March 2025

Annual Project Report
(Harvest 2024)

On-farm trials at
Strategic Cereal Farm South

1. Introduction

Host Farmer: David Miller

Location: Folly Farm (Wheatsheaf Farming Company), Hampshire

Duration: 2021–2024

AHDB Strategic Cereal Farms put cutting-edge research and innovation into practice on commercial farms around the UK. Each farm hosts field-scale and farm-scale demonstrations, with experiences shared via on-farm and online events to the wider farming community.

David has embraced regenerative agriculture practices for over a decade. Folly Farm has adopted cover crops and been fully no-till since 2015, with a goal to be profitable, while maximising carbon sequestration and biodiversity. David's time as a Strategic Cereal Farm host has come to an end, but he will continue his agricultural journey as a regenerative farming advocate and advisor.

2. Impact of cover crops on water quality

Trial leader: Callum Scotson, Joe Martlew, Naomi Menzies, Niab

Start date: September 2021

End date: September 2024

2.1. Headlines

- Cover crops have been grown at Wheatsheaf Farming Company since 2010
- All spring crop ground has included a cover crop since 2015
- Work at the farm by South East Water (led by FWAG-South East) has demonstrated the benefits of cover crops on water quality (reduced nitrate leaching), beneficial invertebrates and wider soil health
- This work also investigated the interaction between the cover crop species mix, soil health status and productivity of following spring crops
- None of the cover crop mixtures had any observable deleterious effect on spring crop establishment, health or yield
- Cover crops increased slug numbers slightly (compared with stubble), but the overall benefits for beneficial invertebrate species outweighed pest increases
- Therefore, the selection of the most appropriate cover crop mixture can be made by considering the rate of establishment, canopy development and capacity to develop above or below ground biomass

- When selecting a cover crop mix, the rate at which various species emerge and develop above/below-ground biomass need to be considered (aim to maximise ground and root coverage)
- For example, radish, phacelia and mustard contributed substantially to the above-ground biomass (helping to, for example, reduce the likelihood of capping)
- Difference in rooting structures meant that only radish and mustard further significantly contributed to below-ground biomass
- However, the dense fibrous root network of phacelia in the top 15 cm of soil created and stabilised a distinct crumb structure

2.2. What was the challenge/demand for the work?

Cover crops provide benefits such as improved soil structure, capturing nutrients and providing organic matter. Cover crops have been used at Wheatsheaf Farming Company since 2010 and all spring crop ground has included a cover crop since 2015. David is working with South East Water, FWAG-South East and Kings Crops to trial cover crops and assess impacts on diffuse pollution, soil health and biodiversity. Assessments carried out by FWAG-South East include nitrate in soil water, soil nutrients, cover crop nutrient content, slug populations, beneficial insects (pitfall traps) and soil health. These data have highlighted peak nitrate concentrations in early autumn together with the role of all cover crops in reducing nitrate losses. The reduction in nitrate losses is strongly related to groundcover with largest losses where crops achieved < 10% cover by December, weedy stubble achieves ground cover of 20-30% whilst cover crops achieved a ground cover of 50-70%. However much less is known about the patterns of below ground biomass and impacts on the following crop. The monitoring within the Strategic Farm South programme focused on filling these data gaps.

2.3. How did the project address this?

Trial design

The 2022-23 trial took place in the same fields as the 2021-22 trial but in different areas (Figure 1). The main cover crop trial took place in Slope field with a comparator winter cropping scenario (wheat in 2021-22; beans in 2022-23) in neighbouring Workshop field. Slope field contained four different treatments: three areas containing different cover crop seed mixes as well as an area of bare stubble. Each of these areas consisted of an unreplicated 18 m wide strip that ran across the field.

The cover crop seed mixes in Slope field were as follows:

- Oats and mustard
- Buckwheat, radish, linseed and phacelia

- Radish, vetch and phacelia (2021)
- Oats, clover, radish and vetch (2022)
- Stubble (control – with weeds and volunteer cereals)

In 2023-24, the trial was moved to Trinleys field ahead of spring wheat. Cover crops were:

- Cereals and brassica
- Legume heavy mix
- Stubble (control)
- Brassica heavy mix
- Winter wheat

In each case the cover crops were destroyed by the farm using total herbicides, ahead of establishment of a spring crop (2022 - spring wheat; 2023 – spring beans; 2024 – spring wheat). Difficult drilling conditions in 2024 meant that two drills were used in the field; the spring wheat strip following cereals and brassica cover crops was established with a different drill than the other strips.

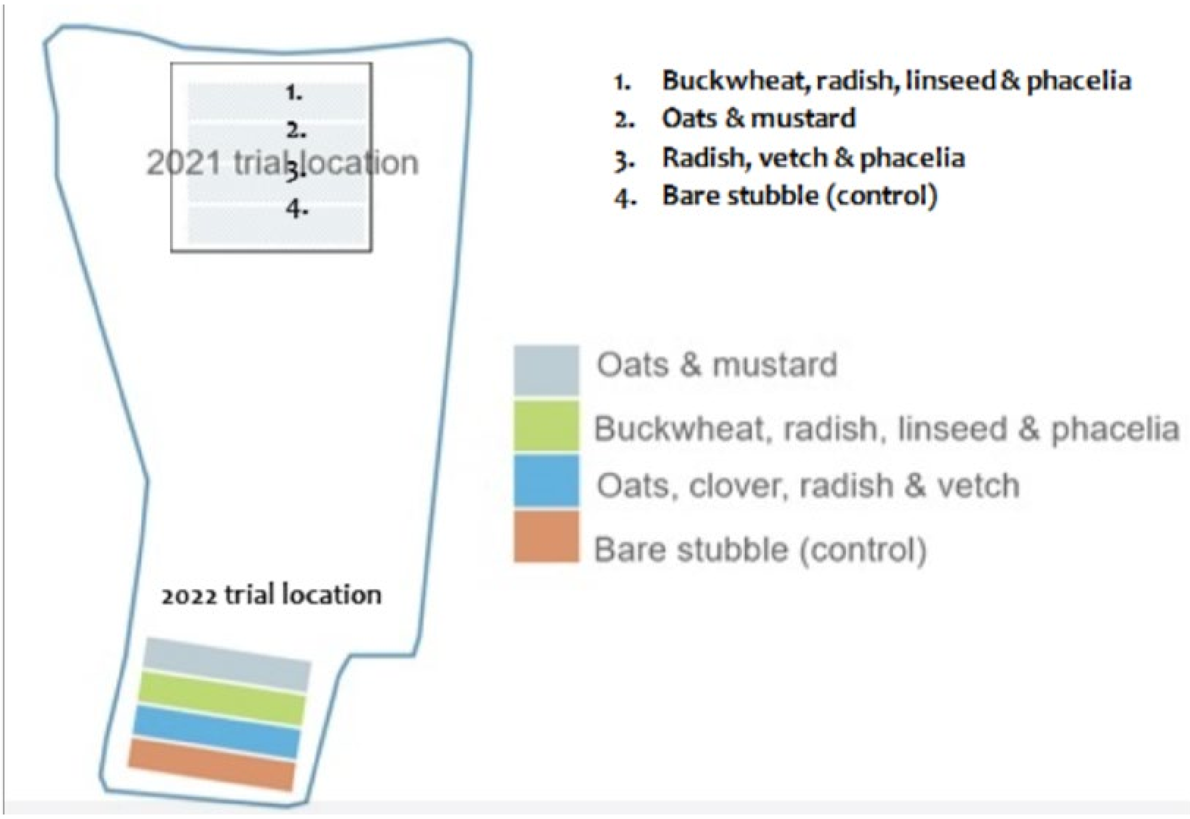


Figure 1. The layout, composition and location of the 'cover crop strips' in Slope field overwinter in 2021 and 2022.

Assessments

Cover crop establishment and biomass assessments (2021, 2022)

Establishment assessments, consisting of plant counts and percentage green cover scores, were undertaken on both the cover crop areas in Slope field and the winter beans in Workshop field at 4, 6 and 8 weeks post-drilling of the winter beans. These assessments were conducted across fifteen 25 cm^2 quadrats in each cover crop area and in the winter crop in Workshop field.

The above and below ground biomass were recorded for each strip of cover crop mix and for the comparator winter crop in Workshop field. All plants were extracted from four 25 cm^2 quadrats in each strip, in addition to the winter wheat in Workshop field. The plants were sorted by species and cut into separate above and below ground sections. Fresh and dry mass was then recorded for above and below ground material of each constituent species of the mix, as well as any weed species present.

Soil health assessments, 2021 and 2022

Late in the cover cropping period, soil health assessments were undertaken using a Soil Health Scorecard approach. The assessments conducted included Visual Evaluation of Soil Structure (VESS) assessments, worm counts and laboratory analysis of the soils. Three sampling sites were identified within each cover crop treatment strip in Slope field, in addition to three sampling sites located in the winter beans in Workshop field.

Assessments of the following crop (all years)

Following destruction of the cover crops and drilling of the spring crop, establishment was assessed at 6 weeks post-drilling. Crop health was monitored through the season.

Yield data was collected from the combine yield maps at harvest for the winter beans in Workshop field and for spring beans from each of the cover crop strips in Slope field. The strips of spring beans in each of the former cover crop areas were harvested individually to prevent crossover. Grain samples were also collected at harvest from four regions of each cover crop treatment area in addition to four areas of Workshop field. These grain samples were then submitted for nitrogen and protein analysis (Niab Labtest, Cambridge, UK).

2.4. Results

Cover crop establishment

In 2021 and 2022 it was clear that the cover crop mixes containing cereals (and volunteer cereals in the control plots) were slower to establish than more diverse cover crops. Data are shown as an example for 2022 (Figure 2). In 2022, the winter beans in Workshop barely achieved 5% ground cover 8 weeks after drilling.

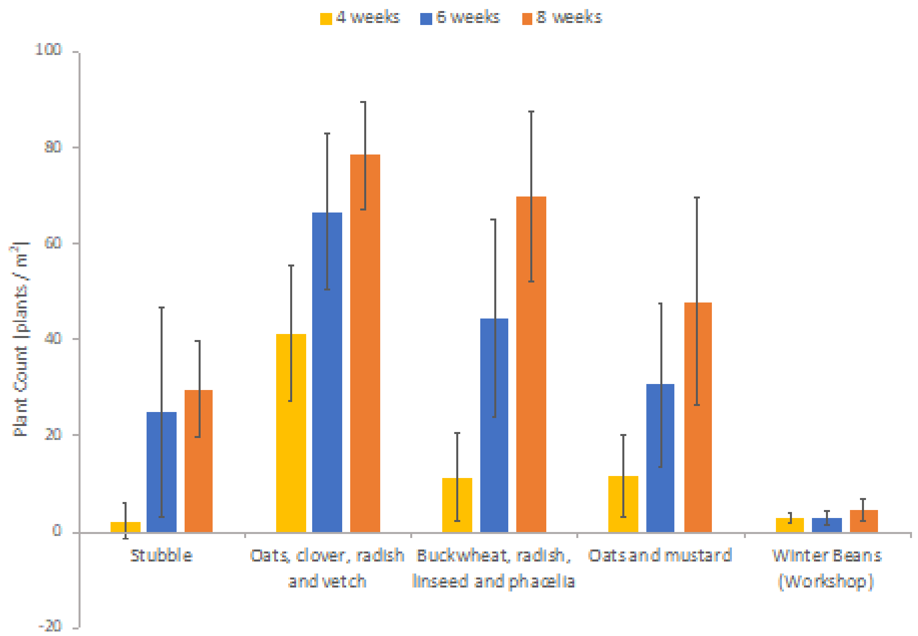


Figure 2. Comparison of plant counts across the four different cover crop strips in Slope field in comparison with the winter beans in the neighbouring field (Workshop). Error bars display the standard deviation.

<u>Cover crop biomass</u>

Where present, radish, mustard, oats and phacelia contributed substantially to the above ground biomass; data are shown as an example in Figure 3. The difference in rooting structures meant that only radish and mustard further significantly contributed to the below ground biomass (Figure 4). In winter 2022-23, considerably less biomass was provided by cereal volunteers in the stubble compared with overwinter 2021-22. However, the dense fibrous root network of phacelia within the top 15 cm of soil created and stabilised a distinct crumb structure. Species which provide substantial above ground biomass were likely to provide larger canopies which in turn could, for example, reduce the likelihood of capping.

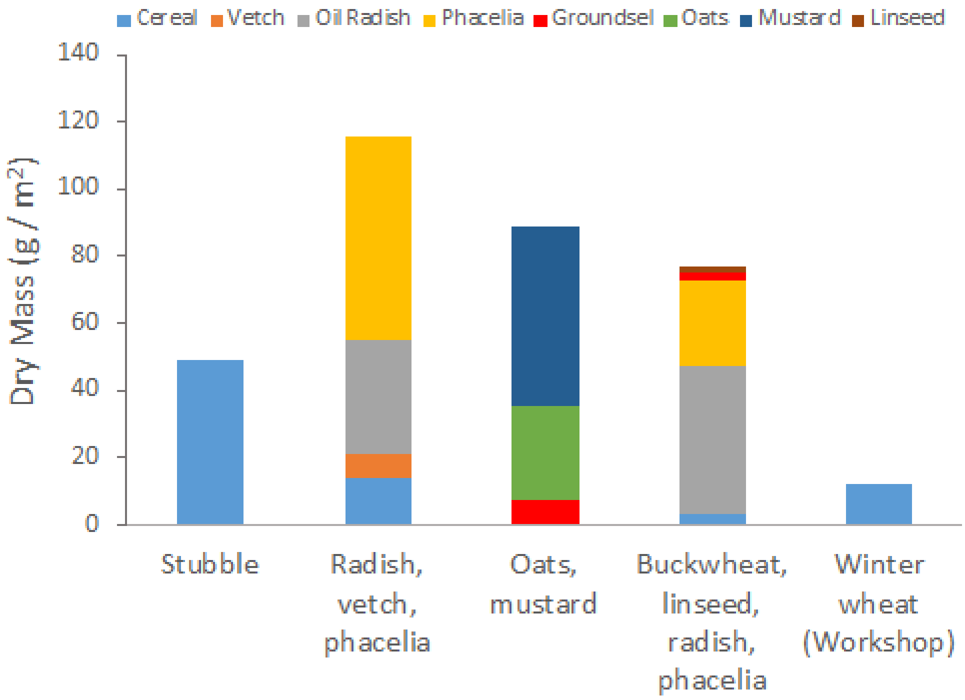


Figure 3. Above ground dry mass (g / m^2) for the constituent plants of the different cover crop seed mix areas measured in December 2021.

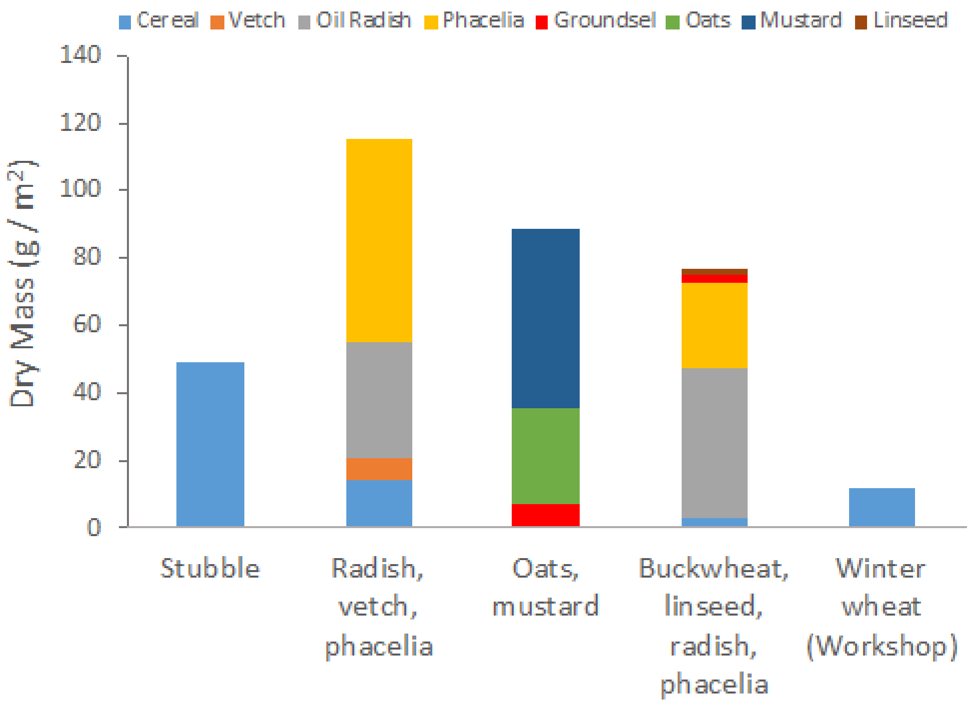


Figure 4. Below ground dry mass (g / m^2) for the constituent plants of the different cover crop seed mix areas measured in December 2021.

VESS assessments were carried out towards the end of the cover cropping period (Figure 5). VESS assessments provided insights into the condition of the soil under the four treatments in Slope field and in Workshop field. The soil within the cover crop strips in Slope field and the winter wheat in Workshop field was generally well structured (Figure 5): the areas containing cover crops received average VESS scores of 1, whilst the strip containing bare stubble and the winter beans in Workshop field received average VESS scores of 2. Considerable soil cohesion was observed at the surface in the cover crop plots, where the soil surface was held together by roots. However, though still well structured, the soil surface cohesion in the ‘bare stubble’ area was poorer – owing to the lack of roots to retain the soil in place. It was noted that the photos collected during VESS assessment provided useful information on rooting patterns and impacts, similar to that provided by the more complex (and costly) detailed sampling. Hence for on-farm monitoring it is suggested that VESS assessments with photos should be used as the main way of monitoring differences in rooting patterns and their impacts on soil structure.

a) Winter beans

b) Bare stubble

c) Seed Mix 1 (oats and mustard)

d) Seed Mix 2 (oats, clover, radish and vetch)

e) Seed Mix 3 (buckwheat, radish, linseed and phacelia)

Figure 5. Photographs collected as part of the VESS process in December 2022 highlighting the differences in rooting patterns and their impacts on soil structure.

Crop health, yield and grain analysis

There were no significant differences in crop emergence and establishment of spring wheat or spring beans across all the former cover crop strips in any of the trials; none of the cover crops had significantly influenced the establishment of the following spring crop.
There were also no major pest or disease pressures and the cover crops did not appear to observably influence crop health.

At 2022 harvest, the yield of the winter wheat in Workshop field was significantly greater than that of the spring wheat in any area of Slope field - as would be expected. Within Slope field, the yield of spring wheat was not significantly different between the different zones of previous cover cropping There were also no clear trends shown in the protein content and specific weight data between the cover crop mix treatments (Table 1).

At 2023 harvest, the yield of the winter beans in Workshop field was significantly greater than that of the spring beans in any area of Slope field - as would be expected (Table 2). Within Slope field, the yield was not significantly different between the different zones of previous cover cropping. There was also a slight trends suggesting higher protein content following cover crop mix treatments compared with bare stubble (Table 2).

At 2024 harvest, yield of the spring wheat seems to have been affected by the different drill used following the cereal and brassica cover crop with a lower yield in that plot (Table 3). However, there was also an apparent yield gradient (north to south) across the trial. Whilst it seems that there has been no effect of the preceding cover crop on grain yield and quality, the trial layout does not allow this to be confirmed; replication or layout of the plots across the underlying gradient would be needed.

Table 1. Average yield (t/ha) and grain quality data for spring wheat, harvest 2022, following cover crop treatments. Analysis provided by Niab Labtest (Cambridge, UK).

Treatment	Average yield (t /ha)	Specific weight (kg/ hL)	Protein content (g/100g)
Winter cropping (winter wheat)	8.6	81.1	10.6
Stubble; control (weeds and volunteer cereals)	4.6	76.2	12.3
Cover crop (radish, vetch and phacelia)	4.4	75.9	11.9
Cover crop (oats and mustard)	3.9	73.7	12.4
Cover crop (buckwheat, radish, linseed and phacelia)	4.6	76.2	12.2

Table 2. Average yield (t/ha) and grain quality data for spring beans, harvest 2023, following cover crop treatments. Analysis provided by Niab Labtest (Cambridge, UK).

Treatment	Average yield (t /ha)	Moisture content	Protein content (g/100g)
Winter cropping (winter beans)	2.2	14.0	26.75
Seed Mix 1 (oats and mustard)	1.1	13.5	30.26
Seed Mix 2 (oats, clover, radish and vetch)	1.2	13.9	31.66
Seed Mix 3 (buckwheat, radish, linseed and phacelia)	1.1	14.0	30.91
Stubble; control (weeds and volunteer cereals)	1.2	14.1	28.90

Table 3. Average yield (t/ha) and grain quality data for spring wheat, harvest 2024, following cover crop treatments. Analysis provided by Niab Labtest (Cambridge, UK). Small hand-samples and hence specific weight could not be determined.

Treatment	Average yield (t /ha)	Protein content (g/100g)
Cover crop (cereals and brassica)	5.3	13.1
Cover crop (legume heavy)	5.8	14.0
Stubble; control (weeds and volunteer cereals)	5.9	14.2
Cover crop (brassica heavy)	6.3	14.0
Cover crop (winter wheat)	6.5	14.2

Harvest of the spring wheat was delayed due to showery weather in August; ear diseases including fusarium and ergot were found in the grain samples (Figure 6).

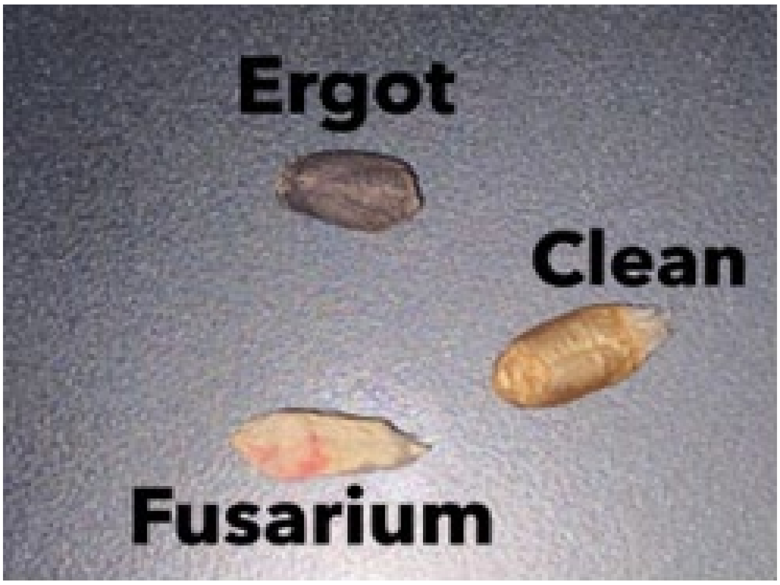


Figure 6. Spring wheat grain collected from Trinleys (harvest 2024) highlighting the high ear disease pressures in the 2024 season.

2.5. Action points for farmers and agronomists

The results confirm that the farm's long-term decision to integrate cover crops on these light/medium soils does not have a deleterious effect on following crop health or yield. Integration of cover crops is not expected to be as straightforward on heavy soils.

Selection of the most appropriate cover crop mixture for any site should consider the rate of establishment, canopy development and capacity to develop above or below ground biomass with regard to the expect drilling date. For example, it was observed within this project that early-season green cover and canopy development varied between mixes and that various species made differential contributions to above- and below-ground biomass production. Assessment of rooting can be made simply on-farm using a spade assessment based on the VESS approach.

3. Impact of management practices on soil and crop health

Trial leader: Callum Scotson, Joe Martlew, Naomi Menzies, David Clarke, Niab
Start date: September 2021
End date: September 2024

3.1. Headlines

- This work investigated the impact of cultivation system changes and cover crop integration on soil health status, crop health and productivity
- The work showed the value of on-farm monitoring and highlighted the need to select representative monitoring sites, carefully drawing on farm spatial data together with farmer knowledge
- It monitored the farm rotation (eight fields) which has been managed using principles of regenerative agriculture for the past decade
- It also monitored a field (Typhrees) which is transitioning to the 'regenerative' system from a conventional system
- Typhrees is in continuous spring barley, now with a diverse cover crop overwinter
- The long-term positive impact of regenerative practices on soil structure and wider soil health (reduced tillage and integration of cover crops) were shown clearly where fields were compared
- The farm data set clearly shows variability between and within fields that results from long-term management differences and differences in inherent soil properties, such as stoniness and texture
- Yield map data can be collated and analysed to derive yield performance zones that can inform identification of management zones to support targeted management approaches

3.2. What was the challenge/demand for the work?

The goal of the Strategic Farm South is to be profitable whilst also maximising carbon sequestration and biodiversity. The farm has adopted cover crops and been 100% no-till since 2015; recent additions to the strategy are to reduce nitrogen and other inputs. Soil and crop health across the rotation were monitored, together with agronomic performance. In 2021 the farm took on a new area of land that had been conventionally managed in continuous spring barley and brought it into more regenerative management by reducing tillage intensity and including diverse cover crops. Soil health and crop performance were compared with the fields with established regenerative systems. These sites also provided a base for work to pilot approaches to compare nutrient density of grain from different management approaches; this is described separately in Section 4.

3.3. How did the project address this?

Trial design

This project monitored 8 fields across the farm to provide a representative picture of the farming system. These fields have been under a management system which incorporates principles of regenerative agriculture (i.e. the use of cover crops and minimum tillage progressing to no tillage) for approximately ten years (Table 4).

In comparison, monitoring was implemented for a field (Typhrees) that had previously been conventionally managed, continuous spring barley, but which is being transitioned to a management system which incorporates principles of regenerative agriculture with no change to the cropping pattern but with reduced tillage intensity and integration of cover crops. In 2022, there was a more focused monitoring of the farm fields under cover crop-spring barley (Old Park, Rye Furlong) to provide a direct comparison with Typhrees.

Table 4. Cropping during the study period in the fields monitored at Strategic Farm South

Field	Harvest 2022	Harvest 2023	Harvest 2024
Old Park	Diverse cover crop followed by Spring barley	Winter oilseed rape with buckwheat and clover companion	Winter wheat
Rye Furlong	Diverse cover crop followed by Spring barley	Winter oilseed rape with buckwheat and clover companion	Winter wheat
Piggery	Winter wheat	Diverse cover crop followed by Spring barley	Winter oilseed rape with buckwheat and clover companion
Big Grange	Spelt wheat	Diverse cover crop followed by Spring barley	Winter oilseed rape with buckwheat and clover companion
70 Acres	Winter rye (failed) followed by Spring beans	Spelt wheat	Winter oilseed rape with buckwheat and clover companion
Ashen Grove	Spelt wheat	Winter wheat (Extase)	Diverse cover crop followed by Spring wheat
Waltham Marks	Winter wheat	Winter beans	Winter wheat
Workshop	Winter wheat	Winter beans	Winter wheat
Typhrees	Diverse cover crop followed by Spring barley	Diverse cover crop followed by Spring barley	Diverse cover crop followed by Spring barley

Three representative sites in each field were identified following a review of the 2021 harvest yield maps and in discussion with David Miller, the farm manager. The locations of the monitoring sites were recorded using What3Words so that they could be returned to readily as part of regular monitoring.

Assessments

<u>Soil health</u>

Soils have a range of inherent properties, texture, depth and stoniness; this soil type/ character determines yield potential and many of the environmental risks for any site. Interventions through tillage, manures, drainage, species /mixture choice in crops and cover crops then interact to determine soil health. It is widely recognised that soil physics, chemistry and biology are interlinked, and all play a role in maintaining productive agricultural systems. The AHDB/BBRO Soil Biology and Health Partnership (2017-2022) evaluated 45 biological, physical, and chemical indicators and considered how these could be integrated into a soil health scorecard to give a 'snapshot' overview of soil health (akin to a car MOT or school report), designed to be repeated in the same place rotationally. A 'traffic light' system was used to provide a visual overview of the status of each indicator to help identify the key constraints to other impacts of sub-optimal soil conditions/ function (e.g. environmental risk where available P is very high) and options for soil improvement. This Soil Health Scorecard methodology and benchmarks are available publicly (https://ahdb.org.uk/greatsoils).

In November 2021, soil health assessments were undertaken in 3 fields under cover crops (ahead of spring barley) and two fields under winter cereals. In November 2023, which was expected to be the mid-point of the overall monitoring programme, soil health assessments were undertaken in all 9 of the monitored fields. The AHDB Soil Health Scorecard approach was in the final pilot phase in 2021, and by 2023 was available for general use. The assessments conducted included Visual Evaluation of Soil Structure (VESS) assessments, worm counts and laboratory analysis of the soils.

The VESS assessment provides a published framework for visually assessing soil physical structure wherein an extracted soil block is given a score of between 1 and 5 based on characteristics including: aggregate size and shape, porosity, and root penetration (Ball et al., 2007). A score of 1 represents good soil structure and a score of 5 represents poor soil structure. Three VESS assessments were conducted in each field (one VESS assessment per sampling site) to a depth of 30 cm.

Earthworm counts are commonly used as an indicator measurement for biological activity in soils. Higher earthworm numbers as well as a more diverse population of earthworm ecotypes and ages would generally indicate a healthier soil. The benchmarks used to interpret earthworm numbers followed those of the AHDB Soil Health Scorecard framework. Three earthworm counts were conducted on 20 cm^3 soil blocks in each field (one earthworm count assessment per sampling site). Total number, number of adults and juveniles, and the ecotype of the species were recorded. Soil samples were collected for laboratory analysis at each of the three sample sites within each field. The samples were then submitted for broad spectrum analysis undertaken by Lancrop (Lancrop, YARA, Pocklington, UK). The broad-spectrum analysis included: soil texture, pH, soil organic matter, Solvita CO_2 respiration, cation exchange capacity as well as available phosphorus, potassium, magnesium, sodium, calcium, and a selection of micronutrients.

Crop establishment and health assessments

Establishment assessments were undertaken 4, 6 and 8 weeks post-drilling. These assessments were walk-over and photo-based; where quantitative comparison was required plant counts and percentage green cover scores were made in 5 x $1m^2$ sample areas at each of the sampling sites in each field.

Above and below ground biomass for the cover crops was recorded for each field in December 2021. All plants from four 25 cm^2 quadrats from across each field were extracted, sorted by species and cut into separate above and below ground sections. Fresh and dry mass was recorded for the above and below ground material of each constituent species of the mix, in addition to any weeds which may have been present.

To monitor general crop health, pest/ disease status was monitored through crop walking throughout the growing season. Where significant disease was noted, leaf layer disease assessments were carried out.

Yield and harvest sample analysis

Crop yield was assessed using cleaned combine yield meter data. Yield data was extracted from CLAAS Telematics and processed following the methods outlined in AHDB Strategic Farm East (2021–2023) (Clarke et al., 2024). Yields were adjusted to 85% dry matter using moisture readings recorded from the combine harvester. For each sampling point, the mean yield within a 15m radius ($707m^2$) was extracted to provide a representative yield estimate.

Grain samples were collected within each of the fields by the farm team. Grain samples were submitted for grain quality analysis as appropriate for the crop at Niab Labtest, Cambridge, UK.

Spatial Monitoring of Soil and Crop Health on Farm

The 9 monitored fields were selected as representative of wider farming practices based on an analysis of 2–5 years of yield maps per field collected between 2016 and 2020. Methods developed as part of previous AHDB Strategic Farm work were integrated, and a single management zone within each field was monitored at three locations. As yield map datasets and other spatial datasets grow over time, it is good practice to periodically revisit and re-perform analyses to ensure that management and monitoring strategies continue to account for evolving spatial variability. Therefore, at the conclusion of this Strategic Farm Programme, a secondary spatial analysis was performed to support long-term monitoring and experimentation at the farm level.

For the monitored fields, yield maps from 2016 to 2024 were extracted from their native platforms (Gatekeeper and CLAAS Telematics). The yield map datasets were assigned a field name based on their location within the field boundary, using shapefiles from Gatekeeper. The crop type was assigned to each data point using a lookup table, and outlier removal techniques were applied to eliminate errors, such as instances where the combine header was not full. Once cleaned, the yield data was assigned to a 15m × 15m grid, reducing the influence of erroneous values. If multiple yield values were recorded within the same grid square for a given year, the mean value was used to ensure consistency.

A machine learning clustering algorithm (Hassall et al., 2019; Clarke et al., 2024) was applied to the yield map dataset for each field. Clustering is a data-driven technique used to group areas within a field that exhibit similar yield performance over multiple years. Instead of treating the field as a uniform area, clustering helps identify spatial patterns where yield tends to be consistently high, low, or variable. Management zones can be detected within each field, where yield patterns remain relatively stable over time. These spatially coherent zones can form the basis for spatial management decisions that optimise input use, improve accuracy and repeatability of long-term soil health monitoring and support on farm experimentation.

3.4. Results

<u>Soil health</u>

The soils at Strategic Farm South are of light-medium texture, calcareous with high pH (often 7.5+) with some chalk and flints. The group of soils found across the farm would fall within the Andover 1 Association with a mix of shallow stony soils over chalk and deeper soils formed in drift on shallower slopes and in valley bottoms. The soils are well drained with naturally high aggregate stability as a result of the high Ca content; this natural mechanism also tends to stabilise organic matter (SOM) within the soil. The parent material is low in potassium and magnesium and the availability of many micronutrients is restricted due to the high pH.

The presence of cover crops improved soil structure in autumn 2021 compared with winter cereals under the same management system. However, the conventionally managed Typhrees field had visibly poorer structure. Distinct layers of consolidation were visible in the soil extracted from Typhrees and there was little evidence of deeper root growth was present (Figure 7). Poorer structure in Typhrees compared with the fields with a longer regenerative history was still found in 2023 after 3 years of cover cropping and reduced tillage intensity (Table 7, Figure 7).

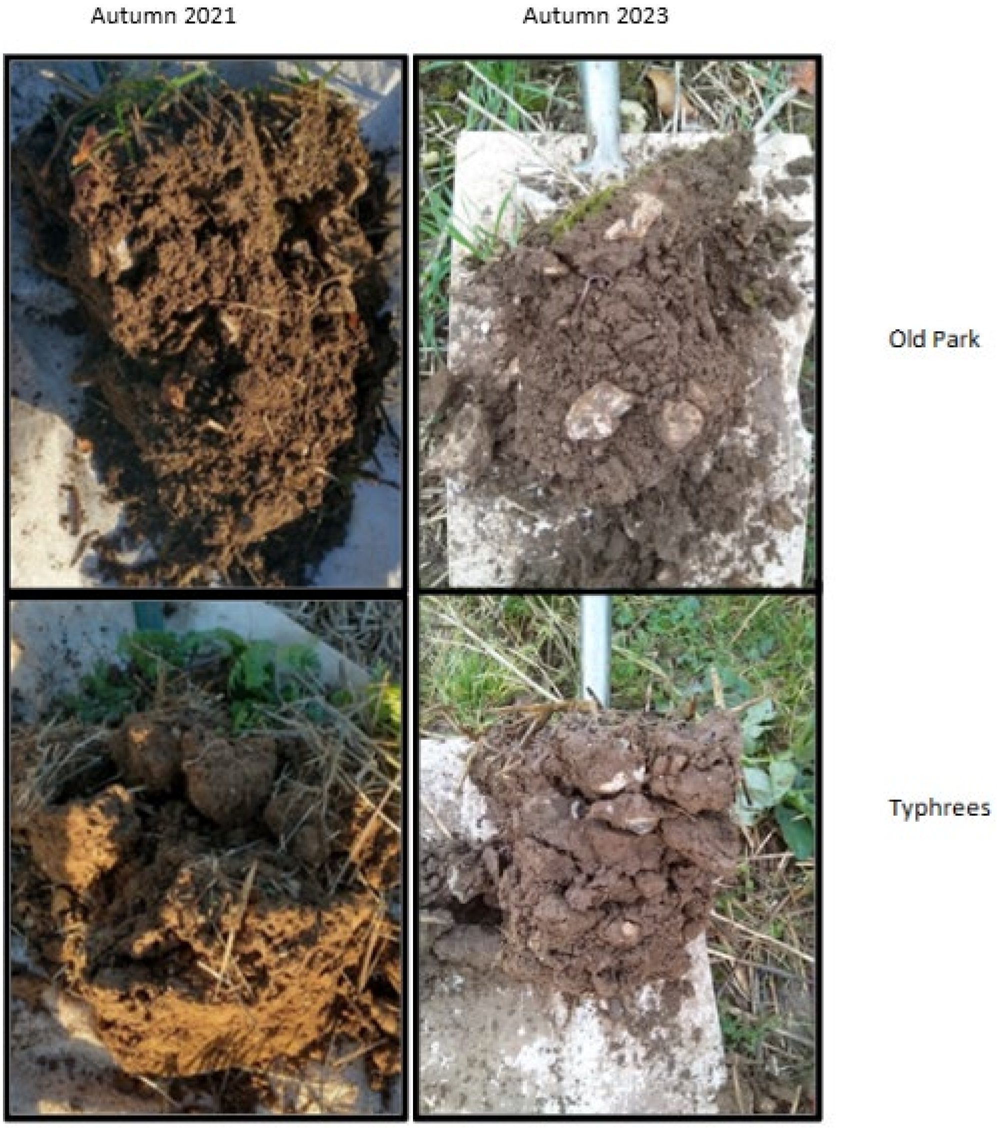


Figure 7. Visual Evaluation of Soil Structure (VESS) comparison between autumn 2021 (left) and autumn 2023 (right) in two fields – Old Park (upper) and Typhrees (lower).

Table 6. Soil Health Scorecards generated in November 2021.

Field name	Crop at sampling	Physical		Chemical				Biological			
										Microbial activity	
		Texture class	VESS (limiting layer)	pH	P	K	Mg	Earthworms	SOM%	PMN	CO_2 burst
Old Park	Cover crop	Silt loam - stony	1	7.5	**48**	151	47	7	4	107	159
Rye Furlong	Cover crop	Clay loam - stony	1	8	**56**	186	32	5	3.9	46	71
Piggery	Winter wheat	Silt loam - stony	1	7.7	**87**	296	50	6	5.2	92	137
Big Grange	Winter wheat	Clay loam - stony	3	7.5	38	222	65	5	3.2	103	154
70 Acres	Winter rye	Clay loam - stony	2	8.2	37	125	28	7	4.2	43	66
Ashen Grove	Winter wheat	Clay loam - stony	1	7.8	28	185	41	5	4	80	119
Waltham Marks	Winter wheat	Silt loam - stony	2	7.8	37	147	43	7	4.7	78	119
Workshop	Winter wheat	Clay loam	2	7.6	29	143	52	5	3.9	64	96
Typhrees *	Cover crop	Clay loam	3	7.6	28	97	29	16	3.7	99	148

*The long-standing regenerative fields can be compared with Typhrees, where regenerative practices had just begun to be integrated (note: the cover crop established poorly). Traffic light coding within the Scorecards is used to identify properties where further follow-up investigation is needed and guide management options that could minimise any potential risks to crop productivity.

‘Green’ – continue monitoring regularly;

‘Amber’ – review (monitor perhaps a bit more frequently than planned);

‘Red’ – investigate. A red traffic light doesn’t necessarily mean soil health is poor, rather it indicates that further investigation is required to understand why a particular property has been highlighted (which may mean repeat testing with a more detailed sampling scheme).

Table 7. Soil Health Scorecards generated in November 2023.

Field name	Crop at sampling	Physical		Chemical				Biological		
		Texture class	VESS (limiting layer)	pH	P	K	Mg	Earth worms	SOM%	Microbial activity CO_2 burst
Old Park	Winter wheat	Silt loam - stony	2	7.4	**46**	115	42	14	4.3	50
Rye Furlong	Winter wheat	Clay loam - stony	2	8	**52**	214	37	20	4.7	71
Piggery	WOSR with companions	Silt loam	2	7.4	**76**	294	45	14	5.5	68
Big Grange	WOSR with companions	Silt loam	2	7.2	27	155	45	15	3.7	99
70 Acres	WOSR with companions	Clay loam - stony	2	8.1	37	122	34	10	5.2	48
Ashen Grove	Cover crop (poorly established)	Silt loam	2	7.8	34	173	41	7	4.6	137
Waltham Marks	Winter wheat	Silt loam	2	7.9	32	116	41	5	5.8	123
Workshop	Winter wheat	Clay loam	2	8.1	23	131	39	5	5	56
Typhrees	Cover crop	Clay loam	2.5	7.5	24	77	32	10	4.1	105

See notes in Table 6.

Across all fields (Tables 6 and 7), available phosphorus (P) and potassium (K) reserves in the soils are generally good (Index 2-3), though some K index 1 sites are seen. Given that extractable soil Ca is also high, then there may be a response of crops to fresh K even at Index 2. No additional fertiliser P is recommended especially where P is much greater than 25. There are 3 fields with P reserves > 45 mg/kg, loss of these soils as sediment via run-off would be an environmental risk. Sites largely show moderate Mg reserve status; >50 mg/kg is considered to be good status. Chalky soils often have marginal Mg availability. There is little change in these measured values between 2021 and 2023 in the fields monitored on both occasions, indicating that current fertiliser management is maintaining soil fertility.

When considering SOM%, most soils are average or better for the climate/soil type; this is associated with cropping rotations with good organic matter inputs. The high Ca levels in these soils also help to stabilise SOM. Whilst the colour coding of the scorecard would suggest there are differences in SOM, it is important to note that these are small and close to the boundary values and within the sensitivity limits of organic matter analysis. In medium rainfall areas, such as this farm, a reasonable target for SOM% to maintain soil resilience is 2.7% on light soils and 4.1% on medium soils. Soils would be considered to have good organic matter levels at 4.2% and 6.1% on light and medium soils respectively. The data seems to suggest that fields are increasing in SOM% during the period of monitoring when comparing 2021 and 2023 data. However, a longer period of monitoring is required to confirm this trend.

Earthworm numbers were good-moderate with no clear pattern with cropping or management history; for example, Typhrees had the highest earthworm numbers in autumn 2021; Rye Furlong had the highest earthworm numbers in autumn 2023.

During the pilot phase of the AHDB Soil Health Scorecard, microbial activity was measured separately in two laboratories using either the PMN (anaerobic incubation) or CO_2 burst method. These are indicator measurements to show potential differences in microbial activity rather than measures of in situ activity at sampling. Numerous factors can influence microbial activity measures including complex biological and chemical interactions in the soil. However microbial activity is usually related to SOM; it is known that sites with higher SOM tend to have higher microbial activity - the most interesting thing to watch for is sites that don't show this pattern. In 2021, the PMN and CO_2 burst measures were well correlated (Table 6). Benchmarks for the CO_2 burst were reviewed as part of the AHDB-BBRO SBSH Partnership. However, it should be noted that there are methodological issues when soil pH is above 7.5 which leads to artificially low values; we have therefore not compared these data to the benchmarks

Cover crop establishment, performance overwinter and impacts on following spring barley, 2021-22

Cover crops in Old Park and Rye Furlong, which have been under a regenerative management system for approximately ten years, initially established well and continued to provide significantly more ground cover over winter than the cover crop in the previously conventionally managed Typhrees field. This can be observed in the significantly lower plant counts and percentage green cover values recorded in Typhrees relative to the cover crops in Old Park or Rye Furlong (Figure 8).

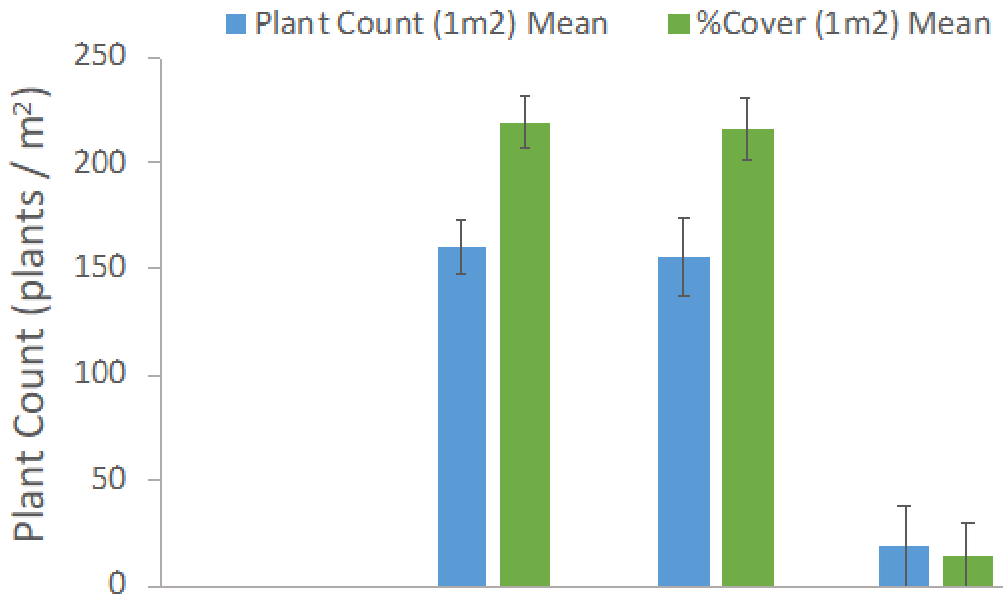
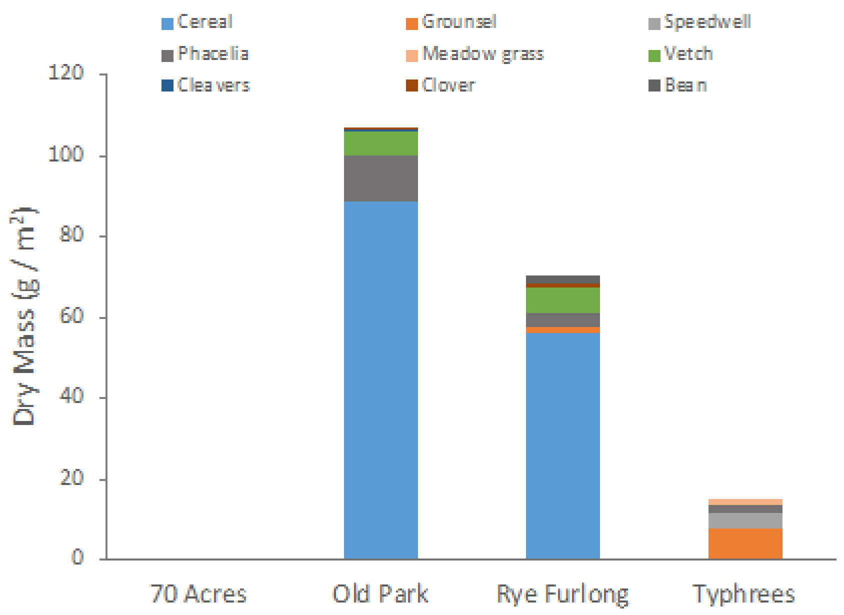


Figure 8. Comparison of the mean plant count and percentage green cover across the three fields with cover crops in late autumn 2021. The cover crops in the regeneratively managed Old Park and Rye Furlong fields provided significantly more percentage ground cover at this stage than the cover crop in the previously conventionally managed Typhrees field.

Despite not contributing substantially to the percentage ground cover, cereals provided much of the above and below ground biomass (Figure 9). The biomass recorded for above and below ground material of cover crops was significantly greater in Rye Furlong and Old Park than in Typhrees. Most of the biomass recorded for Typhrees field was the weed groundsel (Figure 9) confirming the poor growth of the sown cover crop species observed in the establishment assessments.

A.



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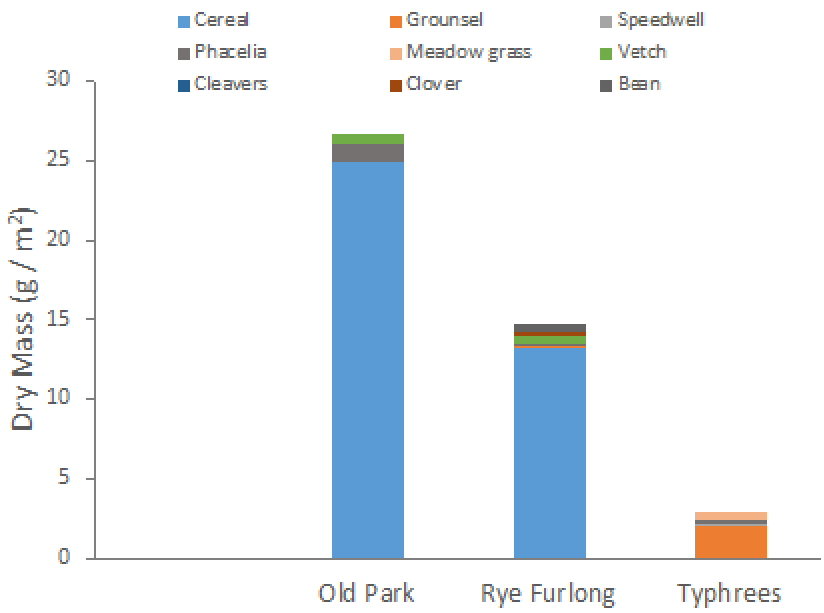


Figure 9. **A**. Above ground dry mass (g / m^2) for the cover crops in the different fields measured in December 2021. Cereals, despite not contributing substantially to the percentage ground cover, provided much of the above ground biomass. **B**. Below ground dry mass (g / m^2) for the cover crops in the different fields measured in December 2021. As with the above ground biomass, cereals provided the bulk of the below ground biomass.

When plant counts and percentage green cover assessments were repeated in the spring barley (8 weeks after drilling) following destruction of the cover crops, establishment of spring barley crops (variety - Laureate) in Typhrees, Rye Furlong and Old Park fields were not significantly different (plant count 250 -200 plants/ m^2; ground cover 60-70%). No differences in yield were found at harvest (Figure 10) and grain quality was not different between the fields (specific weight 68.6 kg/hL; N content 1.5%)

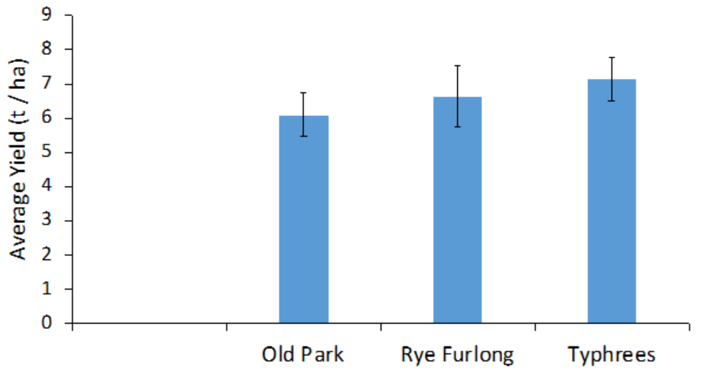


Figure 10. Average yield (t/ha) for the spring barley at harvest 2022. Derived from clean combine data. Bars are presented of the standard deviation for yield in each field.

<u>Crop health and disease pressure</u>

In 2022, disease levels were low through the season. Leaf layer disease assessments were undertaken in the spring barley crops. Disease levels were low with only low levels of Rhynchosporium found on all leaf layers. Pest pressure in the spring barley remained low throughout the season, however, it was noted that the beans (70 Acres) suffered substantial aphid damage late in the season. Disease levels on wheat were low with some low levels of Septoria observed.

In 2023, disease levels were low throughout the season and no significant pest damage was noted in any crop. In 2024, a warm February followed by a wet March and dull conditions throughout the season, created a high septoria risk. The farm used a robust T1 and T2 programme completed by the end of May across most of the wheat area, which effectively contained the disease risk to levels that did not limit yield. On a field (Peewits) growing a blend of wheat varieties (Champion, Dawsum, Graham) where the aim had been to use no fungicides a targeted T3 top-up fungicide programme (azoxystrobin, tebuconazole) was applied in late June. Although this was not part of the monitoring programme, grain samples were collected, and yield map analysis was carried out to see if the impacts of fungicide use could be quantified. Visually, there was a noticeable increase in disease pressure where no T3 spray was applied. However, further review of satellite date from earlier in the season, also showed a separate apparent yield limitation affecting the same part of the field. Without replication in the tramline trial it was therefore difficult to quantify yield effects, although trends suggest that the targeted fungicide application was very cost effective in protecting yield. This highlights the need to consider existing spatial variability carefully when carrying out simple tramline trials, as well as using replication where possible, to provide more robust conclusions. It was noticeable in 2024 that blackgrass was present on farm at levels not previously seen, partly due to the difficult autumn and spring conditions that restricted the timing of herbicide applications and potentially reduced efficacy. For example, the levels of blackgrass in Old Park were higher than those in the neighbouring field Rye Furlong and were expected to affect yield due to crop competition.

Yield

Crop yields at Strategic Farm south over this period have been in line with good-performing regional comparators, usually with lower-than-average variable costs due to the farm's focus on reducing inputs where appropriate.

Table 8. The average yield (t/ha) in the monitored fields. Quality data for the focus fields only. Analysis provided by Niab Labtest (Cambridge UK).

Field	2022		2023		2024	
	Crop		Crop		Crop	
Old Park	Spring barley	6.1	WOSR	4.2	Winter wheat	11.0
Rye Furlong	Spring barley	6.6	WOSR	4.5	Winter wheat	14.1
Piggery	Winter wheat	11.0	Spring barley	8.4	WOSR	4.3
Big Grange	Spelt wheat	7.6	Spring barley	4.7	WOSR	3.8
70 Acres	Spring beans	2.0	Spelt wheat	6.4	WOSR	2.9
Ashen Grove	Spelt wheat	8.1	Winter wheat	9.3	Spring wheat	n/a*
Waltham Marks	Winter wheat	9.7	Winter beans	2.7	Winter wheat	9.4
Workshop	Winter wheat	8.6	Winter beans	2.2	Winter wheat	9.0
Typhrees	Spring barley	7.1	Spring barley	5.9	Spring barley	5.4

** No telematics available for Ashen Grove in 2024. Surrounding spring wheat fields yielded 5.9 t/ha on average.*

Spatial Monitoring of Soil and Crop Health on Farm

Figure 11 shows the overall spatial yield analysis. The sampling sites selected for monitoring in 2020 generally remain within single zones. However, with the benefit of additional years of data, it is evident that the sampling locations in Ashen Grove and Workshop could have been better positioned to be situated within a single yield performance zone.

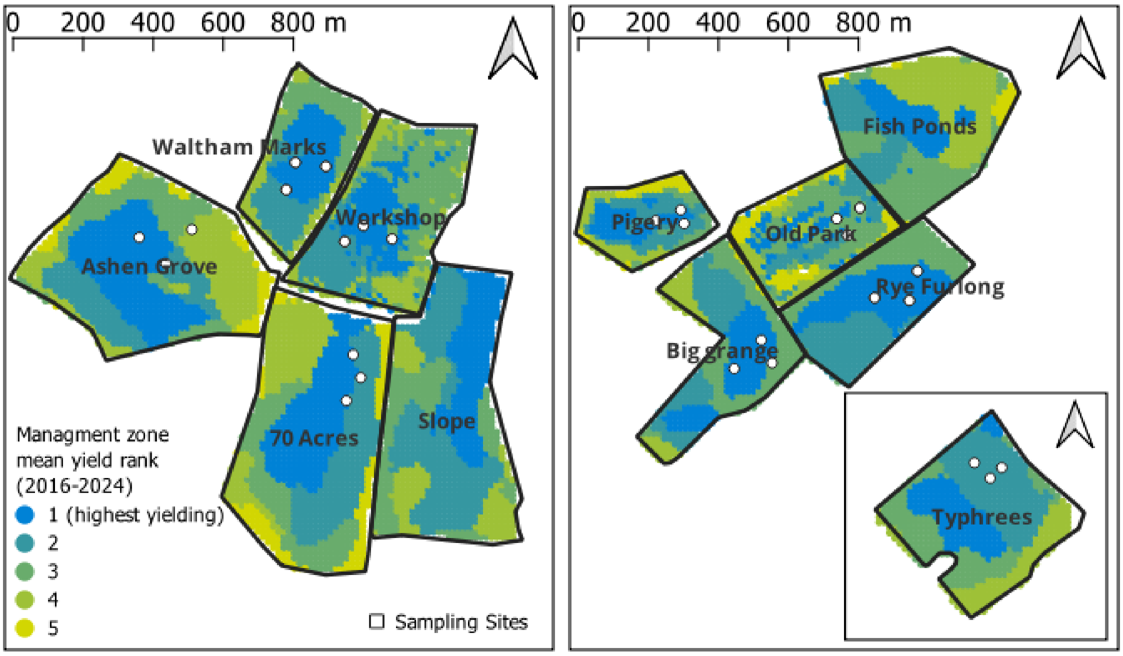


Figure 11. Spatial yield analysis for the nine monitored fields in the Strategic Farm South Soil Health Monitoring project, along with two additional fields (Slope and Fish Ponds) used for split-field trials. Clustering was performed using yield map data collected between 2016 and 2024. White dots represent monitored sampling sites. Colours represent management zones (clusters) ranked by their mean yield within each field, where blue (1) indicates the highest-yielding zones. Each field contains three to five distinct zones, reflecting spatial variability in long-term yield performance.

A range of farm management steps can be based on the management zones identified, for example:

- Soil health scorecards should be conducted within management zones to reduce the impact of spatial variability in soil properties on scorecard results. Ideally, as many zones as possible should be sampled, however prioritise the largest and then incorporate additional zones.
- Grain nutrient sampling for offtake budgeting or agronomic benchmarking should be performed within each zone or a subset within each field that captures wider variability.

- Tramline or chessboard experiments should be set up within management zones to ensure that historical yield variability does not interfere with treatment effects, allowing for a clearer identification of treatment differences.
- Management zone-specific soil or crop properties should be utilised to apply nutrients spatially. This management zone-based approach aligns with the 2024 Sustainable Farming Incentive schemes. According to SFI guidelines: "The VRA equipment must be either pre-programmed with a ‘variable rate file’ using data from zonal soil or crop testing and analysis or remote sensing."

3.5. Action points for farmers and agronomists

This project was intended to emulate the format and intensity of soil health monitoring which might realistically be undertaken by non-specialists at farm-scale. These monitoring strategies can be used on-farm and at field scale to monitor changes in soil health status and links to yield over time. especially where changes to farming systems are implemented or where particular issues, which may constrain productivity, have been identified.

Changes in soil health can often not be observed over short timescales therefore monitoring in alternate years, as is implemented for this project, should be effective to detect long term trends. When establishing a long-term monitoring programme to study the farm (or to compare it with others), it is important to recognise that the data collected will have increasing value as it is integrated across seasons. In some years, the stand-alone value of data collected may seem to be low, but in a well-designed study, it should be possible to draw some comparisons in each year.

This work also highlights benefits to farms in the use of yield maps and other spatial datasets to identify stable and variable zones within fields, enabling targeted soil health assessments and crop monitoring. Conducting soil and grain nutrient sampling within these management zones helps account for spatial variability, improving long-term soil monitoring and management. Additionally, setting up on-farm experiments within identified zones minimises the impact of historical yield variability, ensuring more accurate evaluation of agronomic practices and treatment effects.

4. Impact of interventions at crop establishment on soil and crop health

Trial leader: Callum Scotson, Joe Martlew, Naomi Menzies, Niab
Start date: September 2021
End date: September 2024

4.1. Headlines

At the Strategic Cereal Farm South, a variety of approaches to enhance the soil–plant interaction at drilling was tested to see if early crop growth can be improved. Longer-term soil-improving measures (cover cropping and no tillage in combination) have improved the soil health baseline effectively so that any benefits of these tactical applications of amendments were not detectable. In a separate trial, the use of companion crops to improve soil biology and early crop growth was tested. The presence of unintended volunteer beans meant drawing conclusions from the trial was not possible.

Overview of findings
This project examined two approaches to enhance soil-plant interaction at / soon after drilling. The first experiment (2021-22, 2022-23) looked the effects of two products with different modes of action (vermicompost humates and molasses with microbial nutrition) applied with seed on early crop development, root growth and soil health. No significant differences were detected in crop establishment or root development metrics between untreated areas and any of the treatments. The products did not have an observable influence on establishment or root development in the soil/season/crop combinations that were studied at the Strategic Farm South. The farm is now confident that the longer-term soil-improving measures (cover cropping and no tillage in combination) have improved the soil health baseline effectively so that any benefits of tactical applications of amendments are not detectable.

In a separate field (Workshop), a second tramline experiment (2023-24) was established as a pilot to assess whether a companion crop with wheat has benefits for soil biology and early crop growth. Establishing winter wheat in the presence of beans whether present as a companion crop or as volunteers was successful, but the presence of the volunteer beans means that no treatment effects of the established companion crops were detectable.

Given the inherent variability within soils and root growth habit, any farm thinking of using (or ceasing use of) similar products should consider carrying out well-designed strip trials to support decision-making.

4.2. What was the challenge/demand for the work?

The Strategic Cereal Farm South wanted to know more about whether interventions to support soil functions (soil amendments, companion cropping) can enhance the critical phase of crop establishment. Soil amendments (targeting biological enhancement) are available, and the aim was to investigate if they were able to enhance the soil–plant interaction at drilling and increase yield. Secondly, the use of companion crops, in this case beans, were also tested for their impact on soil biology and early crop growth.

4.3. How did the project address this?

Trial design (1) - soil amendments

There are four treatments included within this trial:

1. Untreated seed (control)
2. Vermicompost humate extract (VCH - Ecoworm)
3. Molasses+ (L-CBF Boost)
4. VCH and Molasses+ (combined)

This trial was located within Fish Ponds field (Figure 12). For harvest 2022, winter wheat (cv. Graham) was grown. For harvest 2023, main crop was a spring wheat (2^{nd} wheat) after an overwinter cover crop. Treatments were applied at /ahead of drilling of the cereal crop This was a replicated tramline trial where the positioning of the treatments was initially randomised. After harvest, the tramlines were relocated and treatments were repeated in the second year.

Figure 12. Layout of the tramline treatments in Fish Ponds field.

The influence of the products on the establishment, root development and productivity of the winter wheat crop was assessed over the course of the year. In addition, the soil health and soil biology status were also examined across these treatments.

Trial Design (2) - Companion crops

In autumn 2023, tramline trials were established in Workshop field, one of the fields that was being monitored as part of the whole farm monitoring programme. The farm established companion crops in this field.

There are three treatments included within this trial:

1. Beans
2. Buckwheat
3. No companion

This work was unreplicated.

<u>Assessments</u>

Crop establishment and health assessments:

In Trial (1) in year 1, establishment assessments were undertaken at 4, 6 and 8 weeks post-drilling of the winter wheat. In year 2, establishment assessments were undertaken in the cover crop and 4 weeks post-drilling of the spring wheat. Plant counts and percentage green cover scores were collected across fifteen 25 cm^2 sample areas in each treatment. At maximum stem extension, all wheat plants in four 25 cm^2 quadrats were extracted from across each tramline and then cut into separate above and below ground sections. Fresh and dry mass was recorded for the above and below ground material. General crop health was also monitored. In Trial (2) winter 2023/24, establishment of the winter wheat as well as performance of the companion crops were monitored by measuring GAI and keeping a representative photo record.

<u>Soil health assessments:</u>
Three sampling sites were identified within each tramline.

In Trial (1), soil health was monitored in late autumn 2021 and 2022 using the Soil Health Scorecard approach. including Visual Evaluation of Soil Structure, worm counts and laboratory analysis of the soils for broad spectrum analysis (Lancrop, YARA, Pocklington, UK). In Trial (1) soil samples were also collected from each treatment for microbial population analysis in December 2021 and March 2022; and then again in December 2022 and under spring wheat in May 2023. In Trial (2), soil samples were collected in late March 2024 under winter wheat in the pilot trial with / without companions. These samples were submitted for microbial population analysis (SoilBioLab, Andover, UK).

<u>Crop root assessments:</u>
In Trial (1) root metrics were recorded in each treatment for winter wheat in at BBCH growth stage 32-33 and for spring wheat in May 2023 including total root length and longest root length per plant. Ten wheat plants were extracted from each tramline. Total root length was calculated from the sum of the length of all primary roots of an individual plant – small secondary roots were not considered. Longest root length was calculated by recording the length of the longest primary roots of each individual plant.

Samples were also submitted for analysis of mycorrhizal colonisation of the roots in Trial (1) in June 2022 and May 2023 and in Trial (2) ahead of broad-leaved weed herbicide applications to take out the companions in spring 2024. Five intact root systems were extracted from each treatment area, with rhizosphere soil retained in place on the surface of roots, and submitted for analysis of mycorrhizal root colonisation (SoilBioLab, Andover, UK). The results of this analysis of mycorrhizal root colonisation are expressed as a percentage.

<u>Yield and harvest sample analysis:</u>
In Trial (1) average yield data was collected at harvest for each tramline in the field – each tramline was harvested individually to prevent crossover between treatments. Grain samples were also collected from each treatment during combining and were submitted for nitrogen and protein analysis at Niab Labtest (NIAB, Cambridge, UK). No harvest assessments were made in Trial (2).

4.4. Results

Crop establishment assessments

Plant counts at all assessment timings showed no significant difference in establishment and early growth of the winter wheat (autumn 2021; Figure 13), growth of the cover crops (autumn 2022) and establishment and early growth of the spring wheat (spring 2023, Figure 14).

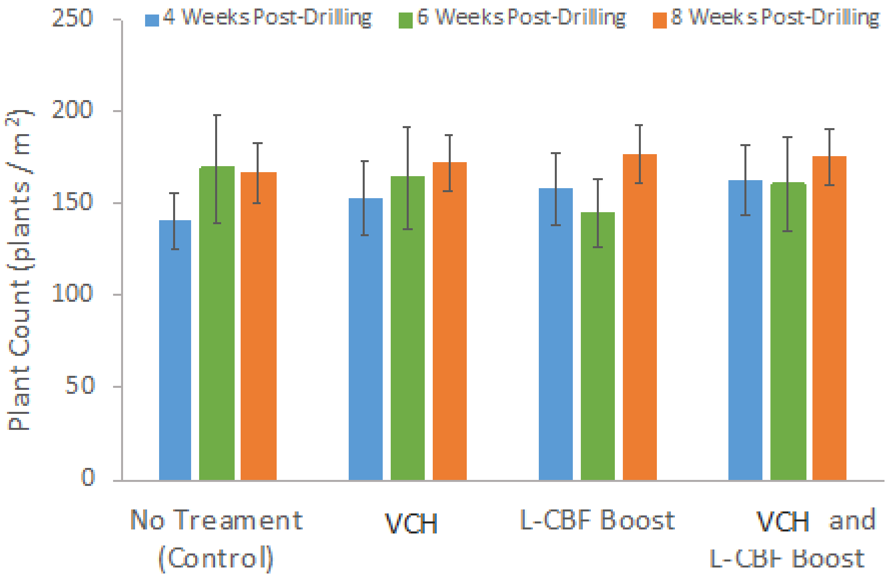


Figure 13. Comparison of plant counts for winter wheat crops at 4, 6 and 8 weeks post-drilling across the four tramline treatments in Fish Ponds field.

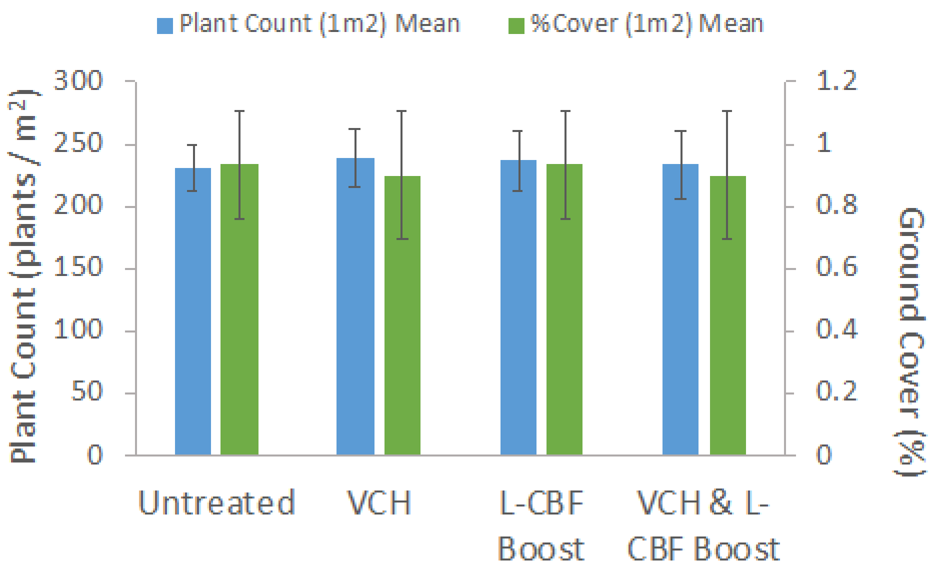
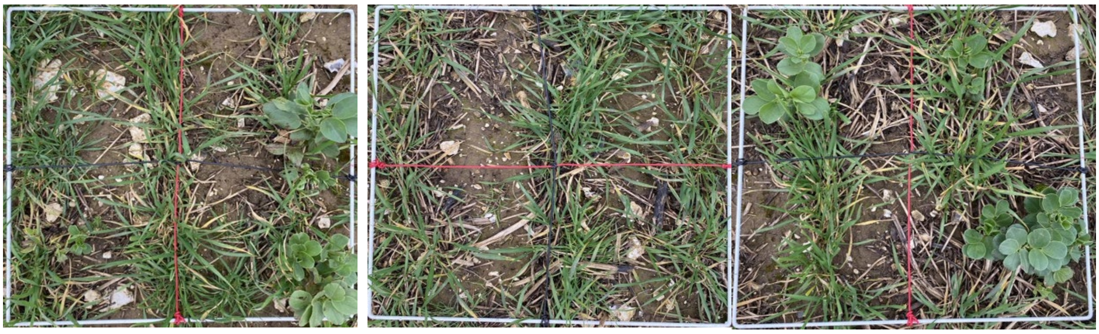


Figure 14. Comparison of plant counts and groundcover of the spring wheat at 4 weeks post-drilling across the four tramline treatments in Fish Ponds field.

In 2024, wheat established well in the presence of the companion crops. But there was no difference between the treatments; in fact, volunteer beans grew as well as the drilled companion beans (Figure 15). Buckwheat established well, but was taken out by frost in early November.



Wheat with Beans *Wheat with Buckwheat* *Wheat – no companion*

Figure 15. Photos taken in late March 2024 with the wheat approaching GS30. GAI was 1.4 at this point for all tramlines. Sown beans and volunteer beans are visible; buckwheat was taken out by frost in early November 2023.

<u>Plant biomass and Root Metrics</u>

There were no significant differences detected in any of the biomass or root metric assessments. The above and below ground biomass was not observed to be significantly different between treatments There were no significant differences detected in any root assessments in spring wheat (Table 9). Based on these metrics, the products did not therefore appear to have significantly influenced root development.

Table 9. Average root metrics (with standard error) for spring wheat recorded for replicate samples collected on 24/05/2023 in each of the treatments in Fish Ponds field

Treatment	**Winter wheat 2022**				**Spring wheat 2023**			
	Total root length (cm)	SE	Longest root (cm)	SE	Total root length (cm)	SE	Longest root (cm)	SE
Untreated	277.4	23.58	87.3	8.06	351.6	11.34	78.4	2.23
VCH	283.6	15.85	93.6	6.56	323.5	18.21	76.9	3.16
L-CBF Boost	284.4	21.50	109.1	8.96	398.8	20.24	91.8	4.83
VCH + L-CBF Boost	297.7	32.74	92.8	9.56	419.0	30.33	91.9	5.29

Soil health and microbial assessments

Overall, the soil in both fields was very well structured achieving a VESS score of 1-2; the aggregates were generally small and easily broken in the hand. Larger objects visible were often flints and not large soil aggregates. Roots could grow beyond the soil surface unimpeded and consolidated the soil well around them.

Earthworm numbers were also not different between treatments in any year. Soil pH was high (c. 8) but otherwise soil chemical properties (P, K, Mg) were non-limiting and not different between treatments. Soil organic matter averaged 5% across the trial area in Fishponds and was also 5% on average in Workshop with no difference between treatments.

Soil microbial analysis

There are no clear seasonal trends or differences between treatments in the microbial measurements, the differences seen here are likely to be the result of within-field variation in Fishponds (Tables 10 and 11). Similarly variable data but with no clear treatment effect was seen in the companion crop experiment in 2024 (Table 12). The mycorrhizal root colonisation analysis showed typical levels of colonisation for wheat (usually 25 -30%) with slightly lower colonisation in spring wheat with no differences between treatments.

Table 10. Soil microbial populations in December 2021 and March 2022 (winter wheat) for each treatment. Analysis and guideline values provided by SoilBioLab (Andover, UK).

Measure	1 - Untreated		2 - VCH		3 - L-CBF Boost		4 – VCH & L-CBF Boost		Guideline values
	Dec	Mar	Dec	Mar	Dec	Mar	Dec	Mar	
Total Bacteria (µg / g)	500	686	409	764	387	759	140	717	250-500
Total Fungi (µg / g)	277	167	297	287	284	210	218	202	250-500
Fungi:Bacteria Ratio	0.55	0.24	0.73	0.38	0.73	0.28	1.56	0.28	1-2
AMF root colonisation (%)		28.6		19.6		25.8		15.4	10-50

Table 11. Soil microbial populations in December 2022 (cover crop) and May 2023 (spring wheat) for each treatment. Analysis and guideline values provided by SoilBioLab (Andover, UK).

Measure	1 - Untreated		2 - VCH		3 - L-CBF Boost		4 – VCH & L-CBF Boost		Guideline values
	Dec	May	Dec	May	Dec	May	Dec	May	
Total Bacteria (µg / g)	759	479	844	378	822	505	1037	473	200-400
Total Fungi (µg / g)	293	941	406	172	539	142	474	242	200-400
Fungi:Bacteria Ratio	0.39	1.97	0.48	0.46	0.66	0.28	0.46	0.51	1-2
AMF root colonisation (%)		17.2		12		11.4		17.6	10-50

Table 12. Soil microbial populations in November 2023 and late March 2024 (wheat) in the companion cropping experiment. Analysis and guideline values provided by SoilBioLab (Andover, UK).

Measure	1 – with beans		2 – with buckwheat		3 – volunteer beans		Guideline values
	Dec	March	Dec	March	Dec	March	
Total Bacteria (µg / g)	842	342	853	282	827	277	200-400
Total Fungi (µg / g)	115	264	311	188	292	80	200-400
Fungi:Bacteria Ratio	0.14	0.77	0.36	0.66	0.35	0.29	1-2
AMF root colonisation (%)		8		9	18.7		10-50

<u>Yield and grain analysis</u>

In Trial (1), there were no significant differences in average yield between any of the four treatments. All treatments achieved average yields of approximately 10 t/ha (winter wheat 2022) and 6 t /ha (spring wheat 2023). In addition, there were no differences in the protein and specific weight data between treatments.

For Trial (2), given the failure of the buckwheat companion and no discernible difference in establishment and crop growth between treatments, the farm decided not to collect grain samples per tramline. Yields of winter wheat in 2024 were 9 t/ha in Workshop.

4.5. Action points for farmers and agronomists

The soil-applied biological amendments did not have an observable influence on establishment or root development in the soil/season/crop combinations that were studied at the Strategic Farm South probably because of the long-term approaches (reduced tillage and cover cropping in combination) that have improved baseline soil health on the farm. In the simple pilot tramline trial, no differences in crop establishment or growth were observed, but this was partly because the field used had a strong crop of volunteer beans.

Considering different soils and their variability, it is important to examine whether such products will have the effect you desire for your crop on your soil within your system. The main monitoring strategies utilised for this project are straightforward, require no specialist equipment and all sample analyses are offered by commercial laboratories. Therefore, these monitoring strategies can be used to examine the effectiveness of products, such as these, on your farm and within your specific system. This project serves as a case study for the implementation of such strategies.

5. Impact of regenerative practices on food quality (targeted grain quality testing)

Trial leader: Elizabeth Stockdale, Niab
Start date: April 2024
End date: December 2024

5.1. Headlines

Do regenerative practices improve food quality and nutrient density when compared with conventional production systems? A pilot study compared some nutrient metrics for wheat grain sampled from Strategic Farm South with samples collected in 2024 from the same varieties on the same soil type in conventional systems. No differences were identified.

The on-going monitoring at Strategic Farm South allowed the development of a pilot testing programme to evaluate the impact of regenerative practices on food quality with wheat grain samples collected and compared with those from conventional farms with matched soils/ varieties. 5 fields at Strategic Farm South growing wheat in 2024 were identified and matched with 10 sites across 6 farms. Co-located soil and grain samples were collected just before harvest and samples were analysed for standard food/feed quality, micronutrients, Inulin and Vitamin E.

Relative wheat yields ranged from 8.2 – 11.4 t /ha with an overall average of 10 t/ha. Protein contents were low in all samples due to the dull (low sunshine) conditions during the grain fill period. Grain was relatively low in iron and zinc due to the high soil pH (in all sites) and consequent reduction of availability of these micronutrients. However, there was no clear impact of differences in variety or farming system on any of the grain quality measures.

5.2. What was the challenge/demand for the work?

It has been proposed that regenerative practices improve food quality when compared with conventional production systems. Given that a wider range of crop, soil and other environmental factors that can affect grain nutrient density, evaluation of this hypothesis is complex. However, the on-going monitoring at Strategic Farm South allows the development of a pilot testing programme with wheat grain samples collected and compared with those from farms with matched soils/ varieties.

5.3. How did the project address this?

Sampling design

4 fields at Strategic Farm South were identified, where there were established monitoring sites, and which were growing winter wheat in 2024.

- Rye Furlong - Dawsum (Group 4)
- Old Park - Dawsum (Group 4)
- Workshop - Champion (Group 4)
- Waltham Marks - Champion (Group 4)

In addition, a further field at SF South (Helltop) was identified in autumn 2023 that would grow winter wheat (Extase, Group 2) for 2024 harvest. A sampling site was therefore established in that field with Soil Health Scorecard and full soil characterisation carried out in autumn / winter 2023. The soil data were compiled and used together with the wheat variety information to identify possible paired sites on very similar soils with matched varieties under conventional management approaches. Niab's members technical committee in Wessex

In particular, we were able to draw on the soil monitoring work carried out as part of a Niab Members' project based in the Wessex region which explores the link between soil health and yield data with the management practices implemented on Members' farms. Working with Niab's South regional Agronomist (Steve Cook), we reviewed the database of soil properties to identify the farms within the group with soils most similar to those at SF South i.e. light-medium texture, high pH (7.5+) with some chalk and flints. We contacted those farmers in spring 2024 to identify sites where they were growing winter wheat (Champion, Dawsum, Extase) for 2024 harvest. These farms have a range of management approaches in terms of organic matter inputs, tillage approaches and use of cover crops in place. 10 fields were identified as potential sampling sites across 6 farms (Table 13).

Sampling and analysis

Close liaison with Strategic Farm South and the paired farm sites sought to ensure that samples were collected in the wheat crop when the crops were fit for harvest. Farmers were notified of the sampling plan i.e. to collect co-located soil and whole crop samples in the off-site pairs and to collect crop samples at the geo-located monitoring sites at Strategic Farm South. The sampling dates were agreed for 1 – 2 August 2024.

Harvest had been stop-start for wheat, but the sampling period fell within a short period of dry weather with large thunderstorms forecast over the following weekend. Unfortunately, some of the planned sampling was not possible due to completion of field harvest ahead of the sampling dates

(Workshop - Champion; Waltham Marks – Champion; Farm D after potatoes – Champion). Grain samples collected from the combine at field-scale were available for Workshop and Waltham Marks; replicate samples from the geo-located monitoring sites could not be collected. Farm F was an outlying site and given the disruption to the detailed sampling of Champion it was not sampled following further farmer liaison during the sampling period.

Table 13. Comparator sampling sites for winter wheat identified on the same soil type as Strategic Farm South but with contrasting management approaches.

Variety/ Farm	***Dawsum***	***Extase***	***Champion***
A		After spring beans Arable, no-till, no cover crops (SFS_NIAB2024/01)	
B	After beans Arable, no-till, cover crops used regularly (SFS_NIAB2024/02)		2nd wheat Arable, no-till, cover crops used regularly (SFS_NIAB2024/03)
C	After OSR Arable, ploughed, cover crops used occasionally (SFS_NIAB2024/05)	After spring oats Arable, ploughed, cover crops used occasionally (SFS_NIAB2024/04)	
D			After poppies Arable, conventional tillage with deep non-inversion, no cover crops ((SFS_NIAB2024/06)
			After potatoes Arable, conventional tillage with ploughing, no cover crops (sampling not possible)
E	After spring barley Mixed, no-till, cover crops used regularly (SFS_NIAB2024/08)	After patchy OSR Mixed, no-till, cover crops used regularly (SFS_NIAB2024/07)	
F			After spring oats Mixed, conventional tillage, cover crops used regularly (samples not collected)

Whole crop samples (straw cut at 2-3 cm above ground) were collected by hand using secateurs from 2 x 1 m areas at geo-located points – either the SF South monitoring points or at farmer-identified locations expected to have very closely matched soil types within the fields. Samples were bagged into paper sacks and stored under ambient conditions before heads were removed, then threshed to obtain clean grain samples. Whole biomass and clean grain samples were weighed to allow relative yield estimates to be determined. Clean grain samples were submitted (Eurofins) for analysis of nutrient density and human nutritional value. The package of tests was agreed through consultation with AHDB and the Strategic Farm South steering group to provide a cost-effective test of the hypothesis that regenerative practices improve food quality.

Grain samples were tested for:

- Proximates in feedstuffs (Ash, Crude Fibre, Crude Protein (from N by Dumas), Moisture, Total Fat / Oil (Feed))
- Grain macro and micro nutrient (dry matter basis; Total Nitrogen, Total Phosphorus, Total Potassium, Total Calcium, Total Magnesium, Total Sodium, Total Sulphur, Total Boron, Total Copper, Total Iron, Total Manganese, Total Zinc)
- Vitamin E (α-tocopherol) by reverse phase HPLC using fluorescence detection.
- Inulin/ Fructo-oligosaccharides (FOS) by enzymatic/HPAED-PAD elution

Results were received in December 2024.

At the off-site locations, soil samples (0- 20 cm) were also collected. Samples were submitted for standard chemical testing (pH, available P, K, Mg) and soil organic carbon together with detailed micronutrient assays. The same tests had formed part of the laboratory analysis carried out for the sites at Strategic Farm South sites. Results were received in September 2024.

Values provided by the analytical laboratories were compiled in Excel spreadsheets for data evaluation. Where possible, analytical values were compared to other sources of comparable data. Sources used included UK Food Composition tables. 2 data points for Total Fat / Oil were well above the expected range; these were discounted, probably due to contamination during sampling / preparation. Given the scoping nature of the study, data were tabulated using various combinations of data sub-groups, descriptive statistics (mean, standard error) and graphical approaches were used to explore the differences between wheat varieties and sites / management approaches.

5.4. Results

Soil types were closely matched; pH offsite ranged from 8 -8.4 with high available Calcium 3386-5688 mg/kg; across the Strategic Farm South wheat fields pH ranged from 7.4 – 8.1 also with high available Calcium 3269-4634 mg/kg. Soil textures were light to medium with high silt content around 60%.

Wheat yield and quality assessments

The range in hand-harvested grain yields was 8.2 – 11.4 t /ha; overall average was 10 t/ha. Yield variation within fields at Strategic Farm South was as great as that between fields - shown by the similar standard errors (Figure 16). Although Extase yielded more poorly in SFS-Helltop than at the non-SFS sites, there is no consistent evidence of a farming system yield limitation, as Dawsum yielded similarly at Strategic Farm South and at non-SFS sites.

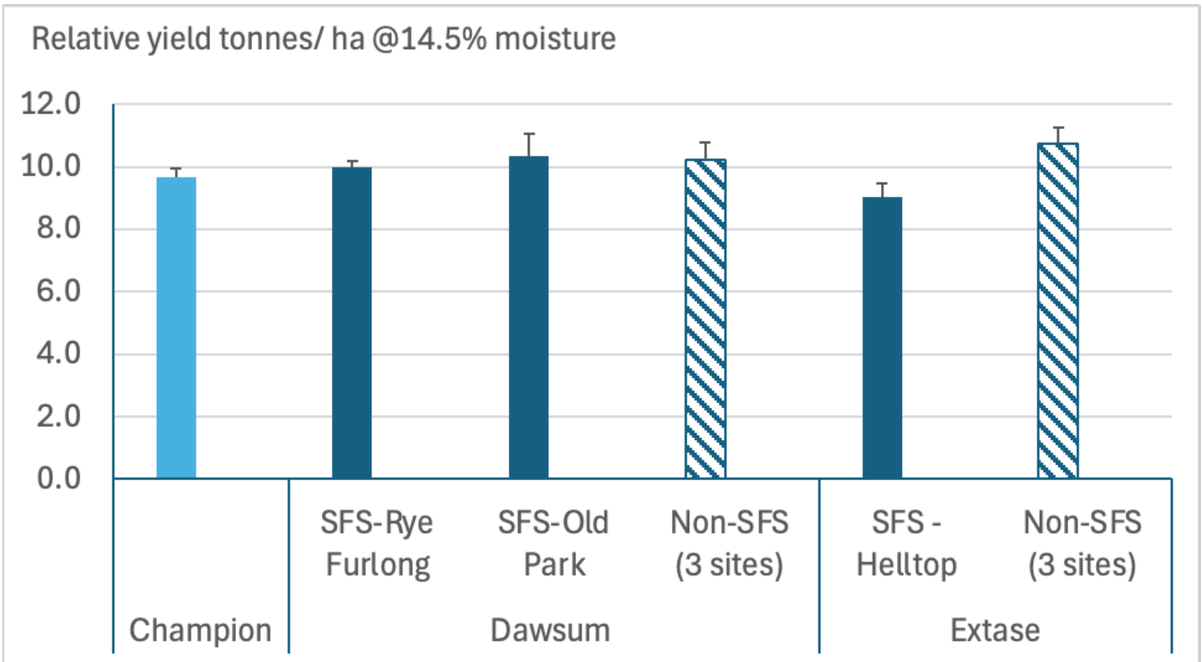


Figure 16. Comparative wheat yields (t/ha) by variety and farm system derived from hand-harvest across the fields

Breeder expected protein levels in these wheat varieties (10.8 – 11.5%) were much higher than those found across these samples (Figure 17) , but the varieties showed the expected relative pattern, Dawsum had lower average protein (8.5%) than Extase and Champion (8.9%). The overall UK picture (AHDB Cereal Quality survey 2024) showed that average protein in 2024 (9.8%) was down compared with 2023 (10.6%); no winter wheat was grown at the reference sites at Strategic Farm South in 2023, but in 2022, which also had a UK average of 10.6% protein, the grain protein achieved was higher at Strategic Farm South with Extase averaging 10.2%. Lower protein in 2024 has been linked to the duller than usual conditions during the grain fill period. Variation within fields at SF South for protein content was as great as that between fields - shown by the similar standard errors. The impact of yield dilution on protein content is shown where the protein and yield are compared for the Extase crops; however, there is no clear impact of farming system on protein content.

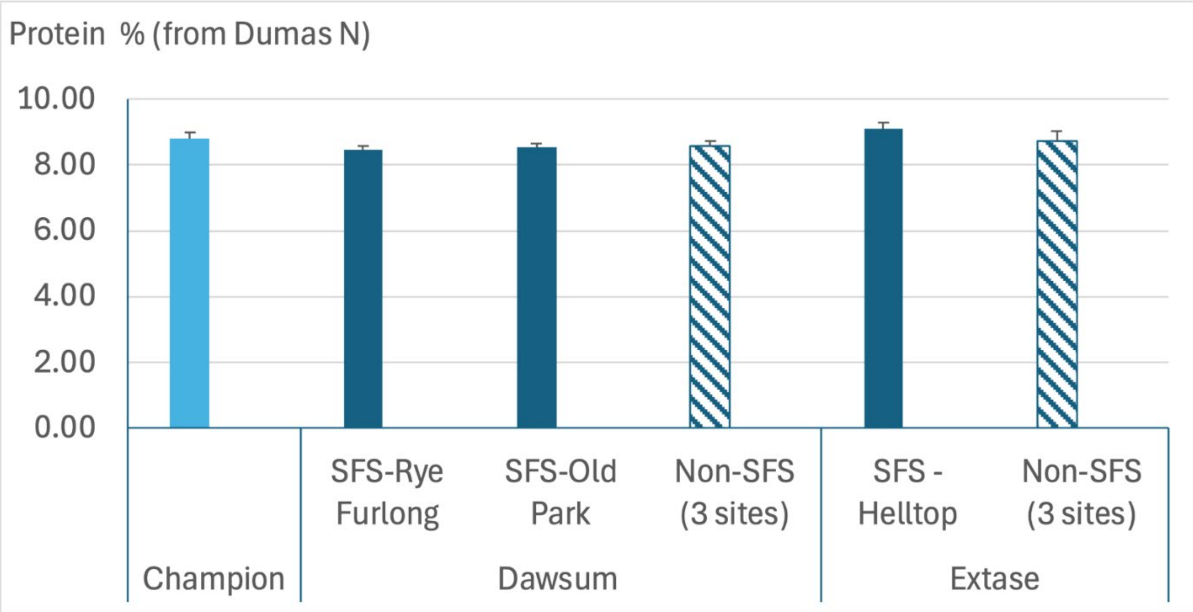


Figure 17. Wheat grain protein (%) by variety and farm system from hand-harvest samples across the fields

Crude fibre was slightly higher in Dawsum (2.83%) than in Extase (2.55%), but the difference is largely driven by one sampling site with much higher crude fibre (6%) in SFS-Old Park (Figure 18). This sample also had high values determined for fat (which were removed as outliers) and hence the high value may also be a result of contamination of the sample, perhaps by weed seed. There are clearly field to field variations in crude fibre, e.g. comparing SFS-Rye Furlong and SFS-Old Park but there is no clear indication that this is driven by differences in the farming system.

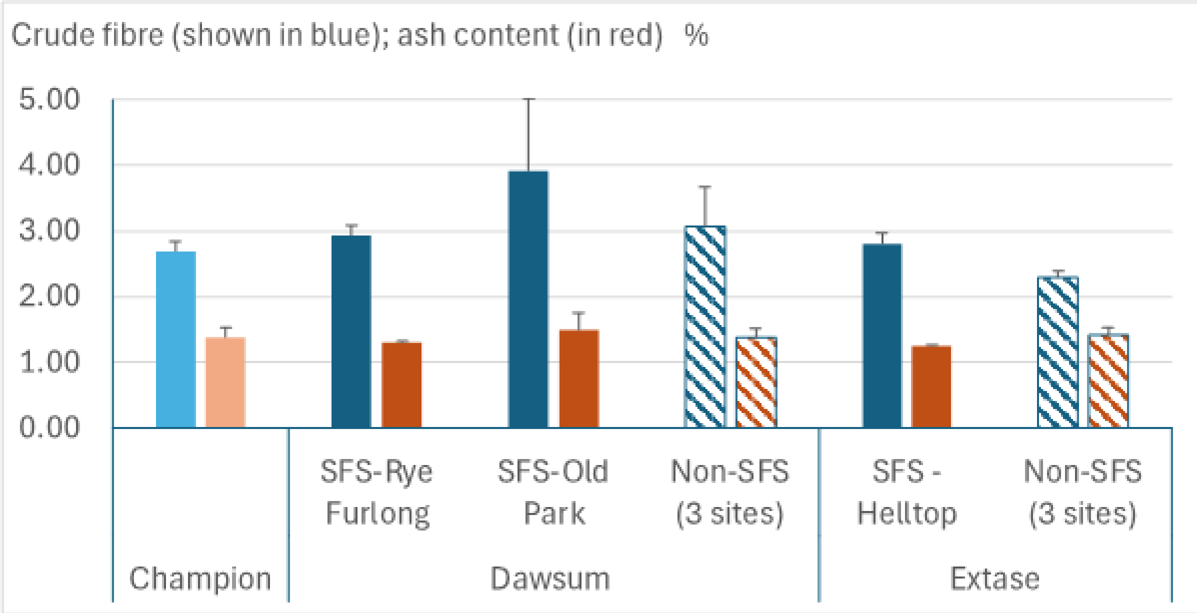


Figure 18. Crude fibre (%) and ash content (%) of wheat grain by variety and farm system from hand-harvest samples across the fields

There was no difference between varieties in total fat (2.2 % on average) or ash (mineral) content (1.37% on average). This average ash content across sites and varieties in this study was also the average also found across a range of wheat varieties and environments by Morris *et al.* (2009). In terms of overall value in terms of macro-nutrients for human consumption there is no evidence emerging from this data set that regenerative practises (on high pH soils) make a marked difference to cereal quality compared with a range of conventional systems.

Grain nutrients

A low grain P (0.16%) was found at the site with the lowest soil P (17 ppm available P by Olsen extraction); but where soil P was > 20 ppm, there was no different in average grain phosphorus (0.24% P) despite the wide range in soil extractable P (Olsen) across the fields up to 103 ppm). The suggested indicator value used post-hoc to assess crop sufficiency of 0.32% was not achieved in any of these samples. Calcium (300-500 mg/kg) and Magnesium (700-900 mg/kg) contents were in found at typical concentrations for wheat grain (Peterson et al. 1986) with no observed differences between varieties or sites despite the high soil Ca and low Mg; this probably reflects targeted Mg applications to these crops given the soil type, as takes places at Strategic Farm South.

Iron (Fe) and Zinc (Zn) concentrations measured in wheat grain were at the low end of the ranges typically observed by others e.g. Oury et al. (2006); Zhao et al . (2009). These low concentrations found in grain grown on these soils reflect the high soil pH and hence lower availability of these cations for plant uptake. Both Fe and Zn show variations in grain concentration; that are not explained by measured soil characteristics (except a noticeable jump in Fe content when pH is <7.5 in one sample collected from SFS Old Park).

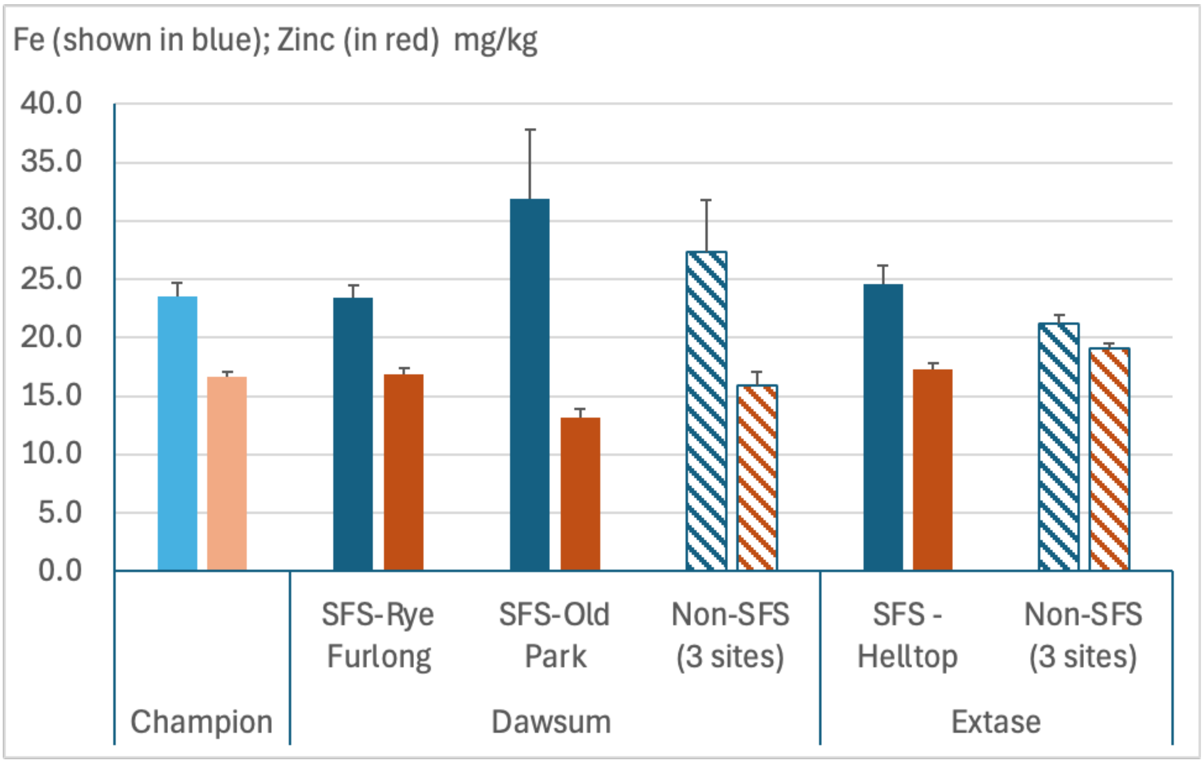


Figure 19. Iron (Fe) and Zinc (Zn) concentration (%) in wheat grain by variety and farm system from hand-harvest samples across the fields

Inulin is a carbohydrate that is non-digestible in the intestine (prebiotic) that may have health benefits; it has been shown that inulin-type fructans are fermented by the colon to produce short-chain fatty acids, with important local and systemic effects. It is often sourced from chicory root to form a functional ingredient. Cereal grains are an important sources of inulin in the diet. These data show that there are relatively small field to field variations in inulin content of wheat grain (Figure 20) and there is no clear impact of variety or farming system on inulin content of wheat grain. Montgomery et al. (2022) compared a range of crops (but no wheat) across paired regenerative and conventional farms in the United Stated and found that on average Vitamin E was 15% higher in crops crown in regenerative systems. It has previously been shown that there are marked differences between wheat varieties in Vitamin E ranging from 2.3 – 5.4 mg /100g (Cabell and Ellis, 1942). The values determined here are much lower (about half of the early data) but there is no evidence that either variety or farming system is having an impact on the Vitamin E content of the wheat grain.

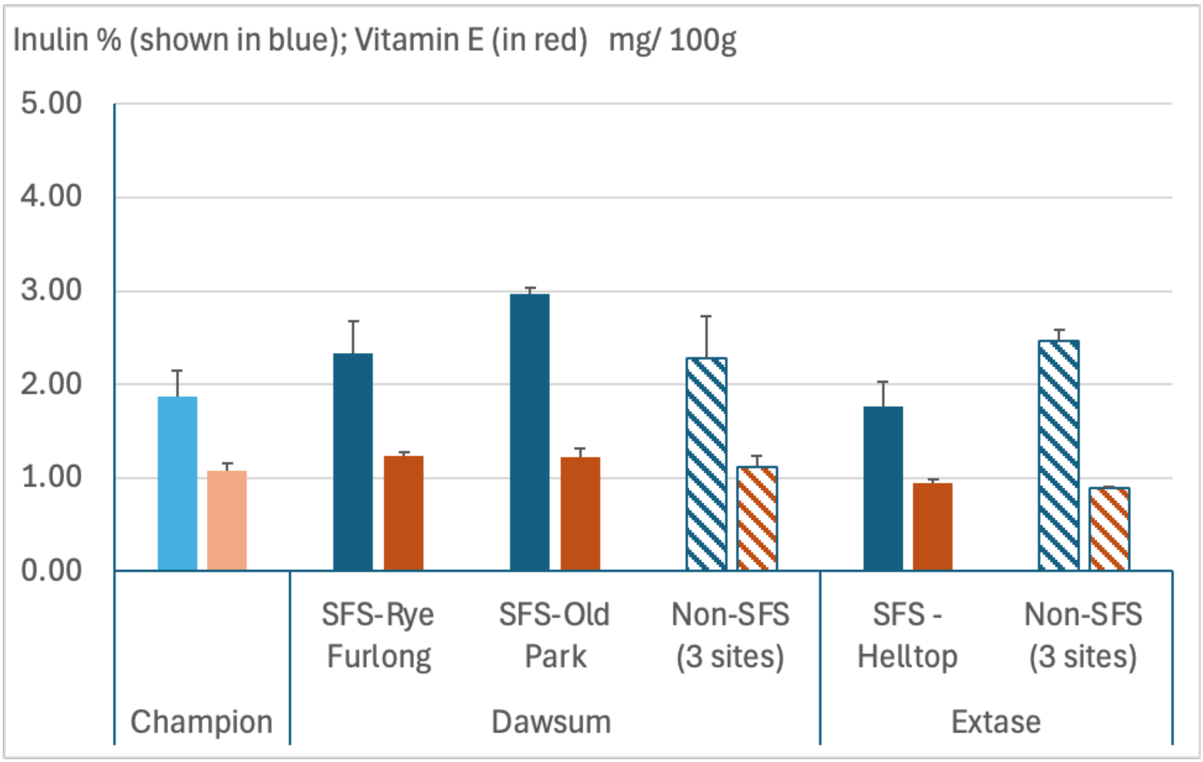


Figure 20. Inulin (%) and vitamin E content (mg/100g) of wheat grain by variety and farm system from hand-harvest samples across the fields

5.5. Action points for farmers and agronomists

More research is needed in this area. A wide range of crop, soil and other environmental factors can affect grain nutrient density. This study has found no differences between wheat grain samples sampled in one year (2024) from a range of farming systems on high pH soils. It is clear that there are no simple links between farming practice and food quality; however, it is likely that farm management changes, as well as actions elsewhere in the food chain, will be needed to improve UK diets in the future.

Other resources

Cabell C. A, and Ellis N. R. (1942) The vitamin E content of certain varieties of wheat, corn, grasses and legumes. The Journal of Nutrition 23(6) 633-644. doi: 10.1093/jn/23.6.633

Morris C.F. et al. (2009) A Comprehensive Genotype and Environment Assessment of Wheat Grain Ash Content in Oregon and Washington: Analysis of Variation. Cereal Chemistry 86: 307-312. doi: 10.1094/CCHEM-86-3-0307

Oury F.-X. et al. (2006) Genetic variability and stability of grain magnesium, zinc and iron concentrations in bread wheat. European Journal of Agronomy 25: 177-185. doi:10.1016/j.eja.2006.04.011

Montgomery et al. (2022) Soil health and nutrient density: preliminary comparison of regenerative and conventional farming. Peer J (Environmental Science) 10:e12848. doi: 10.7717/peerj.12848

Peterson, C.J., et al. (1986). Influence of cultivar and environment on mineral and protein concentrations of wheat flour, bran and grain. Cereal Chemistry 63: 183–186.

Zhao et a. (2009) Variation in mineral micronutrient concentrations in grain of wheat lines of diverse origin, Journal of Cereal Science 49: 290-295. doi:10.1016/j.jcs.2008.11.007