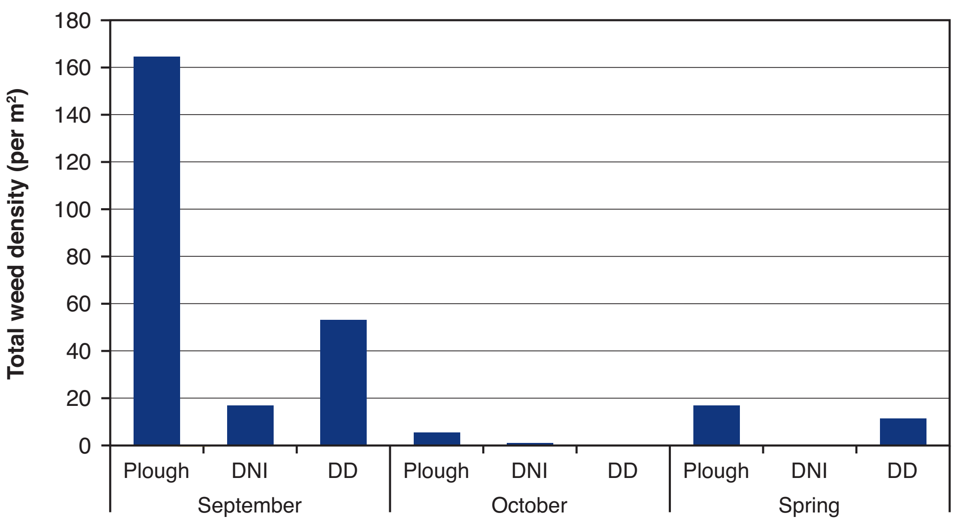


Figure 2. Weed density of a range of broad-leaved weed species in herbicide untreated plots



reduction of 98% compared to the autumn drilling date. For Italian rye-grass this tool is blunted with reductions of 56% and 82% recorded across two seasons. Whilst the reduction in seedling numbers is comparable, and therefore the spring emerging cohort is not necessarily larger, this species is far more competitive in the spring when compared to black-grass, most notably in direct drilled crops. For broad-leaved species there was both a change in density, but more importantly a change in species. The effect of delaying autumn drilling is most profound, where the combination of October drilling and direct drilling resulted in no broad-leaved species emerging in crop (Figure 2). Spring infestations were primarily associated with species such as bind-weed and fat hen. Currently, herbicide resistance in broad-leaved species is extremely scarce, although herbicides can become ineffectual due to uncontrollable factors such as weather, so maintaining a strategy of delayed sowing is useful in reducing the requirement for chemical interventions.

Mechanical methods are part of the future

IWMPRAISE has many commercial partners who have provided access to machinery and other products to enable research to be carried out. Garford Farm Machinery Ltd is one such company, providing NIAB with a RoboCrop inter-row hoe and banded sprayer for evaluation. Not a strictly novel technology, mechanical control is widely used in horticulture and the technology is now available to accurately apply these methods to narrow row crops such as winter wheat. Extensive studies have been carried out to evaluate the potential contribution that inter-row hoeing can have for grassweed control (Figure 3). This has shown that it is a tool that can significantly reduce weed populations even after a robust programme of pre- and post-emergence herbicides have been used. Deployed in the spring, prior to full canopy closure, the additional control provided can be between 10-15%, dependent on the soil conditions on the day of hoeing. A challenge with spring tillage, particularly on the heavy soils around Cambridge, is that soils are either too wet and re-rooting of weeds is common, or the surface bakes hard and penetration with the blades is compromised.

Spatially segmenting control strategies has been suggested to be part of the future of weed control – combining inter-row cultivation and on-row band herbicide applications has the potential to significantly reduce herbicide use without compromising weed control. When used against broad-leaved weeds, at extreme populations, the combination was as effective as the broad-acre application – which resulted in a 64% reduction in herbicide use (Figure 4). From this trial it was interesting that row width had no effect on the success of the inter-row cultivation, which was poor. Similar results were found in spring barley, however the black-grass populations were low across the trial, demonstrating the value of spring cropping as a whole.

Weed control in vineyards

Weed control in vineyards is commonly achieved through the use of herbicides. However, given the on-going loss of herbicide actives and the increasing popularity of organic produce among consumers there is a need to adopt alternative, non-chemical methods. The IWMPRAISE trial in the demonstration vineyard at NIAB EMR aims to

Figure 3. The effect of inter-row cultivation on black-grass head density. Error bars indicate standard error

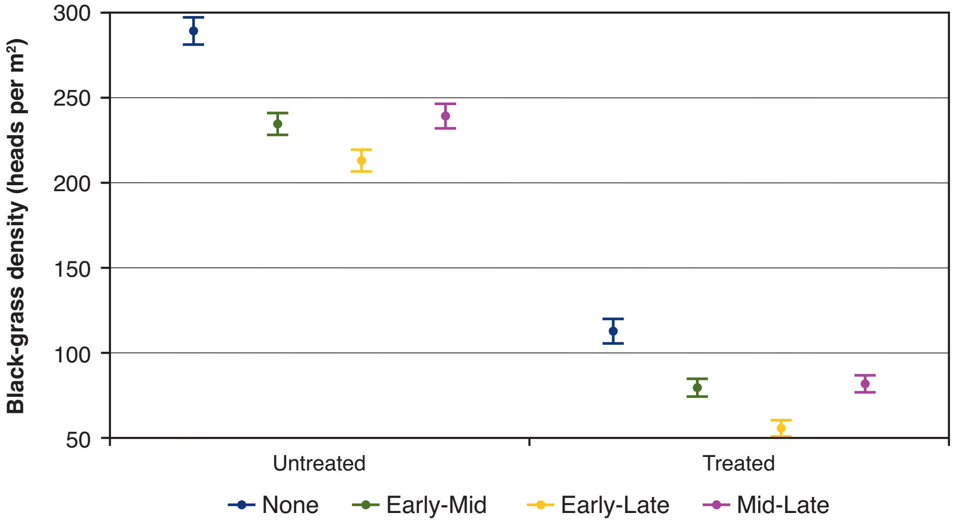
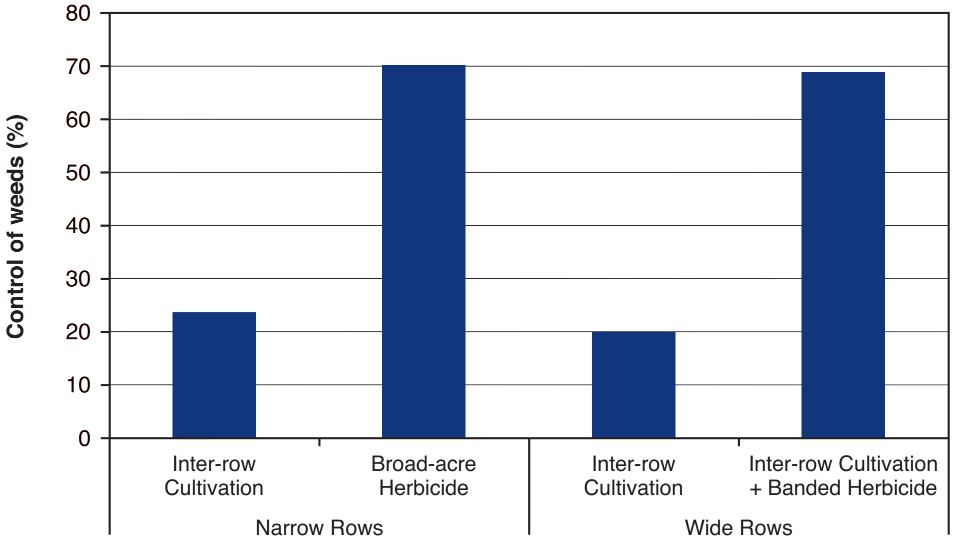


Figure 4. The control of broad-leaved weeds with a range of herbicide strategies

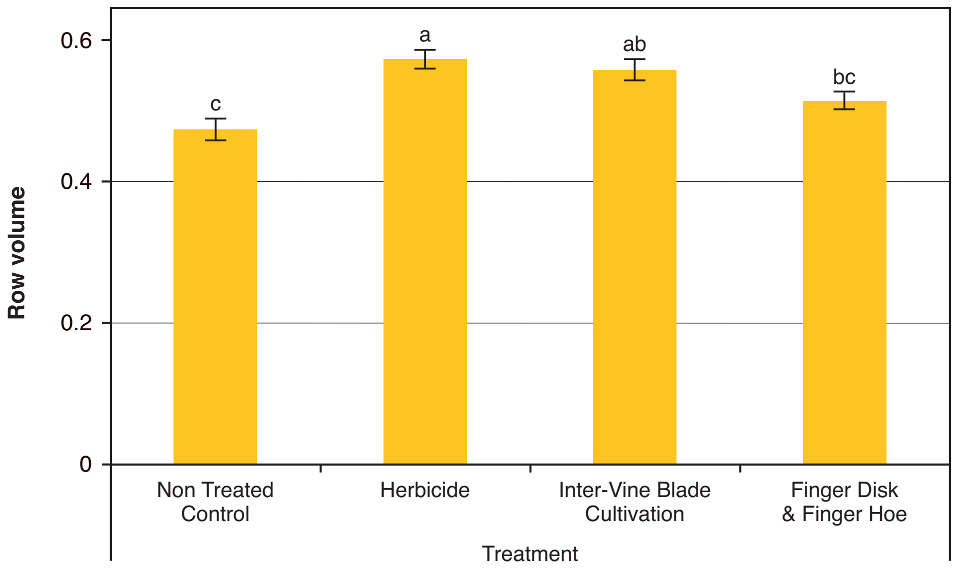


assess the potential of two mechanical weeding methods (blade and finger disk/finger hoe) to serve as alternatives to the commercial standard practice of chemical weed control without jeopardising either the yield or quality of grapes.

The results to date (Figure 5) indicate that there is no disadvantage in using mechanical weeding methods compared with a standard herbicide-based regime in terms of fruit quality (Brix, acids, nitrogen balance index (NBI)), vine vigour (leaf wall area), or yield. Meanwhile, vines in the untreated control (strimming only) treatment had significantly lower yield and quality parameters in 2020 presumably due to the effects of weed competition (Figure 6). This indicates that mechanical weeding methods offer a real alternative to chemical weed control, without any detriment to grape yield or quality. The 2021 season looks set to continue this trend, with both the herbicide and mechanical weed control treatments exhibiting significantly higher NBI values and number of inflorescences at flowering (an early indication of yield) in comparison to vines in the control treatment.

The range of work under-taken as part of IWMPRAISE has shown that adopting and integrating alternative strategies will strongly contribute to maintaining the control of weed populations at the high levels required to prevent rapid infestations building within crops. Although in the majority of scenarios herbicides will still be required, by diversifying control strategies it is possible to reduce the need for them, either by using altering the cropping rotation and using competitive crop species, or by introducing mechanical control techniques.

Figure 5. The effect of different weed management strategies on vine row volume at flowering (June 2021)



This trial was carried out by NIAB as part of IWMPRAISE © 2019. All information produced by NIAB is copyright and is not to be reproduced in any form or distributed to other persons without written permission of the Group. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 727321.

Figure 6. A section of the IWMPRAISE trial in the vineyard at NIAB EMR. From left to right: mechanically weeded (blade), non treatment control (strimming only) and herbicide-treated. Note the chlorotic symptoms of vines in the NTC row (centre)

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Aphid management in potato seed crops

One of the consequences of milder winters is the early arrival of aphid species which vector the potyviruses (PVY strains and PVA) that can infect potato seed crops, causing downgrading or loss of the crop and potential increase of virus incidence in ware crops. This was clearly illustrated in 2020 during an AHDB Potatoes funded experiment at NIAB Cambridge. *Myzus persicae*, a principal vector of PVY was counted at 847 individuals in one yellow spore trap in late May, just a week after 30% emergence of the trial crop. Protecting potato plants from the early ingress of aphid vectors is critical for healthy seed tubers, and has become more difficult with loss of insecticides, aphid resistance, and the inherent difficulty of preventing transmission of non-persistent viruses which can enter the plant after very short feeding probes.

The use of mineral oil sprays to prevent non-persistent virus transmission has been investigated in several countries over several years, and some oils are used commercially in continental Europe on potato seed crops. In the UK, previous AHDB-funded work from 2011 to 2013 showed that they did reduce potyvirus levels in seed tubers, but the effects were variable from site to site and year to year. One of the potential reasons for this variability was thought to be timing of the sprays, particularly at the early stages of crop emergence when rapid leaf development could leave material un-protected, but also at the end of the season before burn-down had been fully achieved.

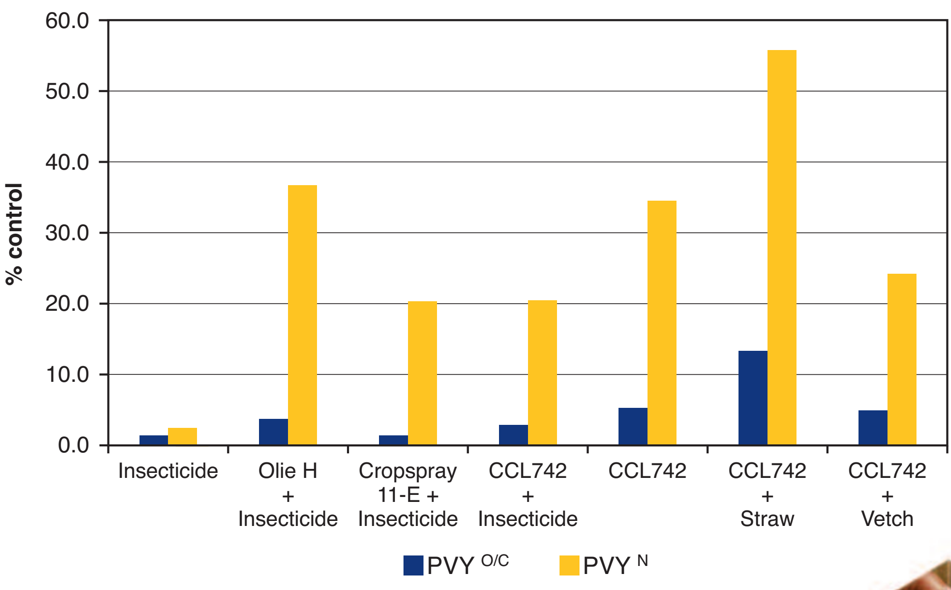
A new project in 2020 therefore aimed to investigate the timing and frequency of early stage mineral oil applications, from 30% emergence, and their continuation after the application of burn down products. In addition, some new cultural options were investigated in conjunction with the mineral oil sprays. These were the use of a straw mulch between the rows, and an inter-row

Vetch plants on 30th June – development probably too late to have any barrier or stylet wiping effect

sowing of vetch. Straw mulches are thought to reduce the visual contrast between the soil and crop, making it more difficult for aphids to locate green material. Inter-row vetch could be acting as a barrier to aphid movement, or have a "stylet wiping" effect. One treatment within the trial used all available insecticide products, within label recommendations. Infector plants carrying PVY strains were planted in rows alongside the test plots. The incidence of PVY $^{O/C}$ infectors in the planted trial area overall was 14%, while PVY ^{N} was 2%.

Two trials have been carried out – the first at NIAB Cambridge during 2020, and the second in Scotland during 2021, which is still ongoing. This was to achieve contrasting vector pressure, while keeping all other aspects of the trial identical. The 2020 season did indeed suffer from very high vector pressure, providing a substantial contrast to the low aphid numbers seen at the Scottish site this year. Results from the Cambridge work clearly showed a reduction in virus incidence in harvested tubers from mineral oil treatments compared to untreated and insecticide only treated plots. The addition of a straw mulch provided additional reduction, though there was no additional effect of the vetch companion crop (Figure 1). Vetch also reduced yield of seed-grade size tubers, presumably through competition for water.

Figure 1. Mean percentage control compared to untreated for oil and insecticide programmes, Cambridge 2020. Infector pressure was much higher for PVY $^{O/C}$ than PVY ^{N}. Olie H is a mineral oil used in previous AHDB-funded projects, and CCL742 is a new product, known as Vazyl Y in France



Tuber borne PVY

Straw mulch between the rows, 10th May 2020

Rapid burn down was achieved in the trial, but mineral oil sprays continued while green material could be seen

While the NIAB Cambridge trial created deliberately high infector and vector pressure, and complete control of virus was not expected, the results illustrate the effectiveness of mineral oils, and the mulch treatment. It is probable that the mulch helps protect the crop in early growth stages, when even weekly oil sprays could leave newly expanding foliage without oil cover. The practical considerations of applying and disposing of straw mulches in commercial situations, harvesting the seed tubers, as well as cost, all need further investigation, and work in AHDB's Strategic Potato (SPoT) Farms this year will go some way towards this. Though the inter-row vetch did not give any additional reduction in virus, this could have been due to its comparatively slow growth during the early stages of crop development, and failure to create a sufficient physical barrier. A faster growing inter-row crop, with less competitive effect, may still be a viable option. However, there is also much potential for more field or landscape scale plantings to be effective in aphid management, such as wild flower strips within crops or on headlands, to encourage aphid predators.

The only mineral oil currently approved for use in the UK is Newman Crop Spray11E, for applications up to tuber initiation, and registration of the products used experimentally in these trials is still ongoing. Genetic resistance to potyvirus infection is also an important factor to consider for the future, but only a small number of varieties in the National List testing system have complete resistance to PVY strains. However, potential does exist for breeders to incorporate resistance in new varieties.

Acknowledgements

Thanks are due to funding from AHDB Potatoes project number 11120177, and colleagues at SASA, SRUC, BiOSS and Scottish Potatoes.

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Improving biodiversity and farm returns

Of the 369,000 known species of flowering plants, only about 7,000 have been cultivated for food, forage, fibre or fuels. And just 30 underpin the world's food supply. Only three: rice, maize and wheat, contribute nearly 60% of calories and proteins obtained by humans from plants worldwide.

Agrobiodiversity conservation for food security is an increasingly hot topic, and Professor Nigel Maxted, at Birmingham University, has been driving action and understanding for conservation of resources – such as landraces and crop wild relatives. He leads a multi-organisational group (the UK Plant Genetic Resources Group) which investigates ways of conserving and understanding resources. But it is important to maintain the *need* and *utilisation* of those resources by actually growing and developing a diverse number of crop species by farmers.

In the UK, 75% of arable-farmed land is accounted for by three crops: wheat, barley and oilseed rape. Similarly, apples and strawberries account for a large proportion of the UK's fruit production, with carrots, onions and brassicas the leading vegetable crops. This dependence on relatively few crops highlights a potential risk to food security and agricultural resilience. Plant breeding and crop husbandry developments continue to support high productivity, but on-farm yields of several key crops have shown little increase over the last three decades.

For some crops, such as oilseed rape, adverse weather, loss of agrochemicals and increased pressure from pests or diseases have led to a decline in the area grown. And the UK is far from self-sufficient in protein crops and imports a huge volume of soybean products each year, mainly for use in animal feed.

With the need to support healthier diets, address climate change and protect the environment through sustainable land management, the identification of new and forgotten species is vital. But they must be economically viable, suited to UK conditions and if possible, enhance diversity of cropping systems too. New production methods like indoor/vertical farming, changing climate, advances in crop establishment and harvesting machinery and new plant breeding techniques mean that the introduction or reintroduction of some novel or underutilised crops may now be feasible.

Figure 1. Spring Ahiflower demonstration at NIAB Innovation Farm and a close up of a flower (AKA Buglossoides arvensis)

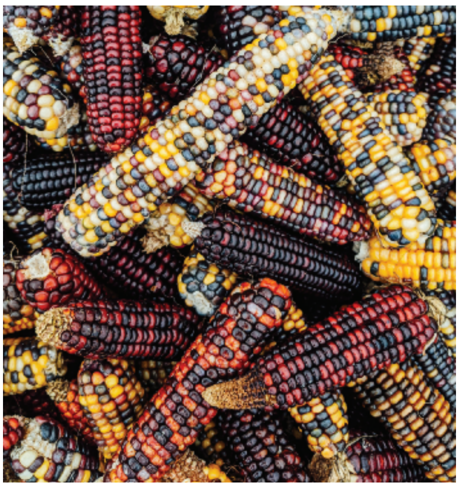
Working with Defra and SRUC, NIAB is exploring the scope for reintroducing more diversity, identifying some of the best from a long list of possible candidates. Our brief was to focus on crops with food, feed, and pharmaceutical uses, and assessing potential opportunities, benefits, barriers and risks for farmers, end-users and possible environmental consequences of introduction.

We set out with a completely open mind and have identified more than 430 possible crops, but some were already well established in the UK, extremely niche, or clearly unsuited to UK conditions. From this we have identified around 160 that have made it onto the final long list that could be cultivated, either in the field, under protected cropping or even in vertical indoor conditions. The next step is to generate a shortlist of the most promising candidates, using a range of suitability, cultivation, economic, environmental criteria that will be agreed with a wide range of stakeholders. Failure to reach the shortlist is not the end of the story; it may be that there is potential for future success, but a major research input or other developments would be needed.

One recent success that came out of NIAB crop development is ahiflower (Figure 1), renamed and developed from field or corn gromwell, a species only ever known as a weed of second wheats. This new crop has benefited from nearly two decades of research and is now a small but successful UK crop, available with Natures Crops International (www.ahiflower.com).

But there will be others that show potential for development and introduction in the short, medium and long-term. Some species that did not make the list include Wild leek, Yarrow, Bambara groundnut, Cowpea and Fonio,

Vigna spp groundnut



Diversity in Maize genetic lines; Germany (pic Winkler)

Yarrow

Bambara

Figure 2. A potential Hemp product

Photo: East Yorkshire Hemp Company

Figure 3. Cultivation and harvesting hemp flowers in Jersey

Photo: Jersey Hemp

rejected for a range of reasons. Wild leek is small and slow growing and unlikely to provide an interesting addition to existing cultivated allium species. Yarrow can be used as a mild pharmaceutical herb to help combat the common cold, but is fairly unpalatable and shows no clear market potential. Bambara groundnut and Cowpea grow well in tropical and semi tropical regions, but are very poorly adapted to UK conditions and work to change this would not be affordable for crops with no obvious domestic market. Fonio is a small grained west African species, quite similar to millet. While it is gluten free and much liked by African consumers, it has limited immediate use or cultivation in the UK.

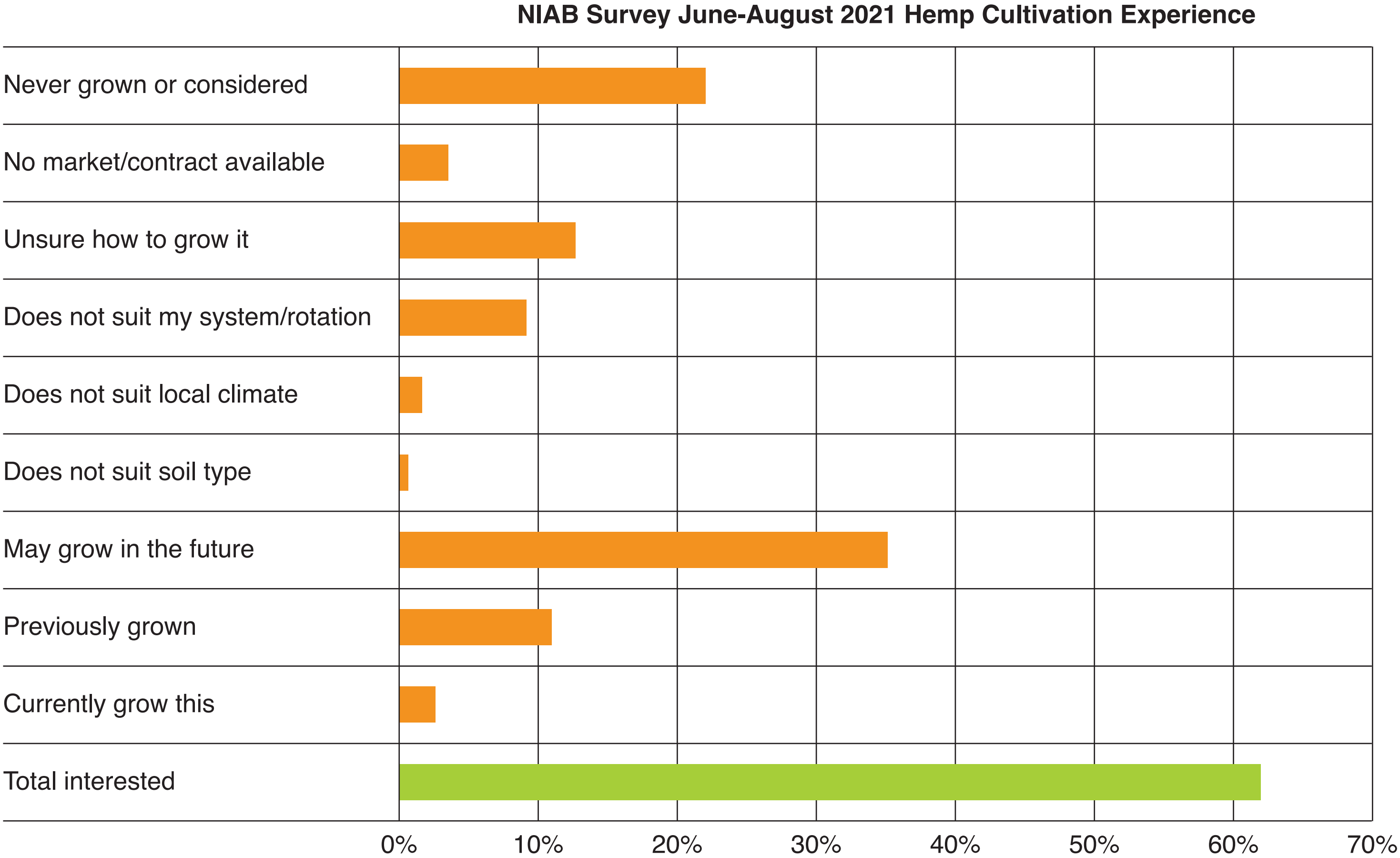
One crop with much potential, and which could form the basis of longer term studies, is hemp (Figures 2 and 3). This species has a number of favourable attributes, including: ease of cultivation in many parts of the UK; low input requirement; beneficial levels of carbon sequestration; good economic returns for the farmer and a marketplace for its many outputs that is already in place and growing at a significant rate. But there are still several issues that will need to be addressed, beginning with a difficult and expensive legislative structure, requiring a Home Office licence for cultivation, even for very safe varieties with respect to psychotropic drug content. There is also a lack of grower guidance, complete reliance on imported seed, through a lack of UK seed and varieties, and lack of post-harvest processing equipment.

As part of our ongoing underutilised crops study, we are engaging extensively with growers and agronomists, including an on-line questionnaire that has just been completed. Of the more than 200 respondents, over 35% expressed an interest in growing hemp in the future (Figure 4). And when taking into account all those who were growing the crop now, had grown it or could grow with more knowledge, this proportion went up to over 60%. ELMs legislation, that will impact UK farmers in the post-Brexit climate, is likely to further encourage farmers to consider hemp, in view of its positive impact on soil organic carbon, reduced need for ploughing and provision for more diversity in the farmed environment.

There are other studies ongoing, including a review of forage and fodder species that are used in livestock production. The outcomes from both completed and planned farmer interactive workshops, alongside web-enabled questionnaires are all contributing to a strategic consideration of how the UK farmed landscape could change in the coming years. NIAB is working closely with government, growers, researchers, agronomists and end users to identify potential and development needs of underutilised crops that could benefit farmers and help to realise carbon reduction targets.

If you would like to participate in the online workshops planned for November and early December, please contact NIAB on niabtagnetwork@niab.com.

Figure 4. NIAB online farmer questionnaire percentage response of 203 UK growers and agronomists



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Labelling of certified seed: how to spot a fake and next steps

Now we all know how important seed certification is and how we should keep labels etc. Anyone spot the problem?

Not the most controversial thing ever to appear on Twitter but there it was, attached to a photograph with the challenge to spot the problem. The species did not match the variety, a point to all those that responded, but what about all the other questionable details? If we all know how important seed certification is, do we all know how to spot a fraud? Does everyone even fully check the labels? And, if you think it is a fake, what do you do next?

The process of certifying seed starts when varieties are first being introduced, often before completing National List testing. Seed certification is essentially a quality assurance process that starts before a seed crop is drilled, has various administration steps, plots are established and recorded, a field inspection (or two, or three, etc.), a seed testing element and fees. Growers can be confident that what they buy is the variety it claims to be, and which meets, or is better than the set purity and germination standards; and if it is not, they have a mechanism to complain and have it investigated. This system has been in place for many years but is constantly reviewed and evolving to fulfil the original brief – to provide seed of a suitable quality for farmers.

In the past, rumours have circulated within the trade of seed bearing fake certified labels and not actually certified. Without evidence no meaningful investigation was possible and people were unwilling to come forward with what amounted to suspicions of where such seed was originating. The belief that such seed was entering the system was, however, undermining the seed industry as a whole. If farmers could not trust that they were buying real certified seed, why pay the premium?

Figure 1. Example of label that could be attached to C1 seed

Pressure on the system rose – it was time for a change.

The Organisation for Economic Co-operation and Development (OECD) provides international standards for the movement of seed under the seed schemes. Representatives from the member countries agree the standards before implementing them at home. The UK has been involved since the beginning over 60 years ago, and NIAB currently has the role of co-ordination centre for the seed schemes, which is a separate task to the seed certification work on behalf of Defra and APHA.

The problem could not be approached directly so the OECD decided to review labels security and the process of labelling. NIAB's Stephen Flack was given the task of preparing a paper on labelling which included label security as well as having a brief to examine possible advances in labelling technology that might be considered for discussion at the OECD Seed Schemes Annual meeting.

As part of the information gathering for the paper, member countries were surveyed to establish what their existing labelling and sealing processes consisted of, what materials were used, whether their system included any additional security measures and the form they take. The responses were numerous and varied, and collated responses were included in a paper. Following presentation and discussion of the papers at seed member meetings an *ad hoc* working group was established to consider practical ways for countries to improve label security against counterfeiting. Simultaneously the group had the task to consider how to develop other labelling systems which might give other advantages for container recognition, speed of handling and fraud prevention.

The Rules and Regulations of the OECD Seed Schemes are agreed by consensus among the member countries, but can be interpreted differently. There

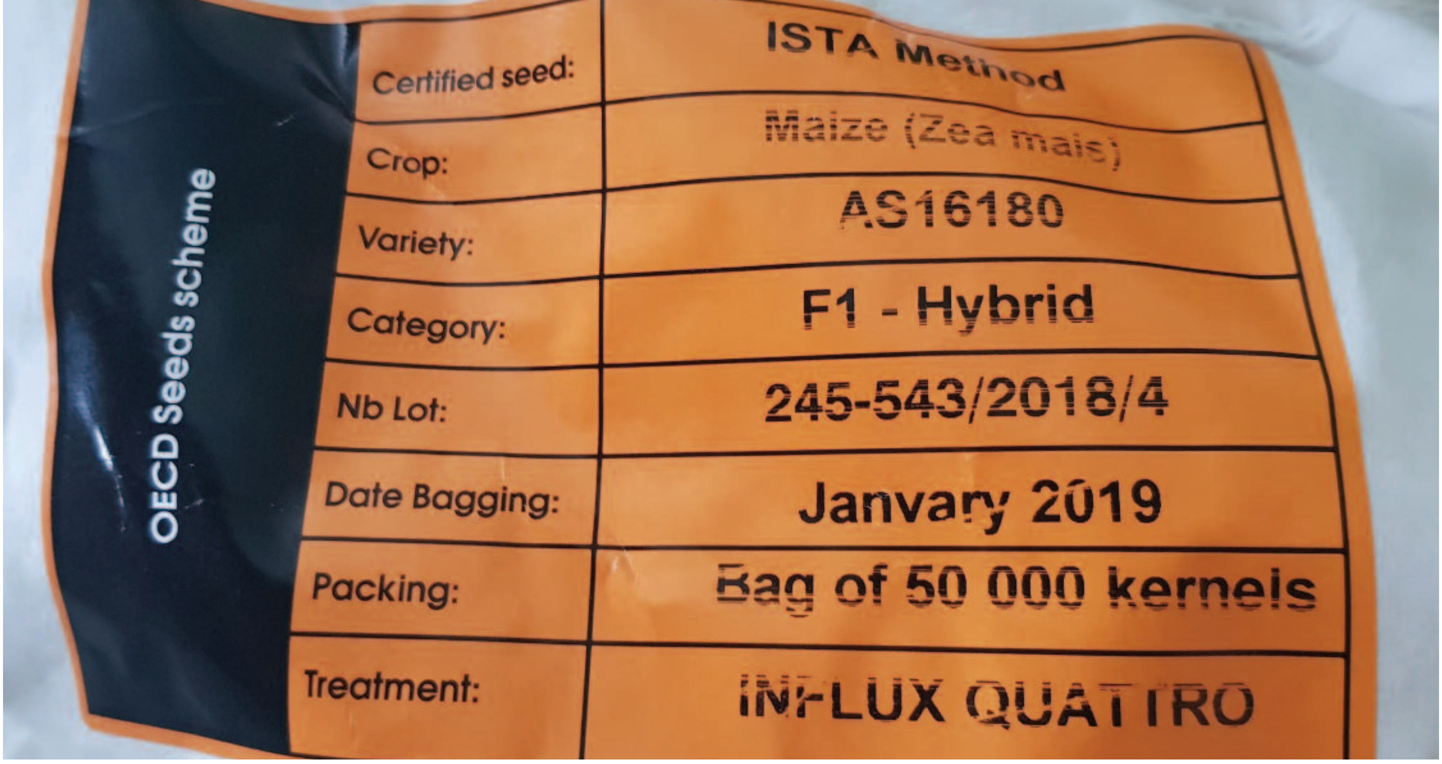

Figure 2. Example of an unauthorised label

can be variations from member to member – labelling is the exception. The format of the labels is specified in the rules and individual countries' designs must be agreed with the OECD Secretariat before use. That means that any seed certified under OECD seed schemes will carry the same style of label, no matter where in the world it was produced. This does not always filter to a national scheme, but here in the UK it does. The requirements for certifying and labelling of seed under the OECD Seed Schemes directly feed into the national systems in the UK (there are three: England and Wales; Scotland; and Northern Ireland). So, there is a certain familiarity between the labels of seed certified in the UK and seed imported from a certifying authority in another member country. However, only seed certified under the OECD Seed Schemes can, and must, carry a 30 mm continuous black stripe down the one edge of the label with specified wording on the stripe.

Labels for certified seed produced in the UK are manufactured by a single officially appointed producer. The criteria and format for the labels is stipulated in the contract with the supplier. The labels must be made from a material that will not dissolve or rip easily and can be stitched through when attached to the bag or container. When the label is removed from the container there must be visible evidence of its removal e.g. stitching through the label results in puncture holes when the stitching is removed. The labels must be rectangular in shape and contain the following information:

- a unique label number (officially allocated to a seed company)
- species
- variety name
- seed lot reference number (allocated during certification)
- month and year sealed
- country of production (seed can be grown in a country different to that in which it is certified)
- weight of the container
- certifying authority – for UK it is Defra, NAW, DAERA and SG
- if appropriate a statement to indicate the seed has been repacked and re-labelled.

The colour of the label is determined by the category of seed. Pre-Basic seed will be white with a purple stripe diagonally across it, a white label for Basic seed, Certified seed of the first generation should be blue labelled and the second and later generations should be red. If the seed was certified outside of England, Wales or Scotland, the label should have a continuous black area along the full left side with "O.E.C.D. SEED SCHEME" and "SYSTEME O.C.D.E POUR LES SEMENCES" (Figure 1).

Signs that a label may not be authentic include:

- if the label is printed on shiny paper
- the colour rubs off
- it is a wheat variety and the species says *Hordeum vulgare*
- the details have been changed after printing
- the same label serial number is on all the bags…the list goes on.

Basically, any deviation from the rules could mean that the label is a fraud and the seed in the container is not as claimed. A very blatant example is shown in Figure 2 – they are not always as easy to spot!

If you have noticed something not quite right about the label of seed, even if not fully sure, contact APHA or NIAB (seed.cert@niab.com) for England and Wales, SASA (Scotland) or AFBI (Northern Ireland) and have the label verified. The seed certification schemes provide a tracking system that follows the seed through multiple generations from breeder to end user – so with a little investigation growers will know if they have bought what they expected.

In the UK all seed of the agricultural species listed in the Seeds Marketing Regulations have to be certified before sale. The certifying authorities have the right to take legal proceedings against anyone found to be marketing uncertified or wrongly labelled seed. Growers have the right to receive the goods they purchased.

Thomas Gent, Oakley Farm, Tydd St Giles, Wisbech

Farmer-led innovation – valuing gentle practice

Thomas Gent, 24, is the fourth-generation on his family's farm, CS Gent and Sons Ltd, on the Cambridgeshire-Lincolnshire border in The Fens. The farm began to convert to no-till and a pioneer of what is now known as regenerative farming practices over a decade ago. Thomas is now still very much based on the farm but is also Founder of 'Gentle Farming' which seeks to reward and recognise farmers carrying out sustainable farming techniques.

So about the farm...

We farm about 800 ha near Wisbech. The land lies mostly on heavy clay and is predominantly a combinable cropping farm, though the rotation is now quite diverse.

How did the regenerative journey begin for the farm?

Dad, Edward, and Grandad, Tony, were at a point where some key machinery was requiring replacement, so it gave them a key decision point. What should they invest in – bigger tractors? But a new approach called 'conservation agriculture' had caught their eye and so rather than bigger tractors they invested in a no-till drill. Quite a few of the neighbouring farmers thought they were crazy; still think they are crazy, in fact, but they were committed to the journey. The initial purchase was a John Deere 750A but it was not well suited to the soils, so it was traded in for a Weaving Big Disc. Tony felt that he could improve the coulter design so he went into the workshop and the patented GD coulter for the Weaving direct drill was born.

What does the system look like now?

I can barely remember seeing the ground ploughed, but can remember being teased about the scruffiness of

the farm a few years in, but it's that diversity that is at the heart of our soil-building system. It is still mainly a combinable crop rotation (wheat, barley, oilseed rape, oats, beans) but we also have quinoa and a range of 'forage' crops destined for a local energy producer (anaerobic digester). We've got long-term cover crops and stewardship mixes and work with others to bring livestock to the system, providing grass for horses and working with a local grazier to bring in sheep to graze the cover crops. There have also been positive benefits of grazing early-sown crops of oilseed rape to reduce the impact of cabbage stem flea beetle larvae. We've been reducing input spend where we can, introducing flower margins, pollen and nectar mixes and diverse margins, helped by stewardship funding. There have been no insecticides on the farm for many years with fungicide spend coming down through careful integrated management.

What impact has there been?

In the first few years after going no-till there was a drop in yields, but wheat yields now average 8-10 t/ha. Soil organic matter levels have increased from a start point of 3-4% to 8-10% across the farm now. We can see the impacts of that on soil structure and, most importantly, on the way water moves in the soils – the crops stay greener for longer than the neighbours' in dry periods, and at the same time, when it's wet we can stay on the land for longer. When a hole is dug we see more and different species of worms busy engineering the soil by mixing and burrowing.

So what about Gentle Farming?

Well, what got me thinking was taking a load of grain to the local merchants. As I came out I saw another local farmer there who farms very differently to us, very much still a high input plough-based system, and he was tipping on the same heap. I know our grain was so differently produced – so why were we selling in the same way and getting the same reward. It made me annoyed and it niggled away at me. So during lockdown, I made it my project to find a way that a regenerative agriculture farmer could get a better return. I talked with others, especially through BASE-UK, and we began to look together. I came across Agreena (a new name for Commodicarbon) a Danish certification programme for C reductions and C sequestration in farming practice. I worked with them to update their framework so it worked in the UK. Gentle Farming was launched in January 2021 and licences the certification for UK farmers. There are now 40 farmers selling carbon credits for 2021 harvest. I'm just getting going. I have, and will continue to make mistakes, but I'm committed. I just want to do what is right to help support our farm and others who are exploring this better way of farming.

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