March 2025

Annual Project Report
(Harvest 2024)

On-farm trials at
Strategic Cereal Farm North

Contents

1. Introduction

Host Farmer: David Blacker

Location: Church Farm, North Yorkshire

Duration: 2022–2028

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.

Improving soil condition and economic yield are key areas of focus for the duration of the six-year Strategic Cereal Farm North project.

2. Foliar N impact on NUE & Disease (work package 1)

Trial leader: Charlotte White

Start date: October 2023

End date: December 2024

2.1. Headlines

The objective was to assess the effect of different timings (early and late) of foliar nitrogen in comparison to soil applied nitrogen (N). The soil applied N resulted in not significantly greater yield than the foliar N treatments. The soil N treatment had a significantly higher number fertile tillers/m^2 and grains/m^2 compared to the early and late foliar applied nitrogen treatments. It was notable, but not surprising given the season, that the grain nutrient analysis indicated that N was probably limiting in all treatments. The Early and Late Foliar nitrogen treatments yielded 0.8 t/ha and 0.5 t/ha less than the soil applied N treatment, respectively. However, these effects were not statistically significant. Due to the higher application of nitrogen, the soil applied nitrogen treatment resulted in the highest greenhouse gas emissions.

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

The interest of the Strategic Farm North was to compare foliar nitrogen and standard soil applied solid nitrogen applications on winter wheat nitrogen use efficiency (NUE) and disease pressure.

2.3. How did the project address this?

The fertiliser N trial tested three treatments to compare different timings of foliar N against soil applied solid N fertiliser (Table 1). This trial applied foliar N following manufactures' recommendations which advised that 1 kg of foliar applied N is equivalent to 4 kg of soil applied N; therefore the trial involved reducing soil applied N by 40 kg N/ha and replacing with 10 kg of foliar N. The trial was established in Overton 4 (Figure 1) which previously grew winter beans and had two soil texture zones (Table 2).

Table 1. Treatment details for Overton 4 Foliar N (FN) trial

Treatment	Application method	Soil applied N (kg N/ha)			Foilar applied N (kg N/ha)		Total soil N applied (kg N/ha)	Total N applied - Actual (kg N/ha)	Total N applied - 'Effective'* (kg N/ha)
		1st Split 24/03	2nd Split 20/04	3rd Split 17/05	2nd Split 20/04	3rd Split 17/05			
Soil N (SN) farm standard	Solid, Solid, Solid	70	60	30	-	-	160	160	160
SN (- 40) & Early FN	Solid, Liquid, Solid	70	0	50	10	-	120	130	160*
SN (- 40) & Late FN	Solid, Solid, Liquid	70	50	0	-	10	120	130	160*

* Based on the assumption that 1 kg of foliar-N is equivalent to 4 kg of solid N-fertilizer (30 litres/ha of foliar N product in 70 litres of water supplies 10.5 kg N/ha which based on manufactures' advice is assumed to be equivalent to 40 kg N/ha of soil applied fertiliser)

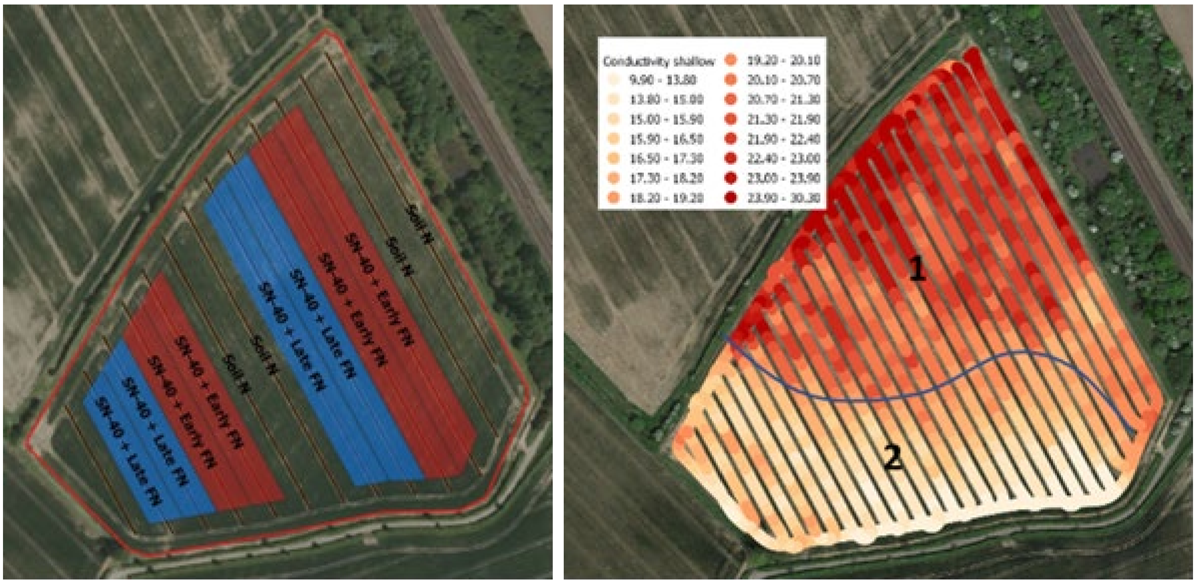


Figure 1. Trial design and shallow electrical conductivity (EC) map for Overton 4

Table 2. Cropping history for Overton 4

Cropping harvest year 2024	Previous crop 2023	Previous crop 2022	Number of soil zones
Winter wheat Champion drilled mid-sept 2023	Winter Beans	Winter Wheat	2

Fertiliser treatments:

'Soil N (SN) farm standard' = ammonium nitrate (34.5% N) applied at each split application

Foliar N (FN): Control release nitrogen i.e. foliar product contains some N as methylene urea (w/v 35% total-N).

'SN (- 40) & Early FN' = soil nitrogen reduced by 40 kg N/ha; with *early* application of foliar N*

'SN (- 40) & Late FN' = soil nitrogen reduced by 40 kg N/ha; with *late* application of foliar N*

The supply of other nutrients was as follows to ensure the supply of other nutrients was not limiting and that all the treatments received nutrients equally:

- 12/04/2024 Manganese Sulphate 32% 3.51 kg/ha
- 21/04/2024 Liquid Sulphur on early N plots (FMC Thio-S) 2586 g/ha
- 24/04/2024 FMC Cereal Plus (Cereal Mix Ultra) 5.18 l/ha
    - Contains manganese, Magnesium, copper and zinc.
- 15/05/2024 Manganese 15% 1.89 l/ha
- 21/05/2024 Molebdenum (Yara Molytrac 250) 35g/ha

Assessments

The following crop assessments were taken at the following growth stages

- Soil mineral nitrogen (SMN) taken twice in spring 2024 and *post-harvest*
- Above ground biomass and total N offtake in spring 2024 to determine soil nitrogen supply (SNS)
- Crop tissue analysis at the start of stem extension
- Foliar, stem and ear disease and green leaf area at GS75
- Crop assessment pre-harvest, including tiller count, above ground biomass and plant tissue analysis
- Grain quality at harvest, including thousand seed weight (TSW) and moisture and grain nutrition via YEN nutrition
- Yield, via Agronomics analysis

2.4. Results (to date)

Soil Nitrogen Supply March 2024

The soil nitrogen supply (SNS) was calculated as 35 -50 kg N/ha, based on a SMN values of between 20-30 kg N/ha and crop N of 15-20 kg N/ha (Figure 2) measured in March and February, respectively. No nitrogen treatments had been applied at the time of soil/crop sampling, so the apparent differences in SNS between the different nitrogen treatment areas are a result of underlying spatial variability in the soil and are too small to be important.

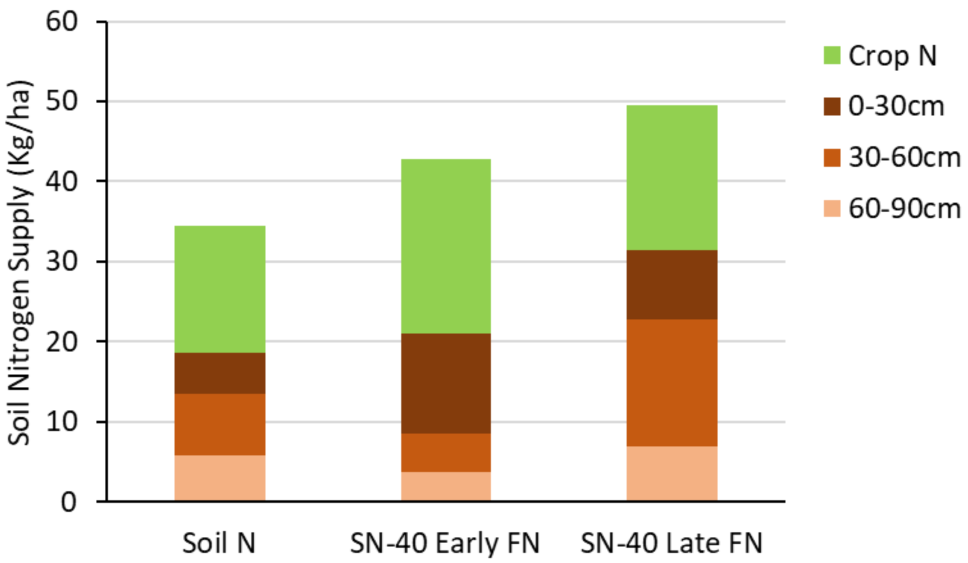


Figure 2. Soil nitrogen supply results: Above ground biomass nitrogen measured in February and soil mineral nitrogen measured in March 2024. Note: soil and crop samples were not taken at the same time, this was due to lab error in February which required repeat sampling and analysis of SMN.

Soil Mineral Nitrogen – Mid-April GS32

The first soil applied nitrogen application of 70 Kg N/ha was applied on the 24 March. However, by mid-April there was no evidence that the crop had responded to the nitrogen and SMN was re-tested to help assess whether the applied N was still available in the soil (Figure 3). The crop was not retested at this time, but there was no visual evidence that it had responded to the nitrogen applications. The increase in SMN in mid-April compared to the measurements taken in March averaged only 8 kg N/ha despite receiving an application of 70 kg N/ha. The lack of both a crop response and no increase in SMN indicates that it is likely that the majority of the first N (applied as ammonium nitrate) had been lost. The pathway of loss could be a combination of denitrification (to N_2), nitrate leaching and run-off.

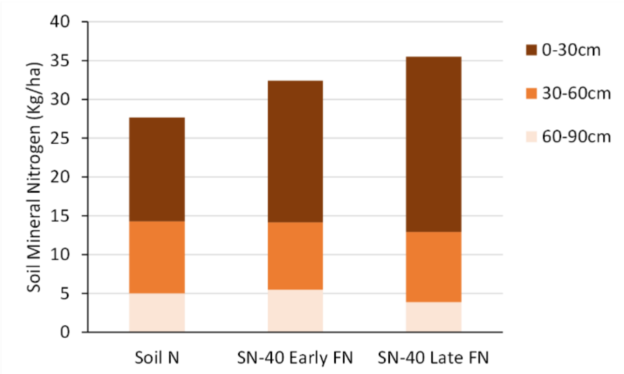


Figure 3. Soil Mineral Nitrogen (0-90 cm), in 30 cm increments, measured Mid-April at GS32.

The above results from the wet spring gave the rationale to alter the originally planned treatments to test the hypothesis if an early foliar nitrogen application would be a good option compared to the recommended (late) timing. Note: At this sampling, all treatments had received the same amount of N as ammonium nitrate fertiliser, so all differences are the result of underlying soil variation.

Satellite imagery

NDVI (normalized difference vegetation index) is a spectral reflectance index which shows a combination of canopy size and greenness, on a scale from 0 to 1. NDVI images were sourced from www.datafarming.com.au, based on freely available 10m resolution data from the Sentinel 2 satellites. The scale varies between images but always runs from red (low) through orange, yellow and green to blue (high). The availability of imagery is constrained by the need for cloudless conditions.

Prior to treatment applications, NDVI imagery showed the effects of the soil zones (Figure 1), with the northern zone 1 having lower NDVI (smaller or paler crop) than the southern part of the field. The treatment direction was almost perpendicular to the change in soil texture, so this should not have affected the fairness of the treatment comparison. As the crop senesced towards harvest, the NDVI trend was reversed, with lower NDVI (more rapid senescence) in the southern soil zone.

In May and June, NDVI was notably lower in the SN- 40 + Early FN treatment, suggesting a negative effect on crop growth relative to the other two treatments.

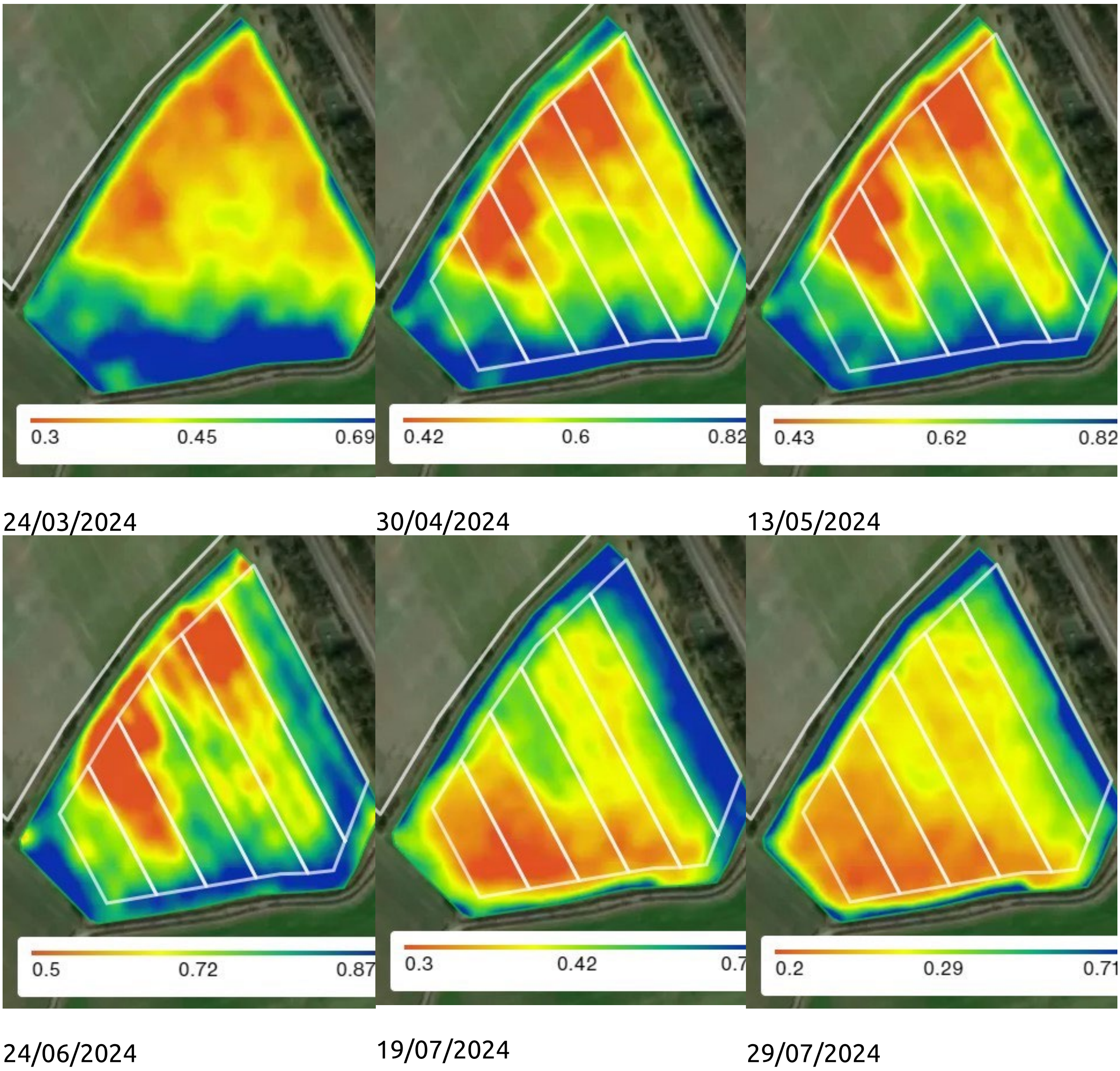


Figure 4. DataFarming NDVI imagery throughout the season

Leaf Tissue Analysis -April GS31

The crop was assessed for leaf nutrient status at around growth stage 31 (Table 3), the results showed that all mean tissue concentration values were lower than the median historic cereal Yield Enhancement Network (YEN) values for GS31, except for Iron. Those values highlighted yellow in Table 3 were lower than the first quartile (25%) of historic cereal YEN values, indicating that the crop was deficient in potassium (K), magnesium (Mg)(on the heavier soil type), sulphur (S), manganese (Mn), copper (Cu), zinc (Zn) and boron (Bo). There were statistically significant differences between the leaf tissue analysis from the two different soil textures in Mg concentration, with the lighter soil texture resulting in a higher concentration in the leaves. There was also a statistically significant difference between the Cu leaf tissue results, where the heavier soil texture resulted in a higher leaf Cu concentration compared to the lighter soil texture.

Table 3. Leaf tissue analysis results at GS30-32 in April 2024. Values highlighted were lower than historic cereal YEN Q1 values at GS31

Field split	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (%)**	**Mn (mg/kg)**	**Cu (mg/kg)**	**Zn (mg/kg)**	**Fe (mg/kg)**	**Bo (mg/kg)**
Heavier soil texture	3.72	0.32	2.42	0.32	0.077	0.15	31.0	3.73	15.9	179	1.17
Lighter soil texture	3.72	0.28	2.09	0.33	0.082	0.13	28.4	3.17	13.8	159	1.50
Mean	3.72	0.30	2.26	0.33	0.079	0.14	29.7	3.45	14.9	169	1.33
P value	0.99	0.15	0.13	0.86	**0.003**	0.09	0.53	**0.04**	0.23	0.66	0.15

Disclaimer: The historic YEN threshold of concern values used are from multi-years and are from a relatively recent and unpublished analysis of the cereal YEN database. They are shared for guidance and general information only. ADAS takes no responsibility if they prove to be misleading.

Disease at GS75

As the field received a standard fungicide programme, foliar disease (Table 4) is low across all treatments, with less than 1% yellow rust and brown rust recorded across the top three leaves. Septoria severity was slightly higher averaging 1.37% on leaf 1, 5.31% on leaf 2 and 10.72% on leaf 3. The only significant differences were for the late foliar N (Treatment 3) which had a higher septoria incidence and lower green leaf area (GLA) on leaf 3. For Brown rust, there was a trend for the early foliar N treatment to reduce severity across all three leaf layers however differences were small and not statistically significant.

Stem disease (Table 5) was also assessed on 4 July, eyespot incidence and index tended to be lower where only soil N was applied in treatment 1, but sharp eyespot incidence and index was higher, but these effects were not significant. Both nodal and internodal fusarium incidence and severity was lowest where only soil N was applied in treatment 1, but increased where foliar N was applied early and increased further where foliar N was applied late, however differences were small and not statistically significant. There was no difference in fusarium ear blight severity between treatments.

Table 4. Foliar disease and green leaf area (GLA) assessed on leaves 1, 2 and 3 of the crop on the 4th July 2024. Values represent the percentage of the leaf affected

	Leaf 1				Leaf 2				Leaf 3			
Treatment	Septoria (%)	Yellow rust (%)	Brown rust (%)	GLA (%)	Septoria (%)	Yellow rust (%)	Brown rust (%)	GLA (%)	Septoria (%)	Yellow rust (%)	Brown rust (%)	GLA (%)
Soil N	1.03	0.04	0.05	90.0	4.64	0.01	0.45	76.2	8.76	0.00	0.67	43.0
SN-40 + Early FN	1.43	0.01	0.02	89.1	4.42	0.02	0.12	78.0	8.77	0.01	0.13	49.5
SN-40 + Late FN	1.63	0.01	0.08	88.7	6.87	0.00	0.78	68.5	14.64	0.00	0.72	24.0
Mean	1.37	0.02	0.05	89.3	5.31	0.01	0.45	74.2	10.72	0.00	0.50	38.8
P	*0.765*	*0.432*	*0.39*	*0.704*	*0.152*	*0.648*	*0.1*	*0.266*	***0.006***	*0.2*	*0.154*	***0.025***
SED	*0.785*	*0.024*	*0.034*	*1.483*	*0.811*	*0.021*	*0.157*	*4.307*	*0.376*	*0.005*	*0.198*	*3.003*
LSD (P<0.05)	*3.378*	*0.102*	*0.146*	*6.383*	*3.49*	*0.088*	*0.675*	*18.53*	*1.618*	*0.023*	*0.853*	*12.921*

Table 5. Stem eyespot, sharp eyespot, nodal and internodal fusarium incidence and index and the percentage of the ear affected by fusarium ear blight, assessed on the 4th July 2024

Treatment	Eyespot Incidence (%)	Eyespot Index (0-100)	Sharp Eyespot Incidence (%)	Sharp Eyespot Index (0-100)	Nodal Fusarium Incidence (%)	Nodal Fusarium Index (0-100)	Internodal Fusarium Incidence (%)	Internodal Fusarium Index (0-100)	Fusarium ear blight (%)
Soil N	6	2.7	5	2.7	50	24.3	71	36	0.10
SN-40 + Early FN	17	6.3	2	0.7	75	36	85	46	0.18
SN-40 + Late FN	12	6.7	2	0.7	86	47.3	94	56	0.16
Mean	12	5.2	3	1.3	70	35.9	83	46	0.16
P	*0.505*	*0.488*	*0.438*	*0.437*	*0.332*	*0.324*	*0.184*	*0.167*	0.288
SED	*7.874*	*3.067*	*2.16*	*1.44*	*18.385*	*11.264*	*7.789*	*6.236*	0.038
LSD (P<0.05)	*33.9*	*13.20*	*9.3*	*6.20*	*79.1*	*48.47*	*33.5*	*26.8*	0.165

Crop assessment pre-harvest, GS91

The pre-harvest sample results were taken at GS91 (grain hard, difficult to divide) and there was an average of 375 fertile shoots/m^2, this is lower than the AHDB benchmark of 460 ears/m^2. The soil N treatment had 442 fertile tillers, significantly (*P*=0.001) more than the two foliar N treatments (Table 6), with late FN having the lowest number of ears/m^2., at 338 ears/m^2. On average there were 14,214 grains/m^2 which is lower than the AHDB benchmark of 22,000 grains/m^2. The soil applied N treatment had significantly (*P*<0.05) more grains/m^2 (15,481) compared to both the early and late foliar N treatments, which had 13,579 and 13,583 grains/m^2, respectively. The average crop biomass was 13.0 t/ha with a harvest index of 46.2.; there were no significant differences between treatments. The values for biomass and dry matter harvest index (DMHI) are lower than the AHDB benchmark values of 18.4 t/ha dry matter with 51% HI. The average thousand grain weight (TGW) was 49.6 g and using the grain N results (Table 8) the nitrogen harvest index (NHI) was calculated to be 69.7%. There was no significant difference between the treatments in NHI.

Table 6. Pre-harvest grab sample, tissue analysis and grain quality results

Treatment	Fertile shoots/m^2	Total biomass t/ha	DMHI (%)	TGW at 15% moisture (g)	Grains/m^2	NHI %
Soil N	442	13.8	47.0	49.2	15481	72.6
SN-40 + Early FN	344	12.6	46.5	50.2	13579	71.0
SN-40 + Late FN	338	12.7	45.1	49.4	13583	65.5
Mean	375	13.0	46.2	49.6	14214	69.7
P	0.009	0.143	0.34	0.71	0.042	0.22
SED	797	0.378	1.0	1.12	325.2	2.79
LSD	34.3	1.623	4.4	4.8	1399	12.0

Pre-harvest tissue samples were analysed for nutrient content. The late foliar N treatment resulted in a significantly higher (*P*<0.05) concentration of K in the straw and chaff at 0.72% compared to the other two treatments (mean K concentration of 0.64%) (Table 7). There were no other significant differences between the treatments in the straw and chaff at pre-harvest (Table 7).

Table 7. Pre-harvest tissue analysis in straw and chaff (%)

Treatment	N %	P %	K %	Ca %	Mg %	S %	Mn mg/kg	Cu mg/kg	Zn mg/kg	Fe mg/kg	B mg/kg
Soil N	0.51	0.06	0.65	0.17	0.07	0.07	18.9	1.85	8.0	33.5	2.85
SN-40 + Early FN	0.52	0.05	0.63	0.20	0.07	0.07	24.2	1.70	5.2	51.8	2.80
SN-40 + Late FN	0.62	0.07	0.72	0.18	0.06	0.10	47.6	2.00	9.3	56.9	2.85
Mean	0.55	0.06	0.67	0.18	0.07	0.08	30.2	1.85	7.5	47.4	2.83
P	0.1	0.80	0.036	0.80	0.12	0.49	0.52	0.21	0.37	0.35	0.75
SED	0.028	0.023	0.014	0.047	0.003	0.023	22.6	0.11	2.29	12.87	0.071
LSD	0.121	0.099	0.058	0.204	0.011	0.098	97.3	0.46	9.84	55.39	0.304

Table 8. Mean grain nutrition results, cells highlighted in yellow indicate those nutrients which are below YEN threshold of concern values (below 75% of all previous YEN results for this crop type).

Treatment	N %	P %	K %	Mg %	S %	B mg/kg	Ca %	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo Mg/kg	Zn mg/kg	N:P ratio	N:S ratio
Soil N	1.53	0.37	0.70	0.11	0.11	1.13	0.03	5.00	40.2	36.4	0.28	31.1	4.18	13.9
SN-40 + Early FN	1.47	0.36	0.70	0.11	0.11	1.11	0.04	4.95	40.2	32.9	0.47	31.4	4.07	13.3
SN-40 + Late FN	1.41	0.35	0.68	0.10	0.11	1.04	0.03	4.60	36.2	34.4	0.27	30.1	4.09	13.5
Mean	1.47	0.36	0.69	0.11	0.11	1.09	0.03	4.85	38.8	34.6	0.34	30.9	4.11	13.5
P	0.19	0.41	0.34	0.25	0.50	0.30	0.56	0.35	0.07	0.55	0.08	0.70	0.78	0.82
SED	0.04	0.01	0.01	0.00	0.00	0.05	0.00	0.23	0.91	2.74	0.05	1.45	0.16	0.86
LSD									3.91		0.20			

Grain nutrition results

The average grain nutrition results are summarised in Table 8. The grain samples were entered into YEN nutrition, one per tramline and more detailed analysis and interpretation for these samples can be obtained from the YEN nutrition reports. All treatments resulted in grain Nitrogen (%) and Sulphur (%) values below the YEN threshold of concern values, which can indicate a potential deficiency.

In terms of treatment effects, the soil N and late FN treatments resulted in lower threshold of concern than YEN values for Ca (%) and Mo(mg/kg). No other treatment effects were detected and all other nutrients were above the YEN threshold of concern values. Across all treatments, the level of grain N was substantially below the grain N% of 1.9% expected for an optimally fertiliser crop. Typically, increasing soil applied N by 30 kg N/ha would be expected to increase grain N by 0.1%. This indicates that crops in all the treatments of this trial were substantially under-fertilised, probably by at least 100 kg N/ha. Although not statistically significant the Late Foliar N treatment had a grain N% which was 0.12% less than the soil applied N treatment which is consistent with it receiving 30 kg N/ha less N in total.

Table 8. Mean grain nutrition results, cells highlighted in yellow indicate those nutrients which are below YEN threshold of concern values (below 75% of all previous YEN results for this crop type)

Treatment	N %	P %	K %	Mg %	S %	B mg/kg	Ca %	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo Mg/kg	Zn mg/kg	N:P ratio	N:S ratio
Soil N	1.53	0.37	0.70	0.11	0.11	1.13	0.03	5.00	40.2	36.4	0.28	31.1	4.18	13.9
SN-40 + Early FN	1.47	0.36	0.70	0.11	0.11	1.11	0.04	4.95	40.2	32.9	0.47	31.4	4.07	13.3
SN-40 + Late FN	1.41	0.35	0.68	0.10	0.11	1.04	0.03	4.60	36.2	34.4	0.27	30.1	4.09	13.5
Mean	1.47	0.36	0.69	0.11	0.11	1.09	0.03	4.85	38.8	34.6	0.34	30.9	4.11	13.5
P	0.19	0.41	0.34	0.25	0.50	0.30	0.56	0.35	0.07	0.55	0.08	0.70	0.78	0.82
SED	0.04	0.01	0.01	0.00	0.00	0.05	0.00	0.23	0.91	2.74	0.05	1.45	0.16	0.86
LSD									3.91		0.20			

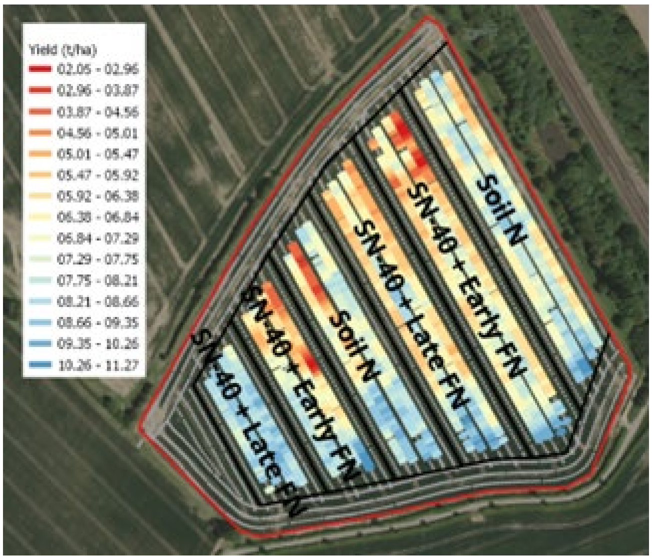
Yield

The fields were harvested with a yield mapping combine and processed using the ADAS Agronomics approach. This cleans the data to remove headlands, anomalous combine runs (i.e. header not full or spanning two treatment areas), and locally extreme data points, and corrects any offset created by changes in combine direction. In this trial, data was also excluded close to treatment boundaries due to the overlapping spread pattern from the spinning disc spreader.

Agronomics results

The average measured yield of the control treatment was **7.62 t/ha**, according to yield map data (Figure 5). This is likely to be a little higher than the true field average due to exclusion of headlands from the analysis.

Using the Agronomics analysis to fit a statistical model to the data, we estimate that the early and late foliar N treatments **reduced yield by 0.82 t/ha and 0.49 t/ha** respectively, relative to the control treatment. However, this is not certain; according to the statistical model, the estimated yield effects could have been the result of underlying soil variation (the P values were 0.059 and 0.312, respectively). The yield reduction caused by the early foliar N is close to being statistically significant at the 95% threshold.



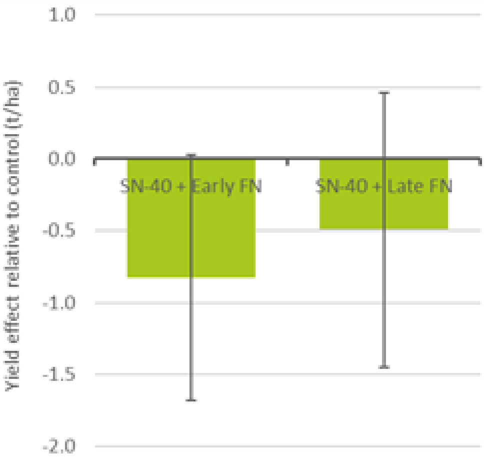


Figure 5. Winter wheat yield map for Overton 4

Soil Zones

A simple analysis was also done on the effect of soil zones. Mean yield was calculated within each zone, excluding the headlands. The mean yields were 6.68 t/ha for soil zone 1 (heavier soil texture) and 8.11 t/ha for soil zone 2 (lighter soil texture).

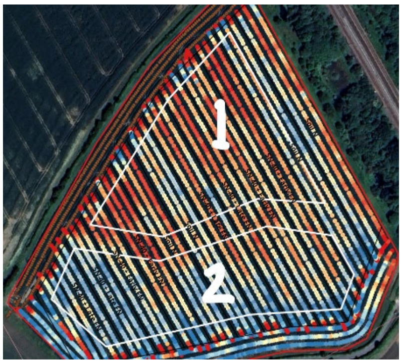


Figure 6. Raw yield map showing areas used to calculate mean yields for each soil zone

Post-Harvest Soil Mineral Nitrogen

Post-harvest SMN was measured on 27th August 2024 Across the treatments SMN was between 20 to 34 kg N/ha (Figure 4). SMN was lowest on the Late FN treatment, with comparably less in the 60-90 cm horizon compared with the other N treatments. SMN was highest in the Early FN treatment.

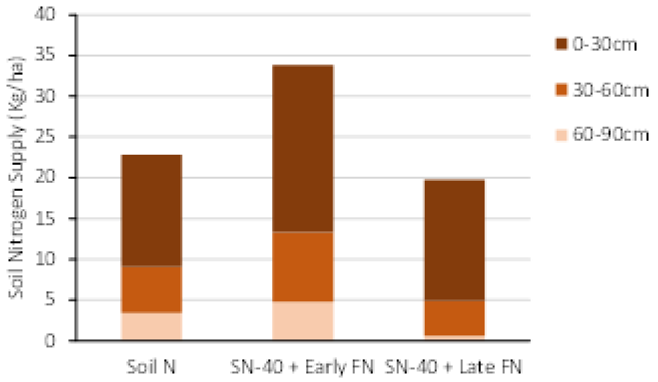


Figure 7. Post-harvest soil mineral N results

YEN ZERO Analysis

Each tramline was submitted to YEN Zero to investigate the impact of the different fertiliser N treatments on greenhouse gas emissions (GHG). The YEN Zero report provides all the detailed information and breakdown of results. The data included here is an overview of the findings (Table 10). The soil applied N treatments resulted in the highest GHG emissions. Soil applied N treatment had the highest GHG intensity at an average of 198 kg CO_2 e/t. The early FN treatment resulted in GHG emissions of 190 kg CO_2 e/t and the late FN the lowest at 167 kg CO_2 e/t. The soil N treatments had a greater amount of the GHG emissions form synthetic nitrogen applications compared to the FN treatments, which was caused by the soil N treatment having a greater N rate.

Table 10. Mean YEN Zero Greenhouse Gas Emission results

Treatment	**Mean kg CO_2e/t**	**Mean kg CO_2 e/ha**
Soil N	**198**	**1,492**
Early FN	**190**	**1,302**
Late FN	**167**	**1,296**

Overall Evaluation

The Early and Late Foliar nitrogen treatments yielded 0.8 t/ha and 0.5 t/ha less than the soil applied N treatment, respectively. However, these effects were not statistically significant, although the effect of the Early Foliar N treatment was close to the 95% threshold. Overall, it seems highly unlikely that assuming 1kg N/ha from a foliar product can replace 4 kg N/ha from a soil applied product will be a cost-effective fertiliser strategy.

The leaf tissue analysis at GS31 before any of the foliar N treatments and micronutrients had been applied indicated that all nutrient levels were below average, with particular deficiencies for K, Mg, S, Mn, Cu, Zn and B based on YEN thresholds of concern values. Disease levels at GS75 were low across all treatments.

Late Foliar N significantly increased septoria incidence and reduced green leaf area on leaf 3. There was no evidence that foliar N may reduce leaf or stem-based diseases.

The soil applied N treatment had significantly more fertile shoots/m^2 and grains/m^2 compared to the early and late foliar N treatments, which corresponds with the soil N treatment having the highest yield. The soil N treatment also had the highest total biomass and highest harvest index, but these differences weren't statistically significant. The values reported for the crop from the pre-harvest assessment were lower than the AHDB benchmarks. There was also no significant difference between the treatments in nitrogen harvest index.

The grain samples had low nitrogen and sulphur values, which indicate a deficient supply of these nutrients. In particular, the grain N% was very low and indicates that the crop was under-fertilised by at least 100 kg N/ha. The Late Foliar N treatment may have been under-fertilised by an even greater amount. Given the loss of nitrogen at the beginning of the spring this result for nitrogen was probably not surprising. There were also indications of low grain nutrient values of calcium and molybdenum. It is recommended to review nutrient applications as well as addressing barriers to nutrient uptake.

The soil applied N treatment resulted in the highest greenhouse gas emissions on a per hectare and per tonne of yield basis, due to the higher application of synthetic nitrogen.

Next steps

Following on from the results of the tissue and grain analysis in this season a foliar micronutrient trial, using an 'active management' nutrient approach is planned for harvest year 2025. This will include a review of nutrient applications for the field with the aim of improving crop productivity. The 'active management' treatment will involve using previous grain nutrient analysis and in-season tissue analysis to inform applications of nutrients during the season; crop performance will be compared to a 'farm standard' approach. There will also be an aspect of testing reduced crop protection treatments, and the impact on disease will be assessed.

2.5. Action points for farmers and agronomists

It is important to revise and adapt planned nitrogen applications to the field and importantly to the season and to investigate if other nutrients are limiting crop performance. It is recommended to optimise nutrient inputs and improve productivity, by focusing on adjusting nutrient inputs in-season based on detailed monitoring of the crop during season (e.g. tissue tests).

3. Improving Earthworm populations (work package 2)

Trial leader: Anne Bhogal
Start date: September 2023
End date: September 2024

3.1. Headlines

The overall objective of the trial was to investigate the impact of a permanent clover understory and compost application on earthworm populations, soil nitrogen supply and crop performance.

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

Baseline soil sampling undertaken during the first year of Strategic Farm North, revealed depleted earthworm populations in all test fields, with counts of 2-7 worms per $20cm^3$ soil pit, comprising mainly juvenile worms. No deep-burrowing anecic worms were recorded. A count of more than 9 worms per pit comprising of both juvenile and adult earthworms with a range of species present is considered to be typical or good for an arable soil. On the farm, strip tillage is used to minimise the negative effects of cultivations on earthworm populations. This work aims to explore other ways in which worm populations can be improved across the farm.

3.3. How did the project address this?

It was intended that this trial be established in Newton 1 in autumn 2023 for a spring bean crop in 2024. Due to the very wet winter and spring none of the treatments could be established and the field was left fallow for the season. A second attempt to establish the trial was made in July 2024 ahead of drilling winter wheat in autumn 2024 for harvest 2025.

Green compost (PAS 100 certified) was applied to half of Newton 1 on 4/7/24 at 25 t/ha (fresh weight). Shortly after (8/7/24) a legume understory was drilled across two replicate double tramlines to give 4 treatments replicated twice across the field (Figure 8 & Table 11). The legume seed mix (Kings 'Living Mulch blend K107) comprised 4 species: yellow trefoil, white clover, subterranean clover and small leaved clover, and was drilled at either 2.5 kg/ha (northern strip) or 5 kg/ha (southern strip).

Figure 8. Trial design in Newton 1 – Improving earthworm populations, impacts of a clover understory and compost addition. Pink dots indicate the points where baseline soil samples were taken to characterize the field (3 soil zones) in autumn 2022; yellow dots indicate fixed sampling points for the trial going forward

Table 11. Treatments within Newton 1

Ground cover treatment	Compost treatment
1. Crop Only	No compost
2. Crop Only	With Compost
3. Crop with clover understory	No compost
4. Crop with clover understory	With Compost

A limited suite of assessments was undertaken during the 2023-24 season and included:

- Topsoil Visual Soil Assessment (VESS) and earthworm count within 5-10 metres of a fixed sampling point (yellow dots in figure 1) in each of the proposed treatment areas (pre-treatment, October 2023)
- Compost analysis to determine nutrient loading rates
- Soil mineral N to 90cm depth ahead of drilling the winter wheat crop for the 2024/25 season (30/8/2024)
- Assessment of the above ground biomass species composition, dry matter yield and N uptake at the time of the August SMN sampling
- Nodulation assessment to check if the legume understory species (clover) had formed nodules and if these were actively fixing nitrogen (August 2024)

3.4. Results (to date)

Baseline soil structure and earthworm count (October 2023)

Visual evaluation of soil structure (VESS) assessments carried out before the treatments were applied identified a 'limiting layer' where scores were slightly higher (indicating a more compact soil) at c. 10cm across the field. Scores for this layer ranged from 2.3 ('intact' soil structure – no concern) to 3.5 ('firm' to 'compact' – monitor), Table 12. Note: a score of 1 indicates a friable soil with good structure and no evidence of compaction, whereas a score of 5 indicates a very compact soil with low porosity. These are similar to the scores reported in autumn 2022 when the three textural zones in the field were assessed (limiting layer score ranged from 2.5 to 3).

Earthworm numbers were variable across the field, ranging from 1 (depleted) to 9 (intermediate/typical) worms per pit (*c.* 20 cm^3 of soil), and comprised of mainly juvenile and epigeic (litter dwelling) worms. This was similar to the 2022 findings where worm counts averaged 3-4/pit.

Table 12. VESS scores and earthworm counts, before treatments were established in October 2023; results have been colour coded according to the AHDB Soil health scorecard: Green: continue to monitor; Amber: review; Red: Investigate

Sampling zone*	VESS limiting layer score**	Worm count (number/*c.* 20cm^3 pit)**				
		Juveniles	Epigeic (litter)	Endogeic (topsoil)	Anecic (deep)	Total
1	2.5	1.3	1.3	1.3	0.3	4.3
2	2.3	5.3	1.3	0.7	0.0	7.3
3	2.8	0.7	0.3	0.0	0.0	1.0
4	3.2	0.3	0.3	0.0	0.0	0.7
5	2.3	3.7	3.0	2.0	0.3	9.0
6	3.5	1.3	0.7	1.3	1.0	4.3
7	2.7	1.7	1.3	0.7	0.0	3.7
8	2.8	2.7	3.0	1.0	0.0	6.7

**See figure 8 for sample zone numbering in autumn 2023*

***Results are an average of 3 pits per sampling zone*

Nutrients & organic matter supply from compost

The composition of the green compost applied in July 2024 is shown in Table 13, compared to 'typical' values reported in 'The Nutrient Management Guide - RB209'. RB209 does not give standard values for pH, readily available N or carbon content, but states that '*compost usually contains very little readily available nitrogen, but repeated use over time can increase soil organic* *matter levels'*. The compost applied in Newton was similar in composition to the standard values in RB209 albeit with a higher phosphate but lower potash content.

Using the analysis results and the MANNER-*NPK* model (which predicts crop available nutrient supply from organic materials, Nicholson *et al*., 2013), the 25 t/ha compost was calculated to supply negligible crop available nitrogen, but about 60 kg/ha of crop available phosphate (P_2O_5) and potash (K_2O) (Table 14).

Table 13. Composition of the compost applied in Newton 1

Property	**Newton 1 compost**	**RB209 Green compost***
pH	8.2	-
Dry matter (%)	52	60
Total N (kg/t FW)	8.7	7.5
Readily available N (kg/t FW)	0.25	-
P_2O_5 (kg/t FW)	5.0	3.0
K_2O (kg/t FW)	3.0	6.8
MgO (kg/t FW)	3.2	3.4
SO_3 (kg/t FW)	2.9	3.4
Organic C (% DM)	21	-
C:N	12	-

**Nutrient Management Guide- RB209, Section 2 Organic materials ; June 2023 does not give standard values for pH, readily available N or carbon content.*

Table 14. Nutrient loadings from compost applied in Newton 1

Nutrient	**Loading rate (kg/ha)**
Total N	220
Crop available N*	10
Crop available P_2O_5 *	63
Crop available K_2O *	60
Total MgO	80
Total SO_3	72

*Predicted using MANNER-*NPK* for the application date (July) and rate (25 t/ha), surface broadcast onto a weedy fallow.

Composition, yield and nitrogen content of the above ground biomass, August 2024

The above ground biomass was assessed at the end of August, *c*. 2 months after the clover understory was drilled. Note the field was fallow for the 2023-24 season so the weed burden was high. The strips where the legume was sown were mown before drilling the legume mix (using a strip-till drill) to reduce competition from the weeds, but weed populations were still high across the whole field (Figure 9 & Plate 1). Only clover appeared to have established from the sown seed mix. Total above ground biomass and N uptake was variable due to the presence of large weeds, particularly on the control treatment and ranged from 0.3 – 0.7 t/ha and 6-16 kg/ha, respectively (Table 15). There were no statistically significant differences between the treatments.

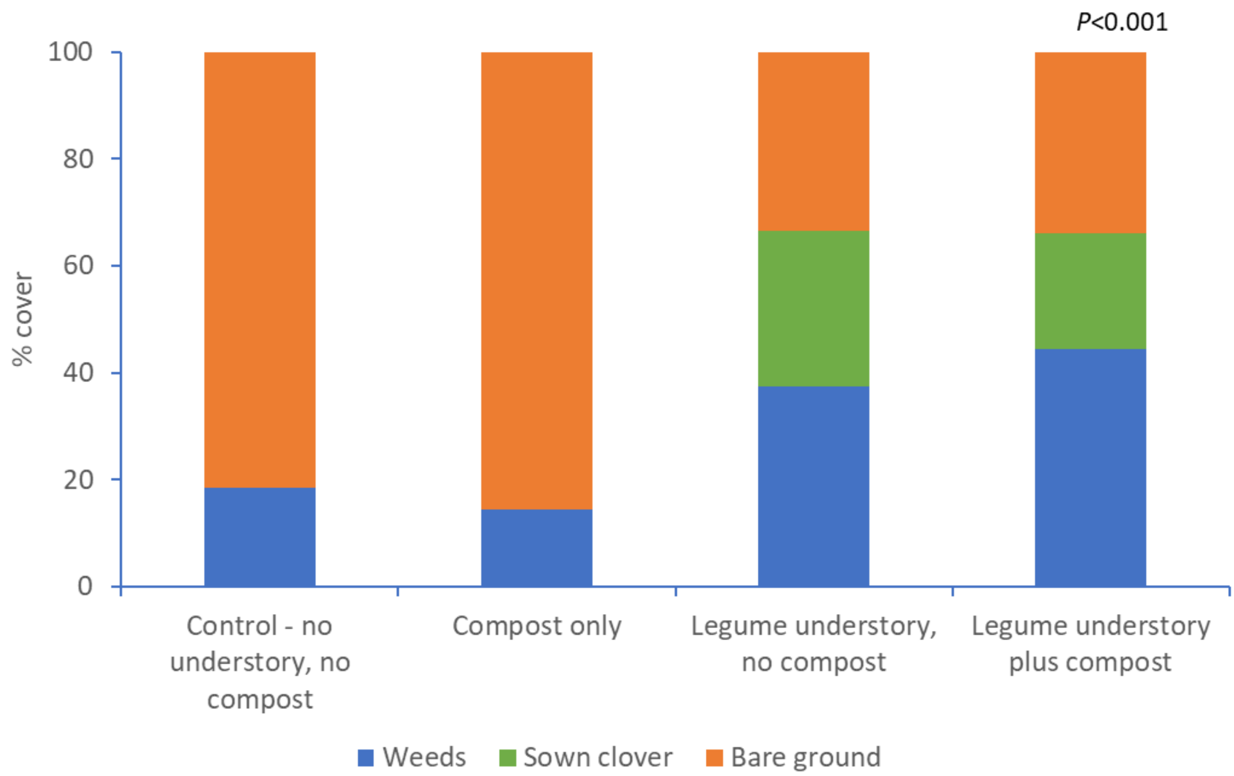


Figure 9. Ground cover on the different treatment tramlines recorded on 30/8/24. Results are an average of 3 quadrats per replicate (6 quadrats per treatment).

Plate 1. Contrasting and variable ground cover across the treatments; left – sampling point 7 (Compost only); right – sampling point 8 (legume understory + compost). Three quadrats were assessed within 5m of the sampling point

Table 15. Percentage cover, above ground biomass and nitrogen uptake, August 2024; P>0.05 standard errors in brackets

Ground cover treatment	Cover (%)	Biomass (t/ha)	N uptake (kg/ha)
1. Weedy fallow no compost (control)		0.68 (0.35)	12.4 (6.6)
2. Weedy fallow with compost		0.28 (0.08)	5.8 (1.7)
3. Clover understory no compost		0.64 (0.14)	15.8 (3.4)
4. Clover understory with compost		0.69 (0.09)	16.0 (2.7)

Clover nodulation

Nodules had formed on all but one of the white clover plants assessed (5 plants/quadrat, 3 quadrats per ‘plot’; 60 plants in total; Plate 2). The clover in the legume + compost treatment had significantly more nodules (actual count) compared to the legume no compost treatment (Table 16). Nodule size was similar between the two treatments and all nodules were found to be active when cut open. The clover in the legume + compost treatment also had a significantly higher nodulation score compared to the no compost treatment.

These results show that at the time of sampling the clover was responding positively to the application of compost, possibly due to the additional P and K supplied by this treatment.

Table 16. Nodulation assessment results. An average of two ‘plots’ per treatment and 15 plants per ‘plot’. A T-Test was carried out on the data using GENSTAT and a Probability value is given as well as the standard error of the difference.

Treatment	Number of nodules/plant	Nodule size, mm	Nodulation score*
Legume understory, no compost	9.0	1.3	2.3
Legume understory, + compost	12.4	1.1	3.2
Mean	10.7	1.2	2.8
P (T-test)	**0.05**	0.157	**0.006**
SED	1.6	0.116	0.293

*Nodulation score: 0 = none; 8 = extremely abundant

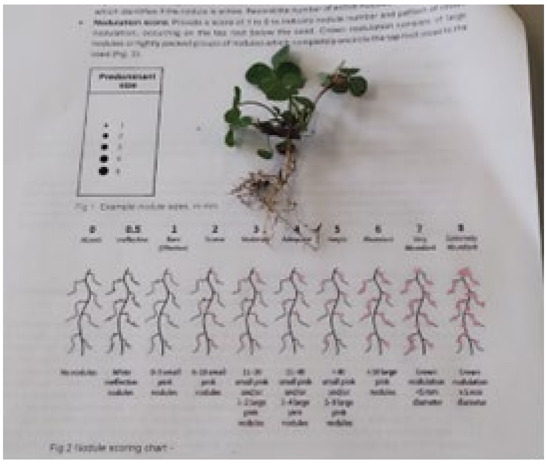


Plate 2. Assessing clover nodulation: Left: close up of a white clover plant showing root system with nodules; Right: nodulation scoring system

Soil mineral N

Soil mineral N (SMN) at the time of sampling the above ground biomass in August 2024 (Figure 10) was significantly lower on the legume understory treatments ($P<0.001$), most likely reflecting the higher biomass and N uptake on these treatments (Table 15). These differences were mainly seen in the top 30cm of soil. There was no difference in SMN due to compost addition in the presence of a legume understory, but in the absence of the understory, SMN was lower where compost had been applied, with the highest SMN measured on the control treatment. This did not reflect the differences in above ground biomass or cover (Table 15), although this was very variable, particularly on the control treatment due to the presence of large weeds. The C:N ratio of the compost (Table 13) was relatively low (at 12) so should not have resulted in significant immobilisation of soil N following its application.

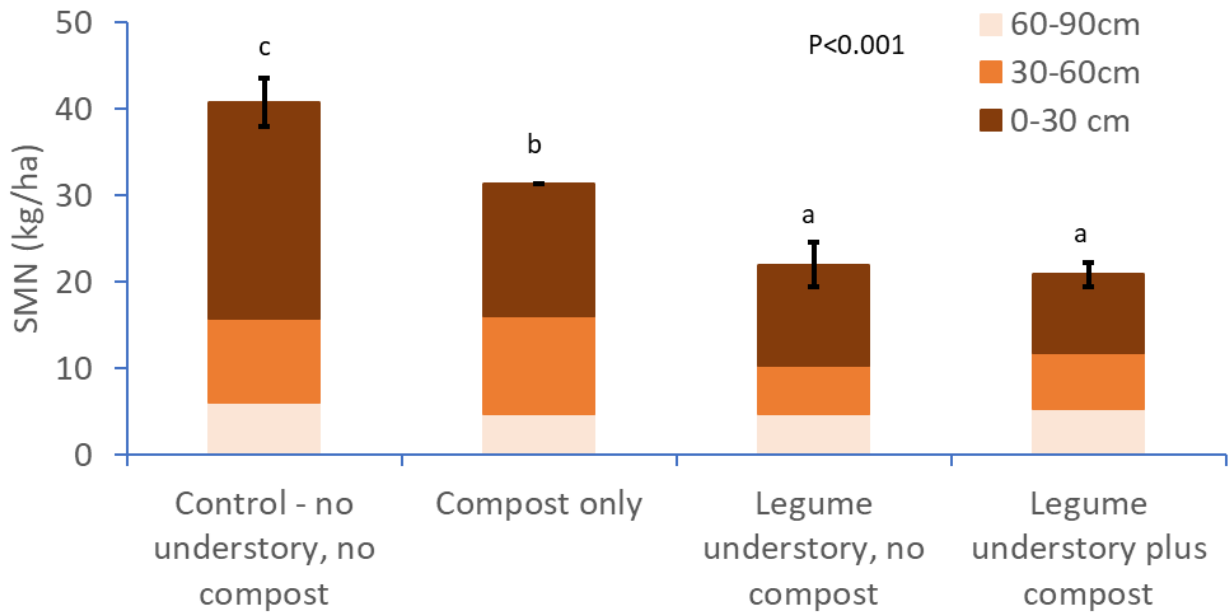


Figure 10. Soil mineral N (to 90cm depth) in August 2024

Next steps

Winter wheat has been drilled for the 2024/25 cropping season. VESS and earthworm assessments will be undertaken again in spring 2025 and the performance of the wheat assessed at harvest 2025.

3.5. Action points for farmers and agronomists

Green compost can supply useful amounts of nutrients – particularly phosphate and potash, as well as organic matter. The Nutrient Management Guide – RB209 Section 2 provides typical values for the nutrient content of a range of organic materials, but this can vary depending on the source and management of the material. It is worthwhile either obtaining a recent analysis from your compost supplier or sending a sample for analysis yourself in order to more accurately account for the nutrient supply in planning future fertiliser applications.

Earthworms are a key indicator of soil biological health, often referred to as 'ecosystem engineers' due to their role in breaking down organic matter, improving soil structure and allowing water/oxygen to move through the soil profile. Regular monitoring of their population is useful to understand the impact of crop and soil management practices on soil biological health and help guide future interventions.

Legume understories provide a great opportunity for soil cover and may contribute to improving soil condition. This trial has highlighted the challenges associated with establishing a cash crop into a legume understory in particularly wet years.

4. Drainage trial (work package 3)

Trial leader: Kate Smith, ADAS
Start date: August 2023
End date: October 2024

4.1. Headlines

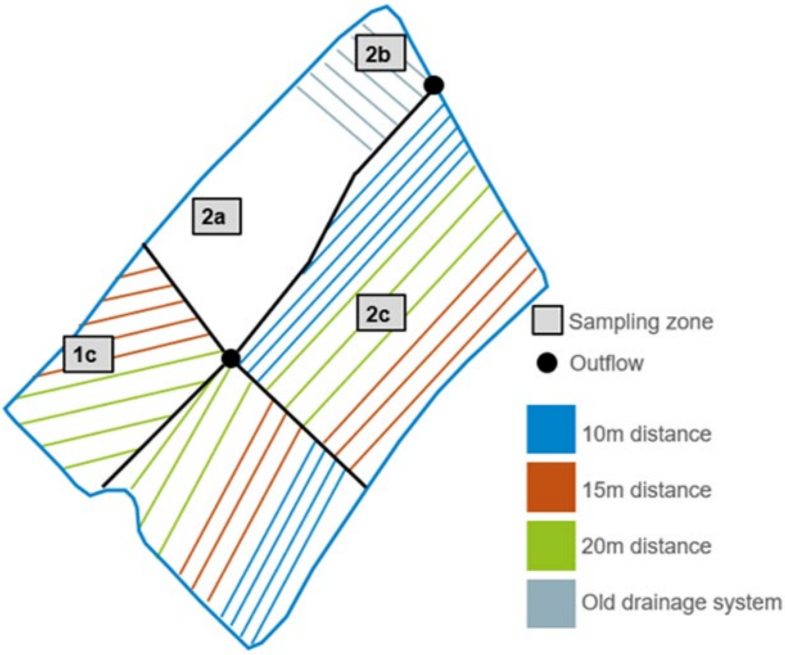
The overall objective of the trial in harvest year 2024 was to investigate the impact of drainage approaches on winter wheat performance. The prolonged and heavy rain from autumn 2023 through to late spring 2024, was particularly challenging for the farm and impacted winter wheat establishment and spring growth. At harvest, there was a clear impact of drainage with crop yields being 1.21 t/ha lower on the ‘no drainage’ (2a) compared to areas in the field of similar soil texture (2c) which had a new drainage system installed in 2022.

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

Strategic Farm North is on a heavy clay soil which is slowly permeable and can be waterlogged for long periods without adequate drainage. There has been a general reduction in organic matter levels in arable soils over the past 70 years which makes them more susceptible to waterlogging and more in need of drainage. There is interest in the time it takes for the soil to restructure, increase in porosity and improve microbial activity following drainage.

4.3. How did the project address this?

Between May and September 2022, Overton 5 was redrained with lateral drains at 10, 15 and 20m intervals covering both lighter (clay loam: 1c) and heavier soil textures (clay: 2c). Within the same field, there is an area which is not drained (2a) and a section with the old drainage system in place (2b). As part of the trial soil and crop sampling was carried out in 3 of the 4 zones (labelled, 2a, 2b and 2c) (Figure 11).



Site details

Field name: Overton 5

Size: 11.6 ha

Soil texture: clay loam to clay

Crop: winter wheat

Drilling date: 15/09/23

Figure 11. Location of the sampling zones (labelled 1c, 2a, 2b and 2c) in relation to the drainage treatments and soil type within Overton 5

Assessments

Soil nitrogen supply	SMN sampling and crop N-uptake, representative samples from zones (2a, 2b and 2c at 10m, 15m and 20m spacing)
Crop biomass	Growth stage, plant count, NDVI, tiller count, plant tissue analysis
Disease	Foliar disease, green leaf area, stem and ear disease
Yield	Pre-harvest biomass sampling, yield map analysis, grain nutrition
Rooting	Post harvest measurements to 1m depth

What results has the project delivered?

Soil nitrogen supply

Soil mineral nitrogen (SMN) (0 -90cm) was measured in October 2023. The results show that 'old drainage' (zone 2b) had the lowest SMN content at 30 kg N/ha; whilst SMN on the 'no drainage' (zone 2a) was highest at 75 kg N/ha; followed by 'new drainage' (zone 2c) at 65 kg N/ha, with no substantial differences between drain spacing (Figure 12). Overall, the differences between 'no drainage' and 'new drainage' were minimal at 10kg N/ha. Most notable, was the difference in the distribution of SMN, with *c.*60 kg N/ha located within the top 30cm for 'no drainage', which was double the amount compared to 'new drainage' (mean = *c.*30 kg N/ha).

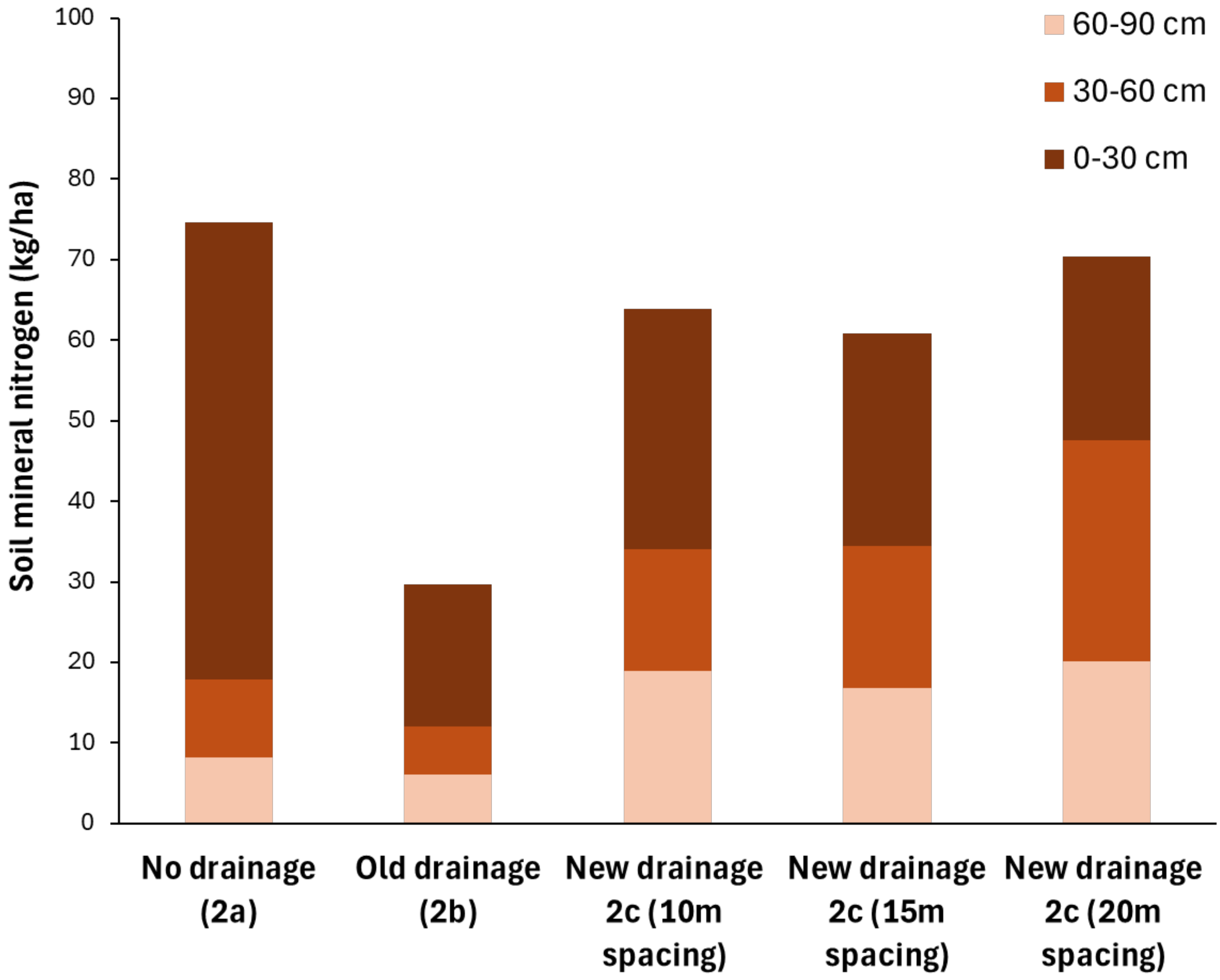


Figure 12. Soil mineral nitrogen (0-90cm), in 30cm increments, measured in October 2023, from the no drainage (zone 2a), old drainage (zone 2b) and new drainage (zone 2c) at 10m, 15m and 20m spacing

Soil mineral nitrogen (0-90cm) and above ground biomass was measured in March and February 2024, respectively. Consistent with the October results, SMN was greatest in the 'no drainage' zone (2a) at *c*.45 kg N/ha, followed by 'old drainage' (2b) and new drainage (2c) zones (all drain spacing combined) at *c*.35 kg N/ha and *c*.30 kg N/ha, respectively (Figure 13). On the 'no drainage' (2a) and 'old drainage' (2b) zones, more nitrogen was distributed in the top 30cms, at 22 kg N/ha and 24 kg N/ha, respectively, compared to 'new drainage' (2c) at 13 kg N/ha. This corresponds with crop N-uptake, which indicated slightly greater N-uptake on the 'new drainage' (at 6 kg N/ha); compared to both 'no drainage' and 'old drainage' zones at mean N-uptake of *c*.4 kg N/ha. However, it should be noted that the differences in crop N-uptake were marginal.

The autumn SMN measurements indicated a surplus of nitrogen on the 'no drainage' (2a) zone possibly suggesting, as shown by the HY 2023 yields, that N-fertiliser was not well utilised by the

2023 crop. It is not clear why autumn SMN on the 'old drainage' (2b) was low in the autumn, and why there was little difference compared to measurements taken in the spring. Furthermore, spring measurements indicated slightly improved N-uptake from the topsoil on the 'new drainage' (2c) zone.

As the trial continues and more autumn and spring SMN measurements taken, it will be possible to build-up a picture of whether the trend in SMN amount and distribution measured here, is typical, and a true reflection of the drainage treatments.

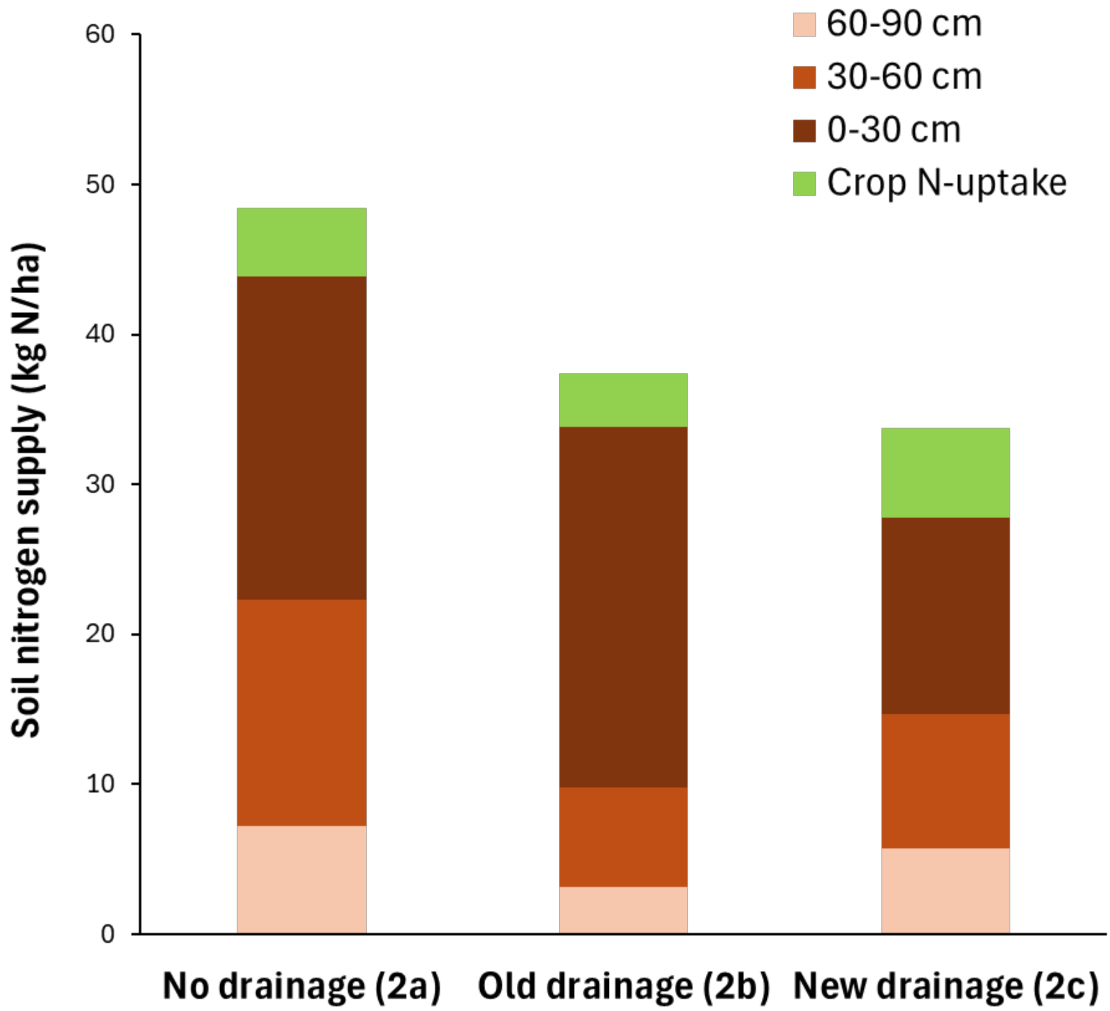


Figure 13. Soil mineral nitrogen (0-90cm) measured in March 2024, and above ground biomass nitrogen measured in February. from the no drainage (zone 2a), old drainage (zone 2b) and new drainage (zone 2c) at 10m, 15m and 20m spacing. Note: soil and crop samples were not taken at the same time, this was due to lab error in February which required repeat sampling and analysis of SMN

Plant Counts

Plant population was assessed at GS22 (Table 17) and the highest population was 252 plants/m^2 in the 'no drainage' (2a) and lowest in the 'old drainage' (2b) area at 231 plants/m^2.

Table 17. Plant population (m^2) assessed at GS22, 25 October 2023

Zone	Plant counts/m^2
No drainage (2a)	252
Old drainage (2b)	231
New drainage (2c)	233

Vegetation indices

NDVI – Normalised difference vegetation index can be a useful indicator of canopy cover and greenness of the crop.

NDRE – Normalised difference red edge can be a useful indicator to chlorophyll content and therefore crop nitrogen status especially later in the season when full canopy cover has been reached and NDVI becomes saturated.

At GS49, the 'no drainage' (2a) treatment had a lower NDVI (normalized difference vegetation index) value of 0.65 compared to the 'old drainage' (2b) and new drained treatment values of 0.71 (Table 18). The 'no drainage' (2b) value also had the lowest NDRE (normalized difference red edge) of 0.26, compared to the 'old drainage' (2b) value of 0.28, which was lower in turn compared to the 'new drainage' (2c) value of 0.29. At GS65 this pattern was still present, the 'no drainage' (2a) area had a lower NDVI value (0.49) compared to both the 'old drainage' (2b) and 'new drainage' (2c) areas (0.70). The 'old drainage' (2b) NDRE value was lowest at 0.20, compared to the 'old drainage' (2b) value at 0.28 which was lower than the 'new drainage' (2c) at 0.30.

Overall, these results indicate that the 'no drainage' (2a) and to a less extent the 'old drainage' (2b) areas had a lower green biomass compared to the new drained treatment.

Table 18. NDVI and NDRE at GS49 (30/05/2024P) and GS65 (19/06/2024)

	GS49		GS65	
Zone	NDVI	NDRE	NDVI	NDRE
No drainage (2a)	0.65	0.26	0.49	0.20
Old drainage (2b)	0.71	0.28	0.70	0.28
New drainage (2c)	0.71	0.29	0.70	0.30

Plant, Tiller and ear counts, biomass and leaf tissue analysis at GS67

At GS67 the plant population ranged from 83 plants/m^2 in the 'no drainage' (2a) area to 112 plant/m^2 in the 'old drainage' (2b) area (Table 3). The number of tillers/m^2 was lowest in the 'no drainage' (2a) area at 351/m^2 and highest in the 'old drainage' (2b) area at 440/m^2. These were lower than the 460/m^2 AHDB Benchmark for final shoot number. The count for ears/m^2 followed the same pattern. Crop biomass was 6.93 t/ha in the 'no drainage' (2a) area, which was 1.02 t/ha lower than the 'old drainage' (2b) area, which was in turn 1.02 t/ha lower than the crop in the 'new drainage' (2c) area.

Table 19. Plant, tiller and ear counts and crop biomass at GS67 (19/06/2024)

Zone	Plants/m^2	Tillers/m^2	Ears/m^2	Biomass t/ha
No drainage (2a)	83	351	347	6.93
Old drainage (2b)	112	440	432	7.95
New drainage (2c)	107	416	411	8.97

In summary, these results indicate that the crop in the 'no drainage' (2a) area was not developing and growing as well as the crop in the 'old drainage' (2b) and 'new drainage' (2c) areas. These results are consistent with the drainage field being waterlogged well into April (Figure 14). During a field visit in mid-April, it was observed that where drains were established in zones 2c and 1c, when looking out across the field the crop was best performing over the drains but looked stunted and yellow a short distance away. This indicated that lateral movement of water to the pipe drains was restricted.

Figure 14. Field conditions at the drainage trial Overton 5, photos taken on 17 April. Photo on left looks towards the 'old drainage' (2b) area and photo on right is taken within the 'new drainage' (2c). Note the greener crop growing directly above the pipe drains

Leaf tissue analysis at GS67

The leaf tissue analysis at GS67 (Table 20) showed that leaf tissue concentrations of N, P, K, Mg, S and Cu were all lowest in the 'old drainage' (2b) area compared to the old drained' (2b) and 'new drainage' (2c)areas. In general leaf tissue nutrient concentrations were higher in the 'old drainage' (2b) compared to the 'new drainage' (2c) treatment. Calcium (Ca) and Manganese (Mn) concentrations were highest in the 'old drainage' (2b) compared to the other two treatments.

Overall, the vast majority of these concentrations were low compared to historic cereal YEN Q1 tissue concentrations taken at flowering.

Table 20. Leaf Tissue nutrient analysis at GS67 (19/06/2024)

Zone	N	P	K	Ca	Mg	S	Mn	Cu
	%						mg/kg	
No drainage (2a)	0.91	0.08	1.03	0.21	0.06	0.11	41.8	1.8
Old drainage (2b)	1.25	0.13	1.32	0.19	0.09	0.13	26.4	2.9
New drainage (2c)	1.03	0.12	1.19	0.17	0.08	0.14	38.8	2.5

Crop disease assessments

Foliar, ear and stem disease was assessed in 'no drainage' (2a), 'old drainage' (2b) and 'new drainage' (2c) on the 12 July (Table 21, Table 22, Table 23). Foliar diseases septoria, brown rust and powdery mildew were present at low levels <10% severity as the field received a commercial fungicide programme. There were no clear differences in foliar disease or GLA between drainage treatments. Traces of glume blotch, fusarium ear blight and black sooty moulds were recorded on the ear but again did not show differences between treatments. Sharp and true eyespot were also recorded but at relatively low incidence and severity and showed no clear differences between treatments. There was however higher nodal and internodal fusarium incidence and severity in 'no drainage' (2a) than 'old drainage' (2b) and 'new drainage' (2c) which were similar. Given that there was no replication it is difficult to know whether this is a true effect.

Table 21. Percent leaf area infected with foliar disease and green leaf area remaining on the 12 July

Zone	Leaf 1-Septoria	Leaf 1-Brown rust	Leaf 1-Powdery mildew	Leaf 1-GLA	Leaf 2-Septoria	Leaf 2-Brown rust	Leaf 2-Powdery mildew	Leaf 2-GLA	Leaf 3-Septoria	Leaf 3-Brown rust	Leaf 3-Powdery mildew	Leaf 3-GLA
No drainage (2a)	4.78	0.07	0.00	63.04	6.55	0.15	0.00	57.26	7.48	0.58	0.00	22.40
Old drainage (2b)	4.74	0.51	0.01	70.42	7.01	1.13	0.04	59.80	8.04	0.77	0.00	22.26
New drainage (2c)	3.34	0.32	0.00	79.76	5.45	1.13	0.00	70.28	6.54	0.99	0.02	22.00

Table 22. Stem disease index (0-100) and incidence (%) on the 12 July.

Zone	Eyespot Incidence	Eyespot Index	Sharp Eyespot Incidence	Sharp eyespot Index	Nodal Fusarium Incidence	Nodal Fusarium Index	Internodal Fusarium Incidence	Internodal Fusarium Index
No drainage (2a)	4.00	1.33	12.00	6.00	46.00	19.33	44.00	16.00
Old drainage (2b)	6.00	2.00	16.00	8.67	8.00	2.67	16.00	6.00
New drainage (2c)	8.00	4.67	18.00	8.67	4.00	1.33	18.00	6.00

Table 23. Ear disease severity scores (average % of ear infected) on the 12 July

Zone	Glume blotch	Fusarium ear blight	Black (sooty) moulds
No drainage (2a)	0.03	0.53	0.02
Old drainage (2b)	0.21	0.58	0.00
New drainage (2c)	0.02	0.15	0.00

Crop assessment pre-harvest, GS91

The pre-harvest sample results were taken at GS91 (grain hard, difficult to divide; Table 8). The 'no drainage' (2a) area had 329 fertile shoots/m^2, which was less than the 'old drainage' (2b) (at 377/m^2) and the 'new drainage' (2a) (at 335/m^2). All zones were lower than the AHDB benchmark of 460 ears/m^2.

The crop in the 'old drainage' (2a) area had the highest biomass (at 13 t/ha) and the 'no drainage' (2b) area resulted in the lowest at 10.8 t/ha. The 'no drainage' (2a) area had the lowest number of grains/m^2 at 11,497, whilst the 'old drainage' (2b) area had the highest number of grains/m^2 (14,041) and the 'new drainage' (2c) area had 12,842 grains/m^2.

The 'new drainage' (2c) area resulted in the highest dry matter harvest index (DMHI) at 48 %, compared to a HI of 43.5% for the other two treatment areas. Thousand grain weight (TGW) was also highest in the 'new drainage' (2c) area at 52.5 g, the 'no drainage' (2a) and 'old drainage (2b) treatments resulted in TGW of 48g and 47.1g, respectively. Using the grain-N results (Table 24) the nitrogen harvest index (NHI) was calculated to be 72% in the 'new drainage (2c), 68% in the 'old drainage' (2b) and 58% in the 'no drainage' (2c) areas.

Table 24. Pre-harvest grab sample results at GS91 on 2nd August 2024

Zone	Fertile shoots/m^2	Total biomass t/ha	DMHI (%)	TGW at 15% moisture (g)	Grains/ear	Grains/m^2	NHI %
No drainage (2a)	329	10.8	43.5	48.0	40.9	11,497	58.1
Old drainage (2b)	377	13.0	43.5	47.1	37.3	14,041	67.7
New drainage (2c)	335	11.9	48.0	52.5	38.4	12,842	72.0

Grain nutrition results

The average grain nutrition results are summarised in (Table 25). The grain samples were entered into YEN nutrition, one per treatment and more detailed analysis and interpretation for these samples can be obtained from the YEN nutrition reports. All treatments resulted in grain nitrogen

(%) values below the YEN thresholds of concern values, which can indicate a potential deficiency. Additionally, the 'old drainage' (2b) soil zone resulted in a low grain Molybdenum (Mo) concentration compared to the YEN threshold of concern values. All other nutrients were above the YEN threshold of concern values. For all treatments, the level of grain N was substantially below the grain N% of 1.9% expected for an optimally fertiliser crop; the 'no drainage' (2b) area at 1.52% was therefore seriously under fertilised or unable to optimally access and utilise nitrogen compared to the drained areas, which resulted in crops with grain-N content 0.20 – 0.24% higher.

Table 25. Mean grain nutrition results, cells highlighted in yellow indicate those nutrients which are below YEN-low values (i.e. below 75% of all previous YEN results for winter wheat)

Zone	N	P	K	Mg	S	Ca	B	Cu	Fe	Mn	Mo	Zn	N:P	N:S
	%						mg/kg						ratio	
No drainage (2a)	1.52	0.40	0.73	0.19	0.12	0.04	1.2	5.6	54.3	40.2	0.31	37.7	3.80	12.7
Old drainage (2b)	1.76	0.42	0.79	0.12	0.12	0.04	1.34	6.3	50.8	42.7	0.22	39.7	4.19	14.7
New drainage (2c)	1.72	0.40	0.76	0.12	0.12	0.04	1.25	6.0	51.1	44.0	0.35	37.8	4.30	14.3

Soil moisture and rooting to depth

Gravimetric soil moisture (i.e. mass of water per unit of dry soil) in the top 20 cm measured on 28 August was 3% higher in the 'no drainage' zone (2a) than in the 'old drainage' (2b) zone and 5% greater than in 'new drainage' (2c) zone compared to 'new drainage' (at 18%) (Table 26). At 20 to 40 cm depth, 'no drainage' (2a) and 'old drainage' (2b) areas had the same gravimetric soil moisture content, at 22%, which was 3% higher than the 'new drainage' area (at 19%). Below 40cm soil depth, the differences between soil moisture in the soil zones was minimal at 1%.

Table 26. Gravimetric soil moisture (%) measured on the 28 August 2024

Soil depth	No drainage (2a)	Old drainage (2b)	New drainage (2c)
0-20 cm	23	20	18
20-40 cm	22	22	19
40-60 cm	20	20	19
60-80 cm	19	19	19
80-100 cm	19	18	19

The no drainage area was less well rooted to 1 m depth than both the old drainage and new drainage areas.

The new drainage and old drainage areas had a higher mean root length density (RLD; cm/cm^3) averaged over all soil depths of 0.60 and 0.66 (cm/cm^3) respectively compared to the no drainage area which had a mean RLD of 0.37 cm/cm^3. The overall lower RLD measured in the no drainage zone was largely driven by differences in RLD at both the 0-20 cm soil depth (which corresponded to a higher gravimetric soil moisture content compared to other treatments) and at 40-60 cm soil depth (Figure 6). Below 20cm depth, rooting was below the critical value of 1 cm/cm^3 to access available soil water, with little difference between treatments.

The RLD data corresponded to a greater root biomass in the new drainage and old drainage areas, over all soil depths with a mean of 0.034 mg/cm^3 and 0.039 mg/cm^3, respectively compared to the no drainage 0.024 mg/cm^3. (Table 11). The new drainage area had the widest average root diameter over all soil depths with a mean of 0.22 mm, which was wider than the average of 0.19 mm from roots in the old drainage area, and both were wider than that of the roots from the no drainage area, which had an average root diameter of 0.18 mm (Table 12).

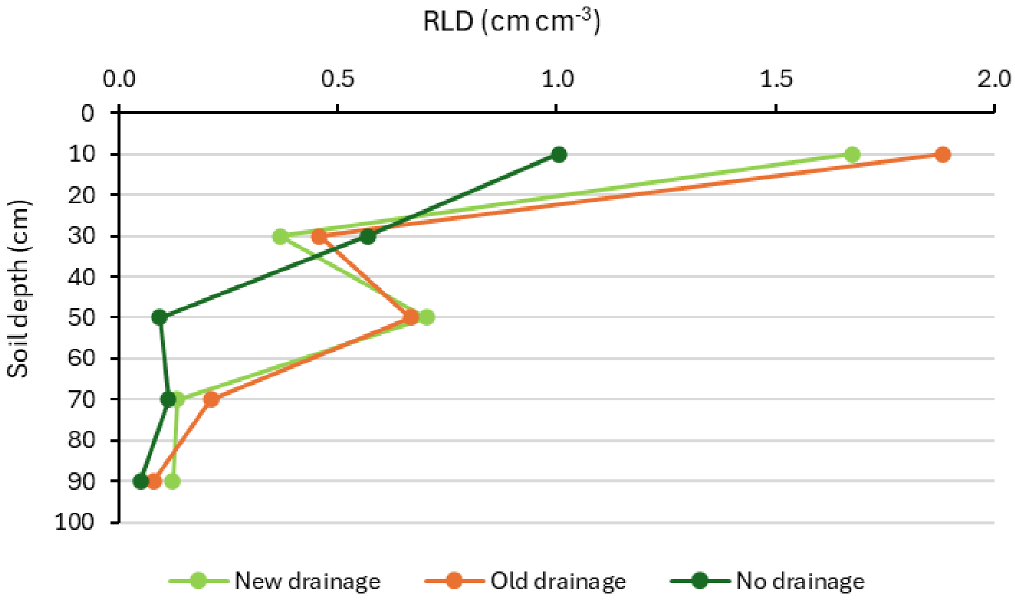


Figure 6: Root length density (cm cm3) measured from the new drainage, old drainage and no drainage zones within Overton 5.

Table 11: Root dry weight (mg/cm^3) measured from the new drainage, old drainage and no drainage zones within Overton 5

Root dry weight mg/cm^3				
Soil depth (cm)	**New drainage**	**No drainage**	**Old drainage**	**Mean**
0-20	0.106	0.089	0.129	0.108
20-40	0.021	0.024	0.019	0.021
40-60	0.032	0.002	0.029	0.021
60-80	0.007	0.001	0.013	0.007
80-100	0.005	0.004	0.004	0.005
Mean	0.034	0.024	0.039	0.032

Table 12: Root diameter (mm) measured from the new drainage, old drainage and no drainage zones within Overton 5

Root Diameter (mm)				
Soil depth (cm)	**New drainage**	**No drainage**	**Old drainage**	**Mean**
0-20	0.19	0.19	0.19	0.19
20-40	0.19	0.18	0.19	0.19
40-60	0.20	0.18	0.17	0.19
60-80	0.20	0.16	0.21	0.19
80-100	0.29	0.18	0.19	0.22
Mean	0.22	0.18	0.19	0.19

NDVI by satellite

NDVI (normalized difference vegetation index) is a spectral reflectance index which shows a combination of canopy size and greenness, on a scale from 0 to 1. NDVI images were sourced from www.datafarming.com.au, based on freely available 10m resolution data from the Sentinel 2 satellites. The scale varies between images but always runs from red (low) through orange, yellow and green to blue (high). The availability of imagery is constrained by the need for cloudless conditions.

Throughout the winter, there was trend across the field for higher NDVI at the southwest side (uphill, lighter soil) to lower NDVI at the northeast side (downhill, heavier soil), but there were no clear differences between drainage treatments. From the end of April, the ‘old drainage’ (2b) and ‘no drainage’ (2a) part of the field began to stand out as having lower NDVI (smaller crop) than the drained areas (Figure 15).

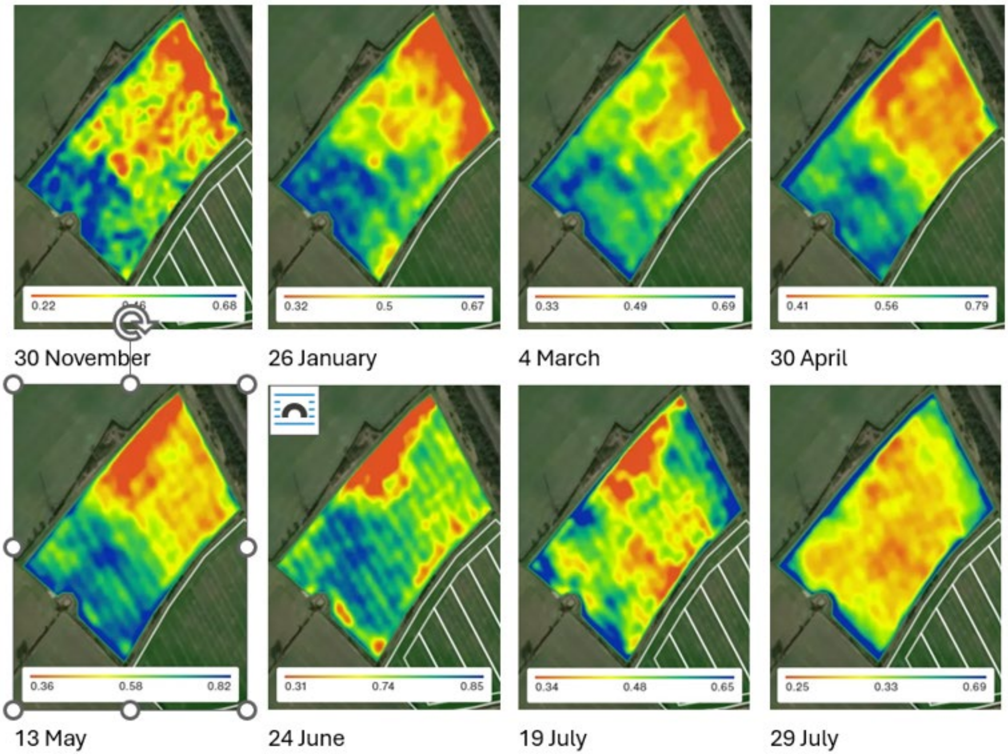


Figure 15. Normalized Difference Vegetation Index (NDVI) for Overton 5 from 30 November 2023 until 29 July 2024. Images sourced from www.datafarming.com.au.

Harvest

The yield data were analysed using the ADAS Agronomics approach. This cleans the data to remove headlands, anomalous combine runs (header not full or spanning two treatment areas), and locally extreme data points, and corrects any offset created by changes in combine direction. The original, raw data map before cleaning is shown below (Figure 16). A statistical model is used to account for underlying spatial variation along and across harvest rows and the effects of wheelings, before the analysis estimates the treatment effect and whether any differences are significant and impacted by treatment (i.e. drainage regime).

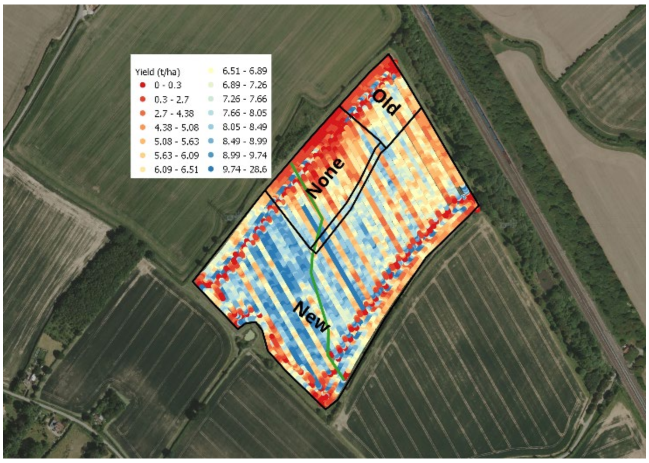


Figure 16. Winter wheat raw yield map for Overton 5. No tramline data or outliers removed, yield adjusted for 85% dry matter.

Data analysis by agronomics shows:

- Average yield, clay soil ‘new drainage’ (2c) was low at 6.72 t/ha. This is likely to be a little higher than the true field average due to exclusion of headlands from the analysis.
- ‘No drainage’ (2a) yielded 1.21 t/ha less (*P*<0.001) than ‘new drainage’ (2c)
- The ‘old drainage’ (2b) area is too small for Agronomics analysis but the map indicates yields were 0.13 t/ha lower than ‘new drainage’ (2c)
- There was a clear soil texture effect with average yields in clay loam ‘new drainage’ (1c) of 8.19 t/ha, compared to the heavier clay texture on ‘new drainage’ (2c) (mean yield = 1.5 t/ha) (Figure 17). This is consistent with NDVI imagery from the winter, which also showed a large effect of soil texture on crop growth.

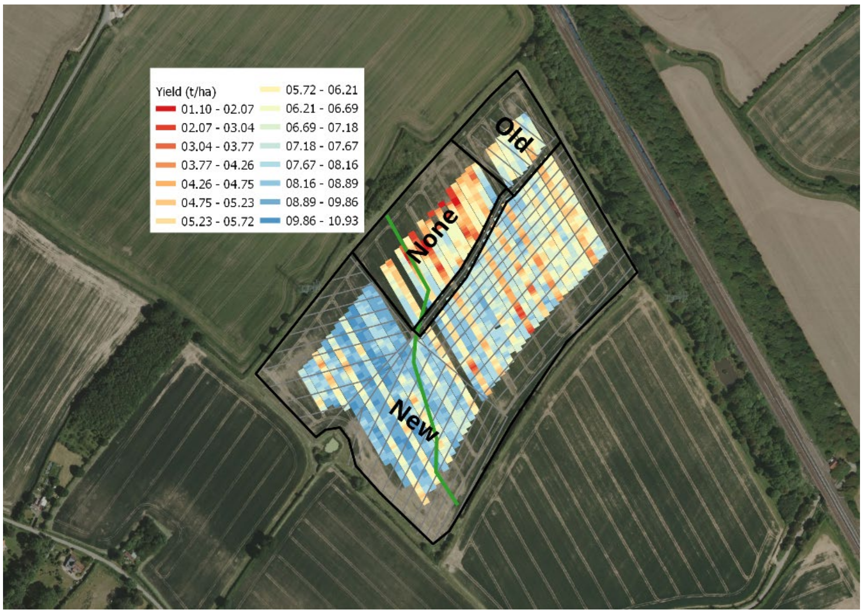


Figure 17. Winter Wheat yield map of Overton 5: The green line marks the approximate boundary between the two soil texture zones

It was not possible to accurately analyse the effects of drain spacing using Agronomics statistics, because the areas of each treatment are too small, but the cleaned yield map was split into areas with different drain spacing (10m, 15m and 20m) and the mean yield calculated for each area (Figure 18). There were no consistent differences between winter wheat yield and drain spacing.

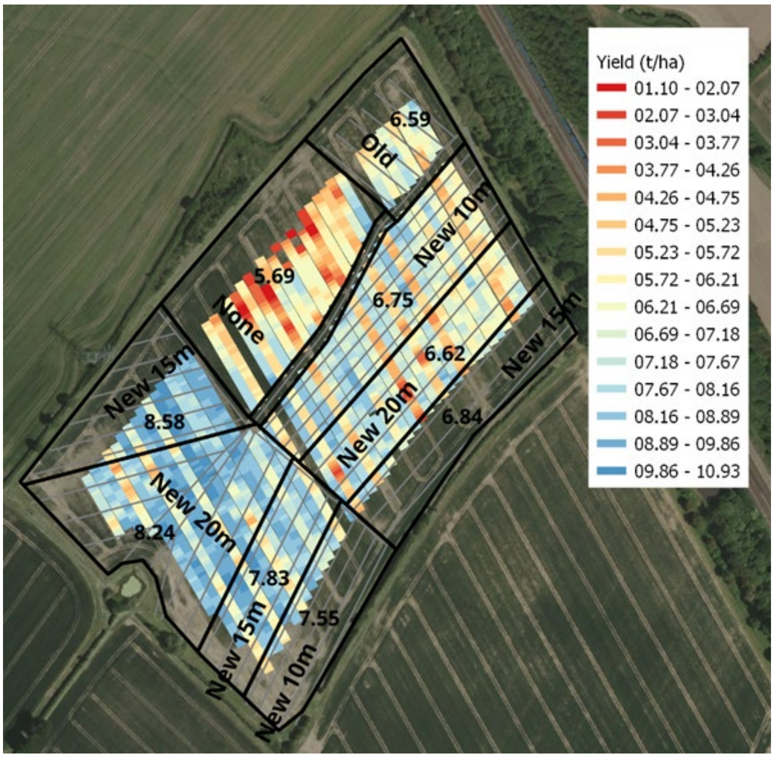


Figure 18. Winter wheat yield map of Overton 5: The numbers on the map refer to crop yield at 10m, 15m and 20m drain spacing

Next steps

The drainage trial will continue into harvest year 2025 and will assess soil nitrogen supply and crop performance. In autumn 2024, mole drains were added to two tramlines within the ‘new drainage’ (2c) zone, this is to help improve lateral movement of water to the pipe drains. Over-winter we are carrying out measurements to compare how effective different drain spacing with and without mole drains are at reducing water table height.

4.4. Action points for farmers and agronomists

It is important to assess fields to see if there is evidence of poor drainage, this may be obvious from the soil surface as surface ponding or saturated topsoils. Equally waterlogging below the surface may not be obvious at the surface but may be evident by poor crop yields. Refer to the AHDB Field Drainage Guide, on how to monitor and improve soil drainage.

Links to further information/references

- AHDB Field Drainage Guide https://ahdb.org.uk/drainage
- AHDB Growth guide for winter wheat https://ahdb.org.uk/knowledge-library/wheat-growth-guide