NIAB TAG

Landmark

ISSUE 43
SEPTEMBER 2020

New maize varieties highlight continued breeding progress

IN THIS ISSUE

Tina Barsby, Chief Executive, NIAB

Impact study highlights socio-economic benefits of NIAB research

In addition to its health impacts, the Coronavirus pandemic has disrupted economic activity, with initial estimates suggesting a reduction in GDP of more than 25% since the end of March.

The House of Commons Science and Technology Committee recently launched an inquiry into the role of research, technology and innovation in the context of the Covid-19 outbreak. In particular, the Committee highlighted the importance of research and innovation in driving economic growth as the UK charts its recovery from the pandemic, citing estimates from UKRI that every £1 spent on research and development in the UK delivers £7 in economic and social benefit.

This inquiry is timely for NIAB, which recently published an independent impact assessment of the value of its research, revealing a return on investment of £17.60 to the wider UK economy for every £1 invested – delivered through improved production efficiency, economic growth, import substitution, export earnings and inward investment.

This is the first ever impact assessment to be commissioned by NIAB, and the study, conducted by economists Brookdale Consulting, focused on five distinct areas of research activity to capture the broad spread of crop-related science and innovation now covered by the NIAB group.

In each of these five areas, together accounting for around 20% of NIAB's total research income, the study identified a high-level of ongoing and potential future impacts, reflecting NIAB's unique interconnecting role between fundamental science and practical application.

The case studies also highlight the diversity of routes through which NIAB today is delivering socio-economic value and impact, including the provision of statutory services to the plant breeding and seeds sector, developing innovative agronomy solutions for potato growers, breeding market-leading soft fruit varieties, supporting growth in the UK's emerging vineyard sector, and supplying new traits and germplasm to support genetic improvement in legumes.

The key findings in each of the five areas can briefly be summarised as follows:

Variety and seed testing

As the largest crop trialling organisation in the UK, NIAB provides statutory variety evaluation services on behalf of Government, as well as for the levy boards and plant breeders as part of the Recommended and Descriptive List systems. NIAB also provides statutory seed certification services on behalf of Government. Together these systems underpin continued investment in variety improvement, selection and performance – estimated in the study to be worth £74 million over ten years.

Potato agronomy

NIAB CUF is a leader in applied potato research, with demonstrable benefits for the industry in terms of improved productivity, cost-savings and resource-use efficiency. The impact study focused on the economic contribution of NIAB CUF research in terms of irrigation scheduling, yield forecasting and agronomic advice. The added value attributed by the impact study to NIAB's contribution in these research areas to improved potato production at UK level over ten years was £25.5 million.

Strawberry breeding

NIAB EMR is a leading UK strawberry breeder. NIAB EMR's high-performing Malling™ Centenary now accounts for 60-70% of the UK market, displacing the dominance of imported varieties. A key contribution of NIAB EMR has been to develop higher-yielding varieties with

extended season of production, improved fruit quality, better picking efficiency and reduced waste. NIAB's contribution to UK strawberry production over ten years was estimated at £298 million.

Concept vineyard

Five years ago, NIAB EMR recognised the rapid growth taking place in the British wine industry, and the need for R&D to support this growth. A research vineyard was planted in 2015, followed in 2016 by the establishment of a consortium of NIAB EMR and leading UK vineyards to fund and co-ordinate R&D support to the sector. NIAB's research covers growing systems and resource-use efficiency, genetic improvement and pest and disease control. The value attributed by the impact study to NIAB's potential contribution to vineyards at UK level over ten years was £101 million.

Legume pre-breeding

NIAB is a leader in pre-breeding research, providing a vital link between the discoveries and advances taking place in fundamental plant science and the translation of that new knowledge into traits and breeding material for use in commercial plant breeding programmes. The impact study considered the potential contribution of pre-breeding in legume crops such as field beans, which offer a potentially valuable break crop with nitrogen-fixing and soil organic matter benefits, and potential to displace imports of soya as a home-grown protein source. NIAB's potential contribution through legume pre-breeding at UK level over ten years was estimated at £28.5 million.

Last year, NIAB marked its centenary having originally been established as a charitable trust in 1919 with the aim of improving UK crop production through better varieties and seeds.

Over that period NIAB has pioneered the internationally recognised systems for plant variety testing and seed certification which have underpinned the growth and success of modern plant breeding and crop production.

NIAB is still widely recognised for its founding role in varieties and seeds, which continues to this day. But as this impact report demonstrates, more recently NIAB has successfully adapted and diversified from its position as quasi-Government institute to become a leading international centre for crop science with a broad and expanding portfolio of near-market agricultural research.

At all levels, the focus of NIAB's applied research activity is to improve the productivity, efficiency and resilience of UK agricultural and horticultural crop production. This independent study provides a resounding thumbs-up to the value and impact of our research.

Jane Thomas • jane.thomas@niab.com

Pre-symptomatic disease detection – approaches and potential

The majority of fungicide applications in arable crops are aimed at protecting plants from disease infection. Yet, protection can be compromised by mis-timed sprays, whether through on-farm workloads or adverse weather, or a lack of information on the disease burden in a field, and whether certain sprays are needed or not.

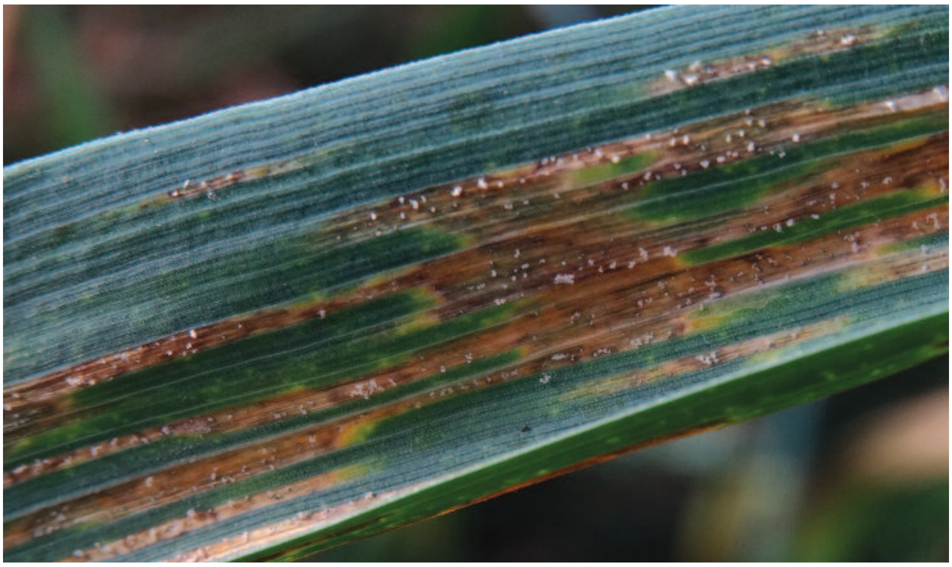
The advent of new fungicides with improved curative activity gives growers more flexibility in planning priorities for different situations whilst still achieving effective control. However, one piece of information that is missing from the equation is how far pathogens have grown within a plant without showing symptoms, and so how much disease may suddenly appear in the future. This is especially problematic for long latent period diseases like septoria leaf blotch in wheat, or light leaf spot in oilseed rape.

There are some simple ways to see whether a disease is present or not, such as incubating oilseed rape leaves to accelerate symptom expression of light leaf spot, but other methods can provide more quantitative assessments and detect infection at earlier stages. This is valuable for a disease like septoria leaf blotch where the symptomless latent period can be a matter of several weeks.

One approach uses the now well-established technique of quantitative PCR (qPCR). This method takes a sample of leaves, grinds them in liquid nitrogen, then host and pathogen DNA is extracted. Primers (short stretches of DNA) which are known to match specific sequences of pathogen DNA are added to the sample, and a reaction is run on a PCR machine. Target DNA is amplified, and the amount present is visualised using fluorescent dyes in the reaction. The outcome is reported as an amount of DNA, usually picograms, using a calibration curve derived from pure pathogen DNA, and reflects the amount of pathogen in the tissue. Higher amounts of DNA reflect both the susceptibility of a variety and the time since original infection. Lower amounts may reflect a more resistant variety, or a very early stage of development. Coupling the information together with variety and agronomic factors, such as date of sowing, can quickly generate a risk factor which drives product choice, rate and timing to protect future leaves.

Despite being a well established technique, this application of

qPCR has several disadvantages. The value of the outcome depends mostly on effective sampling in the field, and only relatively small volumes of leaf material can be handled without incurring prohibitive costs. The research to develop the specific primer sequences has to be done, though fortunately for many major pathogens, primers and assay conditions are now well established. The method does rely on expensive laboratory based equipment, but once a sample reaches a lab, turn around can be rapid, usually 24-48 hours.



Septoria leaf blotch on wheat – infection and development can take 2-3 weeks before typical symptoms appear

Another approach which has generated much interest is the use of imaging technologies linked to drone platforms. It has been demonstrated clearly that visual or multispectral images can pinpoint areas of a crop which are different in appearance to the rest of a crop, but in these cases the symptoms are well advanced. Though useful for scouting and detecting small disease foci, the actual cause of the symptom still needs to be identified through ground truthing. Pre-symptomatic detection of specific diseases has been achieved in some cases with hyperspectral imaging, but these reports are laboratory-based and using controlled inoculations so that the 'signature' of an infected plant can be linked to a specific pathogen.

Though holding some promise for the future, these findings are a long way from imaging a complex canopy, with multiple biotic and abiotic stresses acting on it, to find specific pre-symptomatic signals of a pathogen infection, and with equipment suitable for a drone platform. If future research overcomes some of these obstacles, the technique has one major advantage and that is the potential to capture a whole field risk, and map very high risk areas, without the need to walk the field and take physical samples.

The application of biosensors for the detection of human and animal pathogens is now well developed. Biosensors combine a biologically active material (or a mimic of it) with a chemical or electrochemical detector system. If the biological element reacts with a target (usually called an analyte), the detector mechanism produces a signal which can be converted to a digital output. Small portable devices are being used in clinical environments, though applications in crops are not yet available. They could offer early information on whether spores are germinating on leaves, or whether infections have become established, and send wireless signals to computers or smartphones.

Though many diagnostic systems for pre-symptomatic disease detection offer attractive ways of targeting crop protection products, and avoiding excess use, sampling strategies are key to gaining a sufficiently accurate picture of risk, and significant research still needs to be done to determine these strategies. The role of the grower and agronomist remains critical in providing the crop related knowledge which is essential to maximise the value of detection systems.

Ellie Sweetman • ellie.sweetman@niab.com

Forage survey highlights industry research and technical needs

Stimulated by membership demand emanating initially from the south west region, NIAB circulated a survey on forage cropping in the late spring. Primarily targeted at the NIAB TAG membership but also made available publicly, the survey sought to establish how NIAB can better support members with forage enterprises, asking about forage area, livestock types and numbers, and crops grown, as well as the main challenges around forage production, areas of interest and suggestions.

There were over 120 responses, mainly via the online survey option, with a range of enterprise sizes and covering over 12,000+ forage hectares, 8,000+

dairy cows, 1,000+ beef cattle and 22,000+ sheep. Forage production involved mostly short-term leys with some permanent pasture, as well as maize (50% of respondents), brassicas (55%), legumes (48%) and multispecies swards (37%).

A broad range of grazing systems is employed including mob grazing, rotational, strip grazing and set stocking. The majority make use of the Recommended Grass and Clover List to select varieties themselves; about a quarter rely on their seed merchant.

Of the challenges identified, there was a strong emphasis on grass and forage crop resilience to prolonged dry or wet weather as well as producing consistent forage across the season. Optimising nutrient use, weed and pest management, as well as timing harvest for the best balance of yield and quality and ongoing growth were also identified as challenges. Growing forages at altitude and in maritime climates was also mentioned.

Respondents identified 32 different areas of research and information that would be helpful to their businesses. Many fell in the category of technical/agronomic information on a range of forage crops, particularly home-grown proteins and mixed species cropping such as herbal leys. Others included making the most of stewardship options, regenerative practices and independent variety trials for a range of forage crops as well as incorporating novel technologies into yield assessment.

Taking all of the survey response information into consideration, along with a look forward to the future of forage crop production in the UK, we have identified the following areas where NIAB will target the development of resources for members and identify research gaps and opportunities for new work:

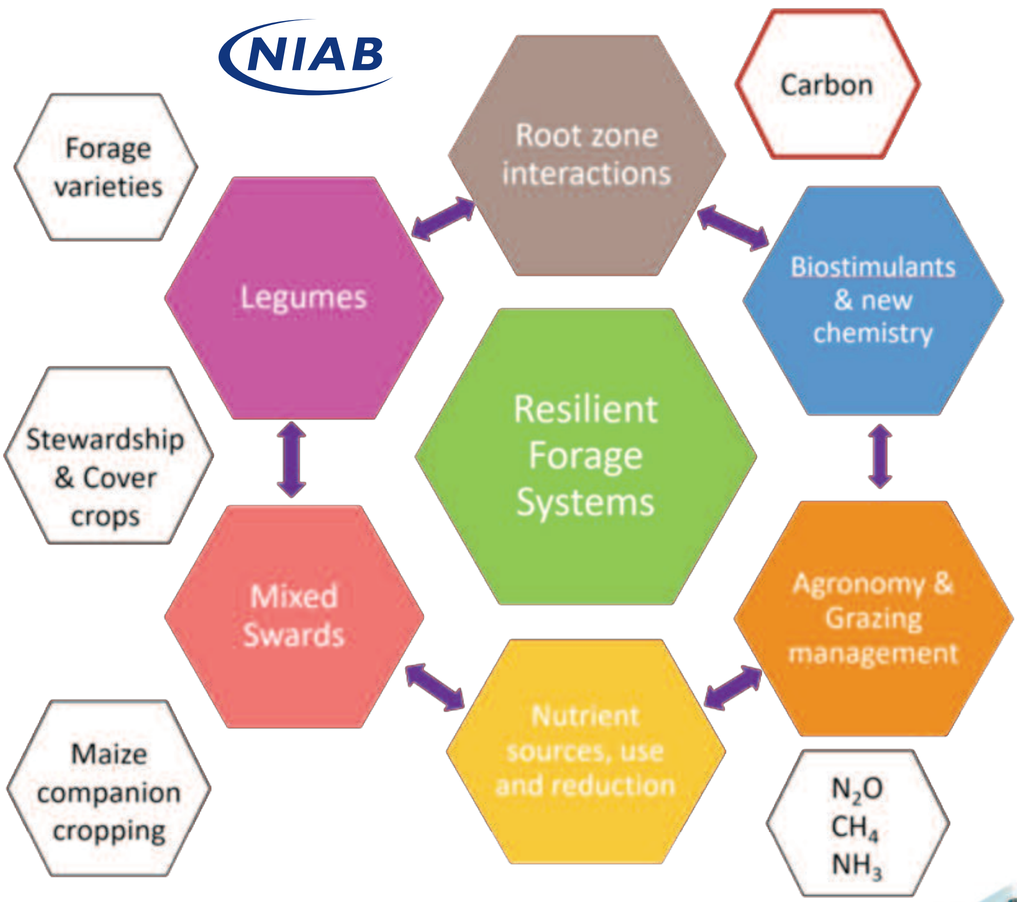
- Grass and clover production – varieties and management
- Mixed swards – species selection, management and utilisation
- Home-grown proteins - legumes and other crops and mixes
- Nutrient use, sources and soil health – reducing inputs
- Trace elements – links between soil, forage and livestock health
- Agronomy – pest and weed management – changing lifecycles and controls
- The forage root zone – symbiosis, nodulation and rhizobial activity in differing conditions
- Biostimulants and new chemistry
- Maize companion cropping (current and ongoing membership trials)
- Reducing GHG emissions and achieving Net Zero Carbon
- Variety information for a range of forage crops
- Agronomy and grazing – harvest guides and tools
- Research summaries and seasonal updates

NIAB will continue to provide independent, science-based forage crop research and information in order to support continued development of sustainable farming systems to produce safe, nutritious food while protecting natural resources and working towards net zero carbon.

We will also build on our agronomic resources and tools to cover these wider topic areas, investigating funding opportunities and appropriate partners to develop research projects in these areas to provide new information for the future. NIAB would also like to work with members to offer technical meetings and workshops on farm as well as to design monitoring projects from 2021 onwards. Findings and updates will be shared in *Landmark* magazine, as well as seasonal agronomy strategy publications, project reports and via events and the members' website.

Thank you to all those who took part in the survey. This is just the start of the conversation. If you would like to be involved in the discussion on our forage activity, on-farm projects, have further ideas, suggestions or forage challenges to raise, please get in touch at either ellie.sweetman@niab.com or 07734 567597. And watch this space!

Figure 1. Development areas



Ellie Sweetman • ellie.sweetman@niab.com

Emily Borton • emily.borton@niab.com

Maize companion cropping and undersowing trial 2019/2020

As the focus of agricultural policy changes, our industry is under increasing pressure to manage crops, not only in sympathy with the environment but in a way that protects and enhances our environmental resources.

From an environmental point of view, forage maize production is an obvious candidate for evaluating crop production methods. The autumn harvest of the crop and subsequent months of bare stubble pose a significant risk of impacting the natural environment through soil erosion, leading to sedimentation and eutrophication in waterways and consequential impacts on watercourse ecology and water quality.

With the capabilities of modern machinery, the maize harvest is now an almost unstoppable force with only the most challenging conditions, such as those of the 2019 harvest, causing wheels or tracks to stop turning. This is great in terms of time efficiency, however this way of operating can lead to serious problems for our soils and a legacy throughout the winter months of erosion and deterioration in soil structure.

We initiated our *Companion Crops for Maize* trial in 2019 as a response to member interest. The main objective was to assess which companion crops could successfully be established within maize plots without compromising the yield. As a crop, maize is particularly susceptible to weed competition and it is thought that the addition of a companion crop has a negative effect on the maize yield.

Three different companion mixtures were used to identify how, and if, different species affected the performance of the maize. We also wanted to assess the understorey growth after the maize is harvested, and the potential yield for grazing livestock, to give an overall forage tonnage per hectare equivalent. The inclusion of clover was expected to provide nitrate for the grass but it did not establish well. The mixed ley contained deep rooting herbs and has been found commercially to achieve high growth rates in lambs.

The crop's hatred of competition also makes weed control an important consideration and a potential challenge when growing a companion crop. In the 2019 trial the maize plots received one post-emergence herbicide application of Diva (a.i. *pyridate*) prior to drilling the companion crops in strips into the maize plots at the 4-6 leaf stage. Each of the three companion crop options established well. The use of limited herbicide input did not hinder maize yield and weed burden was low in the plots where companion crops were included. The untreated plots had a greater weed burden, demonstrating the added benefit of weed suppression from the companion crops.

The 2019 trial included two maize populations (85,000 plants/ha and 105,000 plants/ha), with no significant difference in maize dry matter yield between the two.

There was also no significant reduction in yield from the addition of companion crops at either population. This suggests there could be an opportunity for growers to reduce seed costs while achieving comparable yields from lower plant populations. Larger cob sizes were noticed in the lower maize population treatments but this was not a measured assessment. The 2020 trial will include analysis of maize quality (starch and cell wall digestibility) and some measurements of cob size prior to harvest.

The trial also explored the benefits of growing a companion crop in terms of extending the grazing season for livestock. Treatment 8 (chicory, plantain and red clover at the lower maize plant population) produced the highest yield

Bare maize stubble prone to soil erosion

Grass/clover mix post maize harvest

Table 1. An overview of the 2019/20 maize companion trial results

Treatment no	Description ('000 plants/ha)	Maize yield (t DM/ha)	Companion crop yield – fresh weight				Companion crop yield (t DM/ha *e*)	Total forage (t DM/ha *e*)
			1st cut		2nd cut		Average of 2 cuts taken from drilled area	
			kg/plot	t/ha *e*	kg/plot	t/ha *e*		
1	No companion (105)	15.41	0.00	0.0	0.00	0.0	0.00	15.41
2	No companion (85)	15.59	0.00	0.0	0.00	0.0	0.00	15.59
3	Grass (105)	15.70	8.20	6.1	9.43	7.0	3.80	19.50
4	Grass (85)	16.24	8.63	6.4	7.30	5.4	2.90	19.14
5	Grass + clover (105)	14.86	7.47	5.5	11.13	8.2	4.41	19.27
6	Grass + clover (85)	14.65	7.57	5.6	8.07	6.0	3.17	17.82
7	Mixed ley (105)	15.09	7.17	5.3	17.10	12.7	4.19	19.28
8	Mixed ley (85)	15.78	10.80	8.0	15.07	11.2	3.68	19.46
	LSD	1.8	1.8					

e = equivalent

of companion crop and significantly outyielded the other companion crop treatments. Chicory and plantain are deep rooting, perennial plants that draw up minerals from depth. They contain compounds that inhibit development of gastrointestinal worms, having an anthelmintic affect as well as providing good growth rates in growing lambs and cattle, along with the red clover.

The companion crop plots were cut twice in the spring of 2020 and showed that there is potential for valuable additional forage tonnage per hectare in growing them, with the highest yielding companion treatment in the 2019 trial giving an additional 4.41 t DM/ha and the highest total forage yield treatments giving 19.50 and 19.46 t DM/ha for treatments 3 and 8 respectively (Table 1).

The trial is continuing in 2020, including drilling maize into the standing companion crop plots from the 2019 trial (although the maize struggled to

Figure 1. Undersown companion crops – August 2019

No Companion | Chicory/red clover/ plantain mix | Festulolium | Grass/clover mix

No Companion: Noticeably more weeds when compared with the other plots

Chicory/red clover/ plantain mix: Although there was a weed burden in all the plots this mix seemed to be competing best and had established well underneath the maize crop

Festulolium: Less ground cover/ spread as would be expected

Grass/clover mix: A good amount of grass and clover established

General notes: Companion crops better established where maize population is 85,000/ha compared to 105,000/ha establish in those plots). We will take feed quality assessments for the harvested maize and companion crops.

As is the beauty of trials work, no two years are the same and it just would not fit with the theme of 2020 if the trial ran as smoothly as in its first year. This year's trial has struggled far more with weed competition and we expect this to be reflected in the results at harvest. This is something we will be addressing in the third year of the trial and we will consider both cultural and chemical weed control methods. Alongside a herbicide programme, we hope to experiment with our grass tine harrow to weed between the rows of the established maize crop. We are also planning on trying to establish companion crops in maize plots by broadcasting the seed at the 4-6 leaf stage of the maize.

The 2021 trials programme will include two types of white clover as companion crops with some treatments receiving-mid season N and some not, to assess the ability of the clover to supply nitrate to the maize assuming it is able to establish well enough to nodulate within the maize root zone. The trial's aim is to examine how the use of clover as a companion crop could make maize a more sustainable and appealing break crop option in an arable rotation. Work in the USA has found success in companion cropping maize with field beans, with both crops taken as a whole bi-crop forage, balancing energy and protein. We plan to do further work in this area.

In summary, NIAB's aim is to provide growers with information on undersowing options for forage maize and encourage the uptake across the UK. This should help ensure the continued use of maize as a critically important forage crop without the negative environmental connotations. There are, of course, practical considerations if wishing to employ similar practices on farm and we are hoping to work with members to gather some field-scale information. We would like to hear from anyone with experience of, or interest in, trying out undersowing maize with companion crops – contact me at ellie.sweetman@niab.com or 07734 567597.

Ellie Sweetman • ellie.sweetman@niab.com

New maize varieties highlight continued breeding progress in yield and quality

Six new first-choice varieties have been added to the British Society of Plant Breeders' 2021 Forage Maize Descriptive Lists.

The BSPB 2021 Forage Maize Descriptive Lists are available to download from the BSPB and NIAB websites.

The varieties **Resolute**, **Conclusion** and **Trooper** from Limagrain, **Farmunox** from DSV, **Ability** from DLF and **KWS Artikus** from KWS are all new entrants onto the Favourable Sites DL. The Less Favourable DL, aimed at 'marginal' growing conditions, sees the addition of five new varieties – **Resolute**, **Farmunox**, **Ability**, **Conclusion** and **Trooper**.

The 2021 Descriptive Lists provide a range of varieties for growers to select from, with parameters including dry matter yield, starch, ME and digestibility, in relation to favourable or less favourable growing conditions within the suitable maturity range for the farm location. This diversity allows selection of varieties that best suit the needs of the varied requirements of growers across the country.

Favourable sites

One highlight is the continued improvement of forage quality achieved for growers in all conditions and locations. On the Favourable Sites List, KWS Artikus is the earliest maturing of the new first choice additions with an average 36.2% dry matter content at harvest across the trial sites. It also has the highest starch on the list at 35.4%. Farmunox is the latest maturing of the new varieties but still achieves 31.2% DM. Resolute is at the top of the List with an excellent dry matter yield of 19.0 t DM/ha and good cell wall digestibility at 60.6% at 32.5% dry matter.

Conclusion is a strong all-rounder with excellent yields (18.6 t DM/ha) for its maturity (33.0%), an ME at harvest of 12 MJ/kg DM and a very good standing power of 7.7. Trooper is also a strong all-rounder, providing a very good ME of 11.84 MJ/kg DM, starch at 34.3% dry matter and an excellent standing power of 8.1. Ability also scores 8.1 for standing power, a character of increased relevance in recent years, with second highest dry matter yield of the new varieties at 18.8%.

With increasingly prolonged periods of both dry and wet weather during the growing season, the importance of a range of forage sources has become even more pertinent. Using the Descriptive Lists to identify high ME, digestible maize varieties with good starch content that grow well in your location and conditions can help ensure forage use is optimised with efficient conversion into meat and

milk that meets demands of processors. Higher cell wall digestibility can help support butterfat levels in dairy cows, whereas higher starch can reduce the need for more expensive concentrate feeds for both dairy and beef producers.

Less Favourable sites

There are five new contenders to the Less Favourable DL: Resolute, Farmunox, Ability, Conclusion and Trooper. Growers looking for highly digestible, good quality silage in more challenging growing conditions should look for varieties with good early vigour to make best use of a shorter growing season. Resolute, Farmunox, Ability and Conclusion all yield above 18 t DM/ha with Trooper standing well at 8.0 with good starch at 33.8%.

Very Favourable sites

Three years of trial data now make up the standalone, 'Very Favourable' Descriptive List. Some of these varieties are also found on the Favourable and Less Favourable Forage Maize DLs but others, including some later maturing varieties, are unique to this new List.

Varieties on the Very Favourable DL 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. However, It is important to however, on other sites, varieties from the Favourable or Less Favourable Lists may be better suited to the growing conditions.

Bill Clark • bill.clark@niab.com

NIAB in 2020, building for the future

Over the past few years NIAB has undergone many changes and developments, not only in staff and infrastructure, but also its activities. These developments demonstrate NIAB's continuing commitment to the future of the agricultural and horticultural sectors and, with the lack of face-to-face events and activities this year where we normally catch-up, this article aims to keep our members and supporters updated on NIAB's current actions and future plans.

Ultimately climate change is at the forefront of our research priorities. We use the knowledge of how genetics, environment and management interact to increase quality and production and cope with a more variable and changing climate. Biodiversity protection and enhancement are also key goals, alongside increasing the efficiency of resources, resulting in less waste across the food system, as well as minimising greenhouse gas emissions. NIAB works on a wide range of crops from cereals and oilseeds to potatoes, ornamentals, non-food crops, top and soft fruit and vines. We generate new genetic diversity in pre-breeding material for arable crops, as well as plant breeding services for the fruit sector.

Plant breeding programmes producing new genetic diversity

Re-synthesised modern wheat – part of NIAB's pre-breeding programme

Agricultural crop research

NIAB's research scientists carry out world-leading strategic agricultural crop research addressing pressing global challenges around food production, with an emphasis on climate change. Our mission is to conduct high-quality strategic and applied research, delivering knowledge, products and services that benefit both public and private customers.

We continue to build on our established programmes in cereal and protein crop pre-breeding and genetics, ensuring NIAB leads in the development of crops of global importance. As such, we are expanding our programmes in sustainable pest and disease control, improved diagnostics and novel IPM approaches. Our three major capabilities in biotechnology, data sciences and market-led breeding are being further enhanced to deliver high-quality research and commercial services to key stakeholders.

Crop agronomy

NIAB continues to lead the UK in providing independent crop management R&D, information

and services and aims to be at the heart of productive, profitable, innovative and resilient field crop management practice, fuelled by world-class, science-led agronomy. This is achieved by:

- practical crop and agronomy R&D, knowledge exchange and demonstration
- impartial, research-based crop management information and independent agronomy advice membership and consultancy services
- unrivalled UK trialling and evaluation capabilities for agriculture and horticulture
- specialist crop analytical services.

Agronomy, soil management and rotations remain central to our Farming Systems research. NIAB is a leader in the measurement and maintenance of soil health, monitoring the effects of cropping systems and management practices, and giving practical guidelines on how to enhance soil health. Part of this process is in ensuring we strengthen partnerships, develop new communities and grow membership, prioritising our relationships with farmers, to increase NIAB's impact and influence.

We are exploring new ways of working with farmers. NIAB's membership schemes are an important mechanism for two-way dialogue with industry, ensuring that our services provide maximum benefit and that our research is focused, solution-orientated and impacts on practice. Extending NIAB's on-farm presence, our strategic agronomy services that bridge research, trials and consultancy will support data-driven decisions to achieve year-on-year improvement in crop and growing system performance.

Horticultural crop research

In NIAB EMR we have a world-class centre of excellence for applied research and innovation in commercial horticulture, undertaking work primarily in perennial and clonally propagated crops. We provide scientific research, technical services and practical advice to improve the yield, efficiency and resilience of crop production across the sector.

NIAB EMR recently secured significant new funding as part of the Growing Kent and Medway initiative

Members are key to the success of NIAB's impact from research

and the South East Local Enterprise Partnership. The new funding will contribute to new infrastructure, facilities and services at the East Malling site as part of an industry-wide plan to stimulate research, innovation and enterprise in the Kent region. The plans include an Advanced Technology Horticultural Zone with state-of-the-art glasshouses incorporating high-tech imaging, robotics, precision irrigation rigs, LED lighting and CO_2 systems, as well as a green energy facility to meet the needs of the new horticultural facilities.

Sites and facilities

NIAB is fortunate to be based in Cambridge, which has a global reputation for an active science and technology-based community. But we are also committed to a regional presence across the UK and have recently conferred regional centre status to our Cirencester site and our new Wimbourne site. This takes our number of centres up to 12, plus numerous satellite trials sites and the Eastern AgriTech Innovation Hub, near Soham, in Cambridgeshire, alongside NIAB EMR in Kent.

We have a programme of reinvestment in new facilities, notably at our two sites in Cambridge, but also at NIAB EMR, demonstrating NIAB's commitment to the agritech sector in the UK. Our new headquarters at Lawrence Weaver Road, opened in February 2020, incorporates the Crop Science Centre, NIAB's collaboration with the University of Cambridge, opening on 1 October 2020. The Centre is focused on improving staple crops such as maize, wheat and rice, but also specific crops of relevance to smallholder farmers, particularly those in sub-Saharan Africa. Work is focused on translational research based around three key pillars of research activity: nutrition,


Plans for new Facilities building and new glasshouses at NIAB EMR

pests and diseases, and photosynthesis. The Centre combines the diverse skills and expertise of the University and NIAB, providing an environment for research excellence, with the capability to apply discoveries to crop improvement in the field.

There have been a great many changes to NIAB Park Farm, our site on the northern outskirts of Cambridge, over the past few years, with further construction over the next six months. Barn4, a new agritech business incubator, will be opening to tenants from spring 2021, offering start-ups and SMEs laboratory, workshop and office space alongside specialist technology and facilities. And Barn 5 will offer additional laboratory and storage facilities for NIAB staff and services.

NIAB aims to continue to grow our operation through mergers, acquisitions, and organic growth. This includes diversifying our customer base, and working with an expanding range of partners to deliver improvements across all aspects of crop production. The aim is to develop higher yielding, more climate resilient crops through applied research, the outcomes of which we can transfer effectively onto farm through our industry partnerships and NIAB membership schemes. We will continue to adapt, putting our charitable objectives and our independence at the forefront of growing a strong, research-based enterprise.

New NIAB Headquarters, Cambridge

New Barn4 Incubator Hub, currently under development

Colin Peters • colin.peters@niab.com

Break crops – why and what

In recent years, many growers have found that their crop rotations have come under pressure for a variety of reasons. Foremost in many people's minds at this time are the issues relating to oilseed rape, namely cabbage stem flea beetle, which has been causing establishment problems and significant yield loss in many surviving crops across many regions of the UK.

But there are other up and coming issues causing growers to look for alternative solutions. Grassweed problems and the loss of agchem active ingredients mean that growers are finding that they can no longer rely on the staple crops – winter wheat, winter barley, oilseed rape – and are widening rotations and increasing spring cropping areas.

Some of the more common spring crops are also coming under pressure from pests and diseases, including bruchid beetles in spring beans and an increasing incidence of viruses in sugar beet resulting in British Sugar offering a new assurance fund to compensate growers moving forward.

This spring, NIAB began collating information of some of the lesser known crops for the NIAB TAG membership to provide a basis for consideration. The *Alternative Break Crops Guide* is available on the membership website niabnetwork.com, outlining the processes involved in choosing a different or new break crop. It is accompanied by a range of individual crop infosheets. In the Guide, we go back to basics with a fundamental look at rotations as a whole, starting with the question – why rotate crops?

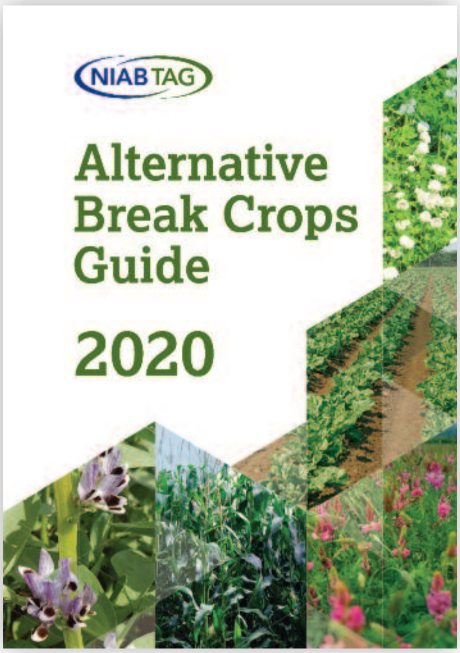
Crop rotation history

Growing different crops in sequence has long been recognised as an effective means of improving soil fertility and reducing the impact of weeds, insect pests and diseases.

Historically, cereals were recognised as a crop that exhausted the supply of soil nutrients and needed to be grown in combination with those that replenish them, such as legumes

(restorative crops). From the Middle Ages, farmers mostly used an autumn-sown crop, a spring-sown crop and a fallow as a three-course rotation. The addition of root crops by Viscount George Townshend, on his Norfolk Estate in 1730, created the traditional Norfolk four-course rotation, where wheat was followed by clover (or ryegrass), oats or barley and, then turnips or swedes.

Over time, we have become aware that changing crops (and their associated timing and type of cultivations) interrupts the life cycles of many crop-specific diseases, insect pests and weeds. Where ploughing and burial of surface trash occurs, this helps to prevent 'carry-over' of some less specific pest problems. The



overall aim is that by the time the same crop returns to a field in the rotation sequence, the weed/pest/disease risks have been severely depleted.

In the second half of the 20th century, the availability of better machinery for cultivating and harvesting, as well as technological developments in fertilisers, crop protection products and plant breeding, meant that many of the benefits of crop rotations could be enjoyed in all-arable enterprises consisting entirely of cash crops. Agrochemicals provided cost-effective answers to some massively disruptive pest problems but, as we are all aware, things have now changed and we need to look more closely at how we manage our soils to benefit from them in a sustainable manner.

Recently, there has been increased interest in maintaining/supporting the soil biological community (bacteria, fungi, … the food web) through crop choice and residue return. Ley-arable rotations have long been known to have higher soil organic matter, improved soil structure and more effective soil biological functioning.

In recent years, the term Integrated Crop Management (ICM) has been used to describe the use of good crop rotations with modern technology to grow healthy, vigorous crops producing economically viable yields and quality by making optimum use of natural resources. In this way the reliance on inputs such as fertilisers and agchems are reduced, but the need for them is by no means eliminated.

The *Alternative Break Crops Guide* looks at how rotations can be planned as there are many variables to be considered that will influence the choice of break crop. We have looked at weeds, pests and diseases as well as soil health and timeliness which have a big impact on labour at peak times. There are also issues to be considered relating to extra equipment or processes with some of the crops that are sold directly to the consumer.

For many of us, maximising first wheat yields will be foremost in our thinking when looking at rotations, for others, wheat can actually be the break crop.

Table 1 shows the basic information of the crops documented so far, each have been presented on individual downloadable sheets so that they can be individually printed but also to ensure they are kept up-to-date and expanded with new information. We will be looking to extend the number of crops in the future.

There are simple rules when looking at alternative crops, especially if they are for a niche market and therefore not a commodity crop as the grower will need to have a guaranteed market, or risk spending time and money growing a crop which may be worthless. Growers need to understand the buyer's requirements and standards to know what they are expected to deliver. Some alternative crops may need different or specialist equipment, precision drills, mechanical weeding or swathing. Harvesting may require sanitising of equipment, specialist drying or screening.

Most crops considered will have preferred regions and soil types. We need to make sure that the right conditions are available to allow the crop to flourish. This will include the right soils to allow timeliness to establish the crop at the best times, the correct soil pH as well as factors such as drainage, if relevant. The choice of break crop may be governed by a need for weed control such as black-grass. This may mean that looking for a late drilled or spring crop or one that allows the required herbicides to be used to facilitate requirements.

So, there is much to consider, and it would be sensible to think about the wider picture. Oilseed rape should not be completely discounted as its value in the rotation should not just be considered by its one-year gross margin. NIAB is just beginning a three-year project, funded by Defra, to look at field-scale options for growing oilseed rape in the presence of flea beetle. This is an exciting project in which we will be working closely with ADAS who are funded by AHDB. However, there are also new and exciting opportunities out there for us to consider and maybe capitalise on.

Table 1. Individual alternative crop infosheets available to download on niabnetwork.com

Crop	Drilling date	Harvest date	Speciality equipment	Other key features
Chickpeas	March - May	August		Legume
Soya	April - May	August - September		Legume
Lupins	March - April	August - September		Legume
Millet	April - May	September	Cleaning/drying	
Borage	April	August - September	Swather	Very vigorous
Herbage (seed)	Various		Stripper header	Also provides forage crop
Naked Oats	Feb - April	August		
Canary seed	March - May	Late August	Cleaning/drying	
Combinable peas	February - April	July - August		Legume
Lentils	Feb - March			Legume
Linseed (spring)	March - April	August		
Linseed (winter)	September	July - August		
Ahiflower	Various	July - August		
Hemp	April - May	Various	Home Office license	
Maize (feed)	April - May	October onwards		
Quinoa	April - May	September - October	Stripper header, drying equipment	

Margaret Wallace • margaret.wallace@niab.com

Encouraging the new while protecting the old – an international vision

Working with, and on behalf of, international seed forums allows NIAB to influence the direction of variety registration and seed certification as it develops in a worldwide context, as well as gaining valuable insights into the systems and programmes around the globe. The experts involved travel on behalf of Defra, OECD, or NIAB. At each technical visit, there is always something to learn or a different point of view that results in an improvement or re-evaluation of our own methods. Although this has been somewhat curtailed this year, our networks (like so many others) sprang into action and implemented online meetings and opportunities for discussion. These have maintained momentum, but hopefully we will meet with our friends and colleagues from the many different organisations again soon.

Your local point of contact at NIAB, that person you call, text or email to ask about Seed Certification or DUS (distinctness, uniformity and stability) testing may be the same person that people around the world contact to talk about our specialised subjects. The NIAB Agricultural Crop Characterisation team members have a few roles when we venture away from Cambridgeshire and the day-to-day world of statutory testing and seed certification within the UK, some of which take us to work on the international stage. We travel on behalf of Defra and the Animal and Plant Health Agency (APHA), representing the UK in technical discussions relating to DUS testing, with NIAB acts as co-ordinating centre for the OECD Seed Schemes. This article and the following ***Worldwide seed trade – ensuring the variety is delivered*** article are about two of the global organisations where NIAB staff play active parts.

On behalf of APHA and Defra, NIAB conducts the statutory DUS testing for National Listing of oilseed rape, wheat, sugar beet, barley, field bean, oat and fodder kale, and for Plant Breeders' Rights (PBR) of those same crops and many ornamental species. The National Listing is an independent review that lets the end user know that the variety they are growing is considered new (DUS) and improved (VCU – value for cultivation and use).

National Listing is national! Decisions are made by the National List Seeds Committee made up of representatives of the four countries of the United Kingdom. Decisions on the granting of UK PBR are made by the same people, but the system is defined by UPOV, the International Convention for the Protection of New Varieties of Plants.

UPOV is the intergovernmental organisation that was established with the convention in 1961 and since then has been working to harmonise DUS testing across the member states. The UK was one of the first of

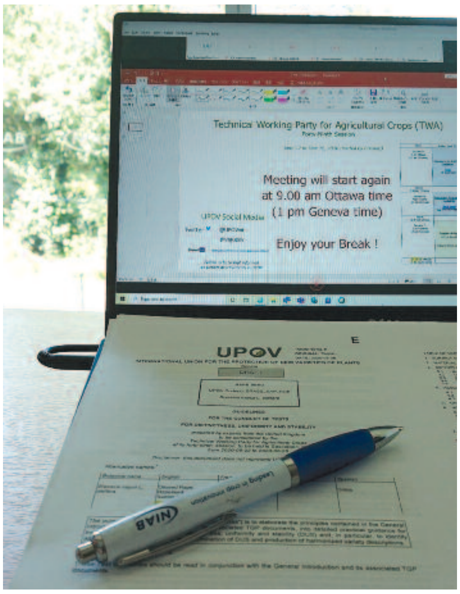
UPOV Technical Working Party for ornamentals and forest trees visiting NIAB the now 76-state membership, with NIAB taking an active role from the start. UPOV's mission is 'to provide and promote an effective system of plant variety protection, with the aim of encouraging the development of new varieties of plants, for the benefit of society'.

Plant Breeders' Rights, Plant Variety Rights and Plant Variety Protection are all names given to a system for plant breeders similar to a patent for inventors. With PBR, breeders can claim royalties when their variety is grown (if you use farm saved seed you will know the drill). Arriving at a successful variety is expensive – thousands of breeding lines are rejected during selection to arrive at the variety available to growers. The PBR system allows breeders to claim a return on their investment, which encourages them to innovate. Simply put, without PBR we would not have modern varieties.

The goal to harmonise DUS testing across all UPOV member states means that wherever a variety is tested (whether agricultural, ornamental, vegetable or fruit) the same principles are followed. There is a Technical Working Party (TWP) for each of the crop groups – TWA (agriculture), TWO (ornamentals and forest trees), TWV (vegetables), TWF (fruit). Experts from across the membership, representatives from countries considering joining, and interested organisations such as ISF, CropLife, CIOPORA and Euroseeds, meet to draft and review policy documents and develop species-specific Test Guidelines appropriate to the group.

NIAB provides the UK technical experts for agriculture (Margaret Wallace) and ornamentals (Hilary Papworth). There is also a TWP for automation and computer programs (TWC) where NIAB's statistician Haidee Philpott is one of three UK experts.

The working parties are an opportunity for like-minded specialists to discuss issues (and swap niche anecdotes that are probably only entertaining to DUS examiners). They are also a chance for breeder representatives to discuss new breeding techniques and aims with the UPOV members and how these may be



Remote meetings have replaced face to face contact in 2020

addressed in the current system or if a revision is necessary. All TWPs consider the same technical guidance and policy documents, the length of discussion is an insight to the challenges faced by different groups. Where a paper by the TWC on combined-over-years analysis will incite hours of debate at the TWA where statistical analysis is routinely applied, it will barely raise comment at the TWO which focuses mostly on self-pollinated and clonally-propagated varieties (but do not get them started on the RHS colour chart!).

Each TWP will review the appropriate Test Guidelines, the basis for every DUS test on that species throughout the member states. Our collective expertise at NIAB has been used to lead, or contribute, to revisions of these guidelines for many species. We have specialist knowledge of over 400 species and a skill set that can be applied to many more. No matter the species or the working party, the procedure is the same:

- A representative indicates to the TWP that a revision is required
- If the TWP agrees, a Lead Expert is nominated and Interested Experts (IEs) are invited to self-nominate
- The Lead drafts a revision and circulates to the IEs for comment
- A second draft is prepared for discussion at the following meeting of the working party
- Comments can be agreed at the meeting or given thought for the next draft (to investigate further or for consultation with crop experts not present)
- The Lead then prepares a revision, IEs comment and so on until the TWP agrees a final draft.
- This is then considered by the Editorial Committee (there are four working languages of UPOV, the documents must work across all translations) and then to the Technical Committee that sits above the TWPs to ensure consistency across the parties for approval.

The procedure is simple, the process may not be. Although UPOV offers harmonisation, it is not a dictatorship. Each member state can interpret the guidance differently so something that may be considered simple in one system could be difficult in another, not to mention the diversity in varieties between members. These obstacles can make the process lengthy but often bring the most enlightening conversations that lead to guidelines that can be applied across the membership. Breeders are encouraged to feed into the revisions (through the Lead Expert, any of the Interested Experts, or the invited breeder organisations). The ongoing revision of the Oilseed Rape Test Guideline is led by NIAB, please contact Margaret Wallace or Alex Talibudeen to discuss.

NIAB's role in UPOV is not limited to drafting TGs and commenting on policy documents. We have provided TWP Chairs – Elizabeth Scott (TWO) and Cheryl Turnbull (TWA), who have represented the TWP and, on behalf of APHA, the UK at the Technical Committee. Margaret Wallace also attends the UPOV BMT (Working Group on Biochemical and Molecular Techniques and DNA-Profiling in Particular) as a UK representative. This group review and discuss the implementation of DNA markers to the DUS testing procedures. This has been a long-term goal for many. With the increasing use of marker-selection in the breeding community, there is a greater acceptance for the use of similar markers or technologies in statutory testing. The breeding representatives play an important part in this group, bringing research and a broad range of views (not all are pro-BMT) to each meeting.

NIAB is well known as a training provider – we train over 200 seed crop inspectors per year – but lesser known is Elizabeth Scott's role as a UPOV tutor, providing advice and support for new DUS examiners and those within the wider industry via the distance learning courses. The courses were designed to give knowledge and understanding of UPOV principles. With our experience, NIAB was in an excellent position to contribute to course development and now with ongoing coaching.

Details of the courses can be found at www.UPOV.int – registration for the next sessions is open now.

Stephen Flack • stephen.flack@niab.com

Worldwide seed trade – ensuring the variety is delivered

The OECD is an inter-governmental organisation primarily concerned with international strategy and economics, aiming to 'shape policies that foster prosperity, equality, opportunity and well-being for all'. One part of this large organisation operates the OECD Seed Schemes, founded to enable trade in seeds between countries in the period of reconstruction which followed WW2. From this beginning the schemes have expanded to include many countries beyond the original European base.

The aim of the schemes is to promote international movement of seed and consequently of newer, improved varieties, by controlling the varietal certification to provide seed which meets internationally agreed standards for trade. Buyers of OECD certified seed know it will have been checked to ensure it is the correct variety and varietal impurities are kept below agreed standards. Tests for germination, content of non-seed matter and weed content are carried out on the seed by one of the internationally recognised seed testing organisations. NIAB staff from the Official Seed Testing Station take an active part in the work of ISTA, which is a major international seed testing organisation.

The OECD seed schemes were founded under an earlier organisation, the OEEC. Former NIAB deputy director Fenwick Kelly and NIAB colleagues were part of the founding group that established the first seed scheme in the OEEC in 1958, concentrated on grass and fodder seeds. Throughout its history, NIAB has consistently taken an active part in the continued development and evolution of the OECD Seed Schemes.

Today, NIAB performs the role of co-ordinating centre for the current schemes. This includes maintaining the OECD List of varieties eligible for certification. This contains varieties from all the seed scheme members countries, effectively a combination of the contents of 62 countries' national lists of varieties, totalling over 64,000 varieties plus 8,000 synonyms. This is kept on a database maintained and updated by NIAB on behalf of OECD. A complete list is published twice yearly on the OECD website, and a query screen function, which allows users to view the current status of varieties, is updated daily. This query screen has become internationally well-known and used – it now averages over 160 separate queries per day, over 60,000 searches per year to check varietal eligibility.

In addition to this, NIAB staff, principally Stephen Flack, provide advice and answers to questions on the seed schemes, resolve queries which arise over listing of varieties, as well as producing technical papers and participating in the twice-annual meetings of scheme members. Questions on the operation of the schemes come from many sources ranging from the OECD secretariat to private individuals. More frequently, members of seed companies may be questioning why their variety is, or is not, included in the list and how they can get it included, changed or removed. Fortunately, only the Designated Authorities in each member country are permitted to make changes to the content of the variety list and even then are restricted to varieties being added, changed or deleted in relation to the authorities' own country. Country B cannot change Country A entries and vice versa.

All aspects of the schemes are open for discussion at the annual meetings but changes can only be made by consensus of all members. Whilst this sounds like a formula for stagnation, it is curiously stimulating in driving discussion and investigating other points of view in order to achieve change. It also forces participants to check they have the same meaning from a given form of words. At times this can lead to more debate on the close detail wording than on the point being decided and it is recognised that final resolution often comes in the opportunities for small groups to discuss the finer points during breaks in the meeting.

New applicants for membership are required to demonstrate their understanding of the rules and their ability and competence to operate the schemes within them. The prospective member often relies on help provided by one or more existing member countries to develop the administrative and technical capabilities which must be in place before membership is granted. This includes operating a seed scheme with standards which are compatible

with those of the OECD seed schemes for a period before the actual application to join is submitted. The country must have in place the means to control the generation system and the seed crop and seed lots which are part of it. There must also be the facilities to test varieties for inclusion in a National List (show DUS and a value for use) and particularly to have adequate descriptions of varieties available and a stored standard sample of each variety. This naturally involves having taken on the varietal characterisation procedures of UPOV and a seed testing organisation's sampling procedures.

When the application to join is submitted, a mission of experts is selected from the secretariat, the co-ordinating centre and the existing member countries. These experts will visit the country to examine the facilities in place to ensure they meet the needs of the OECD seed schemes and can consistently achieve the necessary standards for certification under the OECD seed schemes. The experts expect to be shown growing plots of seed samples in post control trials to check the efficiency of the seed production process in maintaining varietal identity and varietal purity against standard samples of the variety. In addition, they are required to provide evidence that at least three years of post-control trials have been carried out for the species to be certified and schemes which will be operated.

In recent years NIAB, in its role as the co-ordinating centre, has taken part in the missions to Ukraine when it applied to join. After the country has been a member for four years, a second visit is made to examine how the operation of the schemes has developed during the time and once again to examine the arrangements in place. Countries can be required to improve areas of certification found to fall below expected standards. NIAB was part of the two-person team which carried out the review visit to Senegal a few years ago, thankfully with a good outcome for the country.

The OECD seed schemes are separated into eight schemes generally according to species, the exception

NIAB's Stephen Flack attending annual OECD meeting

being the vegetable seed scheme which is according to species and use. The seven agricultural schemes are included in the Variety List and contain 204 separate species. The vegetable scheme, at present, has no list of varieties and an exact number of species and varieties is not available.

The membership of the seed schemes is open to OECD, UN and WTO countries which meet the criteria for joining. Decisions on acceptability of applicant countries are made by existing members at the Annual Meeting normally held in June each year. Only member countries are permitted to take part in this decision and the same is true for decisions to alter the scheme rules in any way.

In addition to the Annual Meeting there are two meetings a year of the Technical Working Group which has the task of discussing and preparing items for consideration by the Annual Meeting. Discussions at the Technical Working Group cover a wide range of subjects related to certification. The group also has the task of founding special interest groups which have the general title of Ad-hoc working groups (AHWG). NIAB, as co-ordinating centre is automatically a member of the Technical Working Group and each AHWG founded. The AHWGs are operated by a small, voluntary sub-group of countries which either have special expertise in the subject or an interest in shaping the outcome of discussions. There are normally four or five working groups active, although it has been more in the past. The working groups meet twice yearly at the same time as the Technical Working Group but are expected to continue their work between the formal meetings to ensure the subjects move forward towards conclusion. According to the scope of the group their longevity varies a great deal with some subjects becoming almost a fixed group in its own right. Others are given a set deadline to reach a conclusion. Recent groups have covered subjects which include security of sealing and labelling, preventing seed related fraud, the introduction and use of biomolecular methods, novel seed production methods, security in re-processing or re-packing seed after certification, standards for production of hybrid barley seed, multiplications abroad and varietal mixtures and how they should be controlled.

Meetings are attended by representatives from international seed producers organisations, other international organisations dealing with varieties and seed, and invited countries which are considering applying to join. The co-ordinating centre is expected to be able to answer queries from any of these in the course of the meetings, putting the co-ordinating centre and secretariat "on the spot" which ensures full attention to proceedings from the co-ordinating centre at all times.

Matthew Milner • matthew.milner@niab.com

Eric Ober • eric.ober@niab.com

Pauline Thomelin • pauline.thomelin@niab.com

Breeding better root systems for higher yield

Over the years, breeders have been successful at improving yield by focusing on what grows above ground, but have largely ignored the part hidden below ground, simply because roots are difficult and time-consuming to examine. While we have a good idea of what a promising ear of wheat looks like, we are not entirely sure what the best root system (the root ideotype) looks like.

The 'Rooty' project aims to improve future wheat yield by optimising root system architecture (RSA), i.e. the way roots grow and develop in three dimensions to explore the soil and mine water and nutrients. It is a root ideotype toolbox to support improved wheat yield.

Rooty is a three-year project within the IWYP funded by the Biotechnology and Biological Sciences Research Council (BBSRC), the Department for International Development (DFID) and the Australian Grains Research Development Corporation (GRDC). The project is an international collaboration involving research groups from Australia, Germany, Italy, Mexico, UK and seed industry partners.

Background

The International Wheat Yield Partnership (IWYP) is promoting research to increase the genetic yield potential of wheat by 50% over the next two decades. By pushing the genetic yield potential of wheat (i.e. yields achieved under ideal conditions), this will also lift up *achieved* yields (yields obtained by farmers in usually less than ideal conditions), benefiting a large number of growers and consumers.

It is logical to assume that as we push yields, the need for water and nutrients to support that crop will increase as well. Are the root systems of our current varieties up to the task, or do more demanding crops need more efficient RSA for water and nutrient uptake? Has the performance of root systems improved over the years as a by-product of selecting for increased grain yields, or do root systems place some kind of brake on continued progress in yield and resilience to stresses such as drought?

To make any kind of improvements to root systems, breeders need information on which particular root traits are important for different growing environments, how to go about selecting those traits, and to have access to donor material that expresses those traits. By combining genetic tools, genomic resources and high-throughput phenotyping platforms, the objectives are to deliver a suite of genetic markers for key root traits and novel wheat germplasm to support high yields for a diversity of farmed environments. As it seems unlikely that root systems are one-size-fits-all, we have instead aimed to develop a 'toolbox' of root traits and markers that breeders can test and mix together to see which combinations work best for local conditions. Some of those variations in RSA may exist within the current gene pool, but the identification and characterisation of *de novo* gene variants (alleles) created via natural recombination, induced mutations, or gene editing is essential to develop novel germplasm.

Testing yield x root trait interactions using lines with high yield potential

The IWYP programme mainly focusses on spring wheat, which is the emphasis of the breeding programme at International Maize and Wheat Improvement Center (CIMMYT). Using current CIMMYT elite varieties as a background, a major component of the Rooty project is developing new lines of spring wheat that contrast for RSA: high and low root biomass; a wide or narrow root angle.

Everyone knows that 'roots grow down', but the growth trajectory that roots establish once they form is often about 60° from vertical. The genes that control this behaviour vary considerably, such that some lines show roots growing almost horizontally, while others are nearly vertical. Wide angle produces a shallow RSA, which is good for anchorage and extracting nutrients that are predominantly found in superficial soil layers. In contrast, narrow root angles tend to produce root systems that place more biomass deeper in the soil, which is useful in dry conditions when the only available moisture is in deeper subsoil layers.

What do the root systems look like in the best yielding UK wheat varieties? Surprisingly, we do not really know.

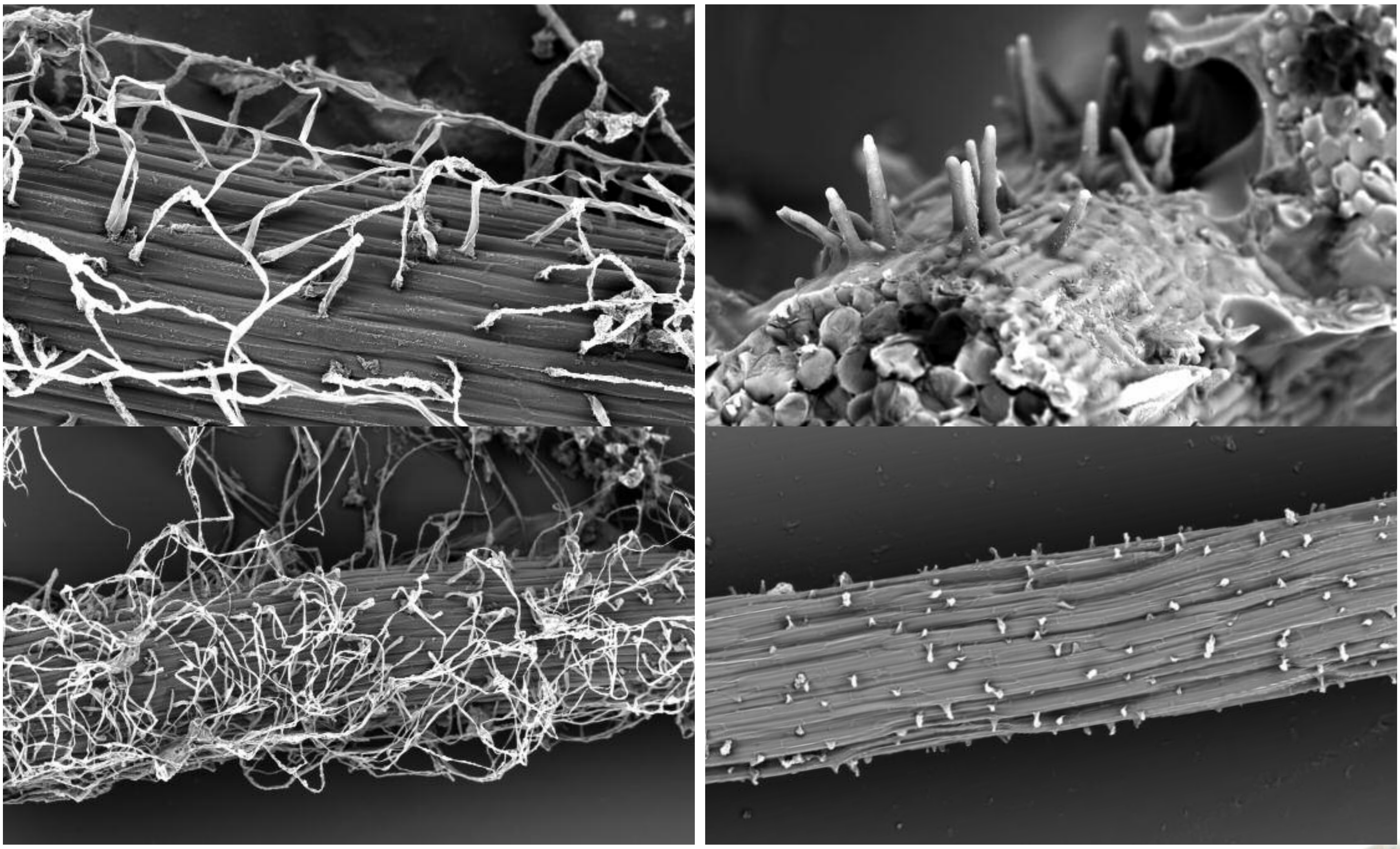
Figure 1. Post-harvest excavated roots from the field. RSA with a rather narrow angle (left image) compared to a wide angle (right image)

Therefore, a component of the Rooty project also examines winter wheat, important for UK and north European breeding programmes.

For this work, we selected 37 winter wheat lines characterised as high yielding, comprising current AHDB UK Recommended List varieties and pre-breeding lines, including several from NIAB's re-synthesised hexaploid wheat pipeline and novel durum (pasta wheat) x modern wheat crosses. A few older, lower yielding lines were added for comparison. We first phenotyped these lines in a controlled environment at seedling and vegetative stages to evaluate their RSA during early development. The lines were then grown in the field this year to compare yield (grain and biomass) with roots measured by excavating plants at different time points as the crop developed (Figure 1). Field evaluations in the 2019-20 season took place at NIAB in Cambridge and project partners Forschungszentrum Jülich in Bonn, Germany and will be repeated in the 2020-21 season.

Genetics are only part of what determines the RSA phenotype. RSA has been shown to adapt to local environmental conditions. The plasticity of root growth to deviate from one set of genetically programmed instructions allows roots to better exploit the local heterogeneous nature of field soils. It also makes it trickier to predict the RSA phenotype from the presence, or absence, of certain alleles that govern root growth. Growing the winter wheat

Figure 2. Images of root hairs in wild-type plants (left images) and in the root hair defects line (right images)



panel in two environments will help us understand the extent of root plasticity for these lines and how much it impacts RSA. Plus, by combining the information collected in controlled environments, and in the field, we will be able to evaluate how root traits measured at early stages (where observing roots and making selections are easier) relate to what we observe later in the field. The data should tell us something about which RSA features have been indirectly selected through selections for grain yield, and provide an indication of the extent of RSA variation that exists within a pool of high yield material.

Exploiting novel genetic variation for beneficial root phenotypes

In addition to growth angle and biomass, other traits are also important for root function. Root hairs are an important feature of RSA for root-soil contact and nutrient acquisition. They are tiny tubular outgrowths of epidermal cells that extend the absorbing surface of roots and largely contribute to the remobilisation of non-mobile elements such as phosphate. Root hairs have been well characterised in rice and maize, but little is known about the genetic control of growth and development in wheat. By identifying key genes that regulate root hairs, breeders would be better equipped to select for superior genotypes.

We took advantage of the availability of a mutagenised population of the wheat variety Cadenza to identify a line with defects in root hair development. Detailed images of the root hair mutant phenotype line showed that root hair formation ceases soon after initiation, preventing the root hairs fully elongating (Figure 2), and indicating the mutation has disrupted a gene that is needed for correct root hair development. We will exploit this line to identify and characterise the genetic factors associated with the phenotype, and to understand the impact of differential root hair growth on water and nutrient acquisition. Obviously, the mutant itself is not agronomically useful, but knowledge of the genes will ultimately allow us to identify alleles that show improved root hair characteristics, perhaps such as the ability to more quickly grow and develop to capture a flush of soil nitrate following fertiliser application, minimising losses through leaching.

Genome editing to create novel variation for deep, narrow root systems

To further deepen our knowledge on genes controlling RSA, we have targeted regions of the genome known to control RSA traits to modify the expression and/or the function of genes present in these regions. With current technique, such as the Clustered Regularly Interspaced Short Palindromic repeats (CRIPSR), we now have the potential to modify RSA by either enhancing the expression of a gene itself or by creating targeted mutations to a specific gene to understand its function in RSA. This technique will allow us to create genetic diversity in a small region of the genome while keeping the rest of the genome unaltered for easier comparison and speed up our understanding of how to breed for better RSA.

Richard Harrison • richard.harrison@niab.com

Lifecycle analysis – the way forward

Richard continues his series of articles for *Landmark* covering his conclusions and recommendations from his Nuffield Farming Scholarship 'Where next for soft fruit in the UK?', with applications beyond the soft fruit industry.

In my previous two articles I illustrated how genetics has a large role to play in a sustainable agricultural future through the rational design of new crop varieties. The systems in which crops are grown must be designed to reduce greenhouse gas emissions and to take advantage of the rapidly changing energy generation and utilisation opportunities afforded by the circular economy approach. The focus of this article is on the need to truly understand the impact that our food system has on our planet, elucidated through linking system-level modelling and lifecycle assessment.

Conclusion 3

It is currently very hard to say what is good and what is bad; more sophisticated lifecycle analysis and digital twinning is needed to quantify externalities of production to shape the design of new systems.

The author Douglas Adams had a set of rules defining the human reaction to technology. To paraphrase, anything that exists when you are born is simply part of how the world works and completely natural. Anything invented through your adolescence and early adulthood is new, exciting and revolutionary and anything invented after you are thirty-five is basically 'magic' and totally against the natural order of things!

This probably extends far beyond technology and certainly was true when it came to my thinking about our food system. Prior to my Nuffield Scholarship I would barely even notice if my

raspberries came from Cape Town or Kent, let alone question if it was sustainable or not.

This all changed during my Nuffield travels. I had the great fortune of spending some time in California and South Africa, both of which are, in my view, weather vanes for the future. I could very well have been in Kent as I travelled around fruit growers in South Africa as the systems were identical, but crucially the environmental impacts are not.

Water scarcity is a far greater issue in South Africa (Figure 1), even more so than in Kent, and the emissions in air freight alone of fresh produce to the UK lead to around 5 kg of CO_2 being emitted for every kg of fruit transported. This disparity in environmental impacts seems to bear little resemblance to the price of food (Figure 2).

Such is the acceptance of our current natural state of things, that many barely question how it is that produce of identical quality and price could have led such a different life and likely had such a different environmental impact. For economists the ‘cost’ to the environment and society not reflected in the price is known as the ‘externality cost’, in this case a negative externality cost.

We already have a lot of different ways to measure the impact of products in our supply chain, a discipline known as Life Cycle Assessment (LCA). Lifecycle assessment is a cradle-to-grave framework, which attempts to estimate the environmental impact of a product (e.g. 1 kg of strawberries), taking account of the impact of both the inputs into the system and the outputs as they flow through the supply chain. Most often nowadays, with the focus on net zero, the greatest attention is paid to equivalent CO_2 emissions – the attempt to scale all types of emissions that have global warming potential to that of the amount of a known quantity of CO_2 emissions. However, LCA can go much further than this and depending upon the sophistication of the approach used it can report on a whole host of metrics, such as water use and environmental pollutants.

Diving into the intricacies of LCA,

Figure 1. Highlighting water scarcity in Cape Town Airport, March 2018

however, reveals some major issues around the accessibility and quality of the data used to calculate these

Figure 2. Raspberry co-mingling in a British supermarket

statistics. I tried extremely hard to first find, and then calculate, a comprehensive LCA for UK-grown strawberries. I soon realised that whatever I did with any of the current tools was likely to be wrong. This is because the data is often out of date, not regionally appropriate, or that the assumptions made in other LCAs that your specific LCA builds upon are flawed. Used as a relative tool, they can be a handy for benchmarking and, in the short-term, should be used to accelerate our transition to sustainable farming, but in terms of absolute quantification, they are not yet fit for purpose.

I would argue that this really matters and that we must put effort into designing better ways of measuring the absolutes as while these remain hidden, we will only get part of the way to designing sustainable systems. As ever, technology provides us with a range of ‘magical’ solutions. We can now measure many things in real-time at low cost and with openness of data, for example the availability of the real-time mix of energy sources (solar, wind, gas, hydro) allows us to calculate the instantaneous level of emissions for power being consumed. We can also understand the impact that our system will have upon land use change (my example in the previous article between the differing land requirements for solar and bioenergy illustrates this point), the effect upon biodiversity, the water table and other important ecosystem service indicators. The integration of technologies should allow harvest-level LCAs, based on real data to be calculated for any crop, anywhere.

However, accounting for what we have done only takes us so far. We also need to be able to understand what we can do and which course of action is both economically viable and the most sustainable. To really take advantage of these opportunities more effort is needed in linking insights from real-time data to multi-scale modelling (also known as digital twinning), to explore and model a wider range of system design options *before they are built*.

Take a glasshouse (or vertical farm) crop as an example. Being able to model a whole range of environments, crop architectures, growing systems and to report back those that are optimal for a specific locality is a compelling thought. We could explore billions of permutations, in search of optimal yet achievable solutions. In some cases the major lever to pull might be genetics, in others, the glasshouse design or the energy supply. Being able to demonstrate system level performance will help de-risk investment decisions and accelerate positive change towards not only net zero systems, but systems that integrate a fuller range of negative externality costs. I have used glasshouses as an example here, but there is no reason why this cannot be applied to any farm business. Indeed, doing this, coupled with the right accounting framework, would allow statutory sustainability accounting, demonstrating corporate best practice in a transparent manner.

The impact of these innovations upon our supply chain could be profound. Better harvest and business analytics will help supermarkets and suppliers make better choices on our behalf, as they will have much greater clarity on both the indirect emissions that occur in the value chain but also other environmental impacts enabling informed purchasing choices to be made. For example, better data could enable choices to be made between producers with low absolute levels of emissions, versus those that are simply offsetting emissions. This may seem fantastical, but all of the building blocks are there to make this happen.

I saw many of these on my visits to Wageningen and California, detailed in my full report available from the Nuffield website (https://www.nuffieldinternational.org/live/Reports).

Recommendation 3

Expanded and more sophisticated lifecycle analysis, drawing together multidisciplinary teams to not only chart end-to-end costs of current supply chains but to model new sustainable scenarios, based on real world data is important. Government can play a key role in facilitating this through multidisciplinary research funding calls in this area. Beyond this, more effort in multi-scale modelling is needed to explore a wider range of supply system options *in silico*; this may extend to the creation of 'digital twins' to model both computationally and visually, the production systems and farms of the future.

In my next article I will explore some of the policy levers that others around the world are using to incentivise green growth and sustainable practice.

Board profile – Dr Helen Ferrier

Continuing our series of interviews with NIAB Board and Trust directors, *Landmark* talks to National Institute of Agricultural Botany Trust member Helen Ferrier about her background and her involvement with NIAB.

Can you tell us a bit more about your background?

I'm the Chief Science Adviser at the National Farmers' Union, where I have worked since 2004 focusing on science policy and advocacy. Before joining the NFU I did a PhD, alongside a research contract, at Imperial College London, modelling dietary exposure to pesticides using uncertainty analysis tools. My academic training was all environmental sciences, with particular emphasis on human health and epidemiology, first as an undergraduate at UEA in Norwich and then a post-graduate at Imperial.

How, and why, did you become involved with NIAB?

When I first started at the NFU I made it my business to take our officeholders to as many of the key agricultural and horticultural research centres in the UK as I could. NIAB was one of the first of course, and I got to know Wayne Powell and then Tina Barsby. Having also got to know Tony Pexton through the NFU, he suggested I may like to join the Trust. Richard Macdonald is an important figure from my formative days at NFU and I've also known Jim Godfrey for many years so I felt like I would also have ready-made links to the Board.

Could you explain how the National Institute of Agricultural Botany Trust supports NIAB?

The National Institute of Agricultural Botany Trust is a separate registered charity which owns all the land and buildings used by NIAB. It has a specific object to support NIAB in the pursuit of its objects including the provision of land, facilities and financial support. The Trust is administered by a Board of Trustees, separate to the NIAB Board.

What do you see as the big challenges facing UK agriculture and horticulture?

Challenges vary significantly between sectors and also between businesses. Uncertainty and volatility are bad for any business; climate change and weather, pests and diseases and limits to the toolbox of products and practices available to mitigate these, alongside supply chain and price imbalances and, of course, Brexit all add up to put a lot of pressure on British farmers and growers. I don't want to sound downbeat, however. What I see in the NFU membership are so many examples of progressive, innovative and resilient people who are proud of the industry and determined to see it prosper.

What current work at NIAB do you believe is making, or could make, an impact on the UK agricultural and plant science sectors?

NIAB's economic impact study, published in early September this year, has fantastically demonstrated the significant return on investment NIAB delivers for the economy. The value of its research for British agriculture and horticulture is a major part of this and the numbers are remarkable – for every £1 spent on research at NIAB at least £17.60 is returned to the UK economy, for example through improved production efficiency across UK farming. One case study covered NIAB CUF's economic contribution to advances in potato agronomy understanding and improvement over the past ten years, for example the development of its digital yield forecasting tools and its irrigation scheduling model, valuing it at £25.5 million. Another looked at NIAB's role in plant variety and seed testing, valued at £74 million over ten years, ensuring growers can be confident in the delivery of improved varieties, that certified seed is quality assured and that new varieties are offering a genuine improvement in performance and quality. For the future, NIAB has a really important role to play in helping farming to both adapt to and mitigate climate change, and for the food system to be more resilient to future shocks.

Getting to know you

What was the last book you read?

A Place of Greater Safety by Hilary Mantel. It gives an imagined backstory to the characters in the French Revolution. It got a bit grim towards the end as you might imagine and wasn't the most cheering lockdown reading but I do love an epic novel.

Which is your favourite sports team?

I spent a huge amount of time rowing while at university in Norwich and in London, training with lots of future GB squad rowers. I love watching the Olympics, seeing the result of all those hours and years of training and the incredible things the human body and mind can achieve.

Where's your favourite holiday destination?

Skiing is my perfect holiday, although I haven't been for a while. We used to go to the Alps when I was a child but more recently I've had some great holidays in the Dolomites in Italy.

Tell us something about you that would surprise people?

I am a violinist and perform classical, folk and even some jazz in various ensembles. Covid-19 stopped that in its tracks unfortunately. I was preparing to play a Bach double violin concerto in a concert at the end of March and then lockdown happened. We still don't know when we'll be able to return to live performances.

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

I love literature and music. It is difficult to make a living out of either but if money was not an issue I'd like to have been a writer or a professional musician.

ARTIS NIAB

Technical training courses

2021 Classroom Courses

10 February	**Better control and avoidance of disease in wheat** • Trained by Bill Clark and Aoife O'Driscoll • TBC
11 February	**Advanced nutrient management for combinable crops** • Trained by Stuart Knight • NIAB Park Farm, Cambridge
17 February	**Best practice in water management and irrigation** • Trained by Mark Stalham • NIAB Park Farm, Cambridge
23 February	NEW **Integrated weed management** • Trained by John Cussans • Mulberry Room, NIAB HQ, Cambridge
12 January	**Advanced crop management of vegetable Brassicas** • Trained by Andy Richardson • Spalding, Lincolnshire
19 January	**Advanced crop management of bulb onions** • Trained by Andy Richardson • Spalding, Lincolnshire
3 March	**Optimising crop management of leafy salads** • Trained by Liz Johnson • Mulberry Room, NIAB HQ, Cambridge
3 March	**Understanding potato growth stages and scheduling irrigation to optimise yield and quality in potatoes** Trained by Mark Stalham • NIAB Park Farm, Cambridge
4 March	**Understanding and optimising potato nutrition and improving potato yields and profitability by measuring and monitoring performance** • Trained by Marc Allison • NIAB Park Farm, Cambridge

To see how we are keeping you safe on our courses and our flexible booking policies visit www.artistraining.com and click the Covid-19 button.

2021 Virtual Course

9 & 10 February	**Benefits of cover crops in arable systems** • Trained by Nathan Morris Course split over two 3 hour morning sessions

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.

01223 342444 info@artistraining.com @ARTIStraining artistraining.com

NIAB TAG

Lawrence Weaver Road, Cambridge CB3 0LE T: 01223 342200 E: info@niab.com www.niab.com

FSC

Printed on 100% recycled, totally chlorine free fibre. This paper is totally recyclable and bio-degradable. NAPM recycled certification.

Edited and published by NIAB TAG. Designed and produced by Cambridge Marketing Limited, 01638 724100