December 2023

Annual Project Report
(harvest 2023)

On-farm trials at
Strategic Cereal Farm Scotland

CONTENTS

1. Introduction

Host farmer: David Aglen

Location: Balbirnie Home Farms, Fife

Duration: 2020–2026

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. [Strategic Cereal Farms]

Reducing artificial inputs is a long-term goal for Strategic Cereal Farm Scotland.

2. Cover crops ahead of direct drilled spring barley (work packages 1 and 2)

Trial leader: Fiona Burnett

Start date: March 2023

End date: August 2023

2.1. Headlines

- As with the 2022 trials, sow date was a more significant driver of spring barley yield than cover crop
- All three sow dates were in April in 2023, which was later than in 2022 (because of the wet March in 2023)
- Autumn-established cover crop survival differed markedly between the two fields. In one it had largely disappeared by the spring. In the other, it remained so vigorous that it was hard to control, which negatively affected spring barley establishment
- One of the two spring barley crops ultimately failed due to a combination of difficulties in establishment and slug damage where cover crops were still well established at drilling
- There was a small yield advantage to the inclusion of cover crop for the first two sow dates in the surviving field
- However, a trend that retaining the cover crop until after drilling reduced yield in the later drilled plots was observed for a second season
- Retaining cover crops gave a trend to improve soil health and raise organic matter levels

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

Cover crops can help return nitrogen to the soil and protect soil from structural damage, reducing the risk of soil nutrients being lost through run-off and erosion.

In terms of integrated pest management (IPM), cover crops may attract beneficial insects that overwinter in the soil and supress weeds (through competing for space). However, there are also downsides, as cover crops can become a home for pests, such as slugs, and may act as a “green bridge”, carrying pests over from the previous season.

The purpose of this trial is to quantify the benefits of establishing a cover crop prior to direct drilling spring barley, and to see whether benefits translate into opportunities to reduce inputs in the cash crop.

2.3. How did the project address this?

Trial design

A replicated field trial was established on two fields (Table 1) at Strategic Cereal Farm Scotland.

Table 1. Fields included in cover crop trial

Field Name	Area (ha)	Previous crop (2022)
Tile Park	12.6	Spring barley (direct drilled)
Bottom Boiler/Strip	16.0	Spring barley (direct drilled)

The trial explored the impact of the establishment and management of cover crops on crop biomass, crop yield and soil health. It used a similar trial design to 2022, so that a second season of data could be gathered.

Three cover crop treatments were established following the previous crop. The cover crop consisted of forage rye, peas and beans. The treatments were:

1) No cover crop (0)
2) Cover crop sprayed 2 days after drilling of spring barley (A)
3) Cover crop sprayed 5 days before drilling of spring barley (B)

A fourth treatment (in the 2023 season) investigated the effects of grazing off the cover crop. However, it was abandoned after time to move the sheep to the fields prior to drilling the spring crop ran out.

Drilling dates were:

1) Drill date 1 – Standard local practice (3 April 2023)
2) Drill date 2 – Delayed (17 April 2023)
3) Drill date 3 – Very delayed (30 April 2023)

In each field, the three treatments were replicated twice in a split-field design, giving a total of four replicates per treatment at the farm level. Plot sizes were multiples of 36 m widths x 70 m, to fit with spray widths. Layout and randomisation differed between fields (shown in Tables 2 and 3).

Table 2. Randomisation and treatments in Tile Park field

1 No cover crop Drill date 1	2 SB drilled into standing cover crop Drill date 1	3 Cover crop sprayed off Drill date 1
4 Cover crop sprayed off Drill date 1	5 No cover crop Drill date 1	6 SB drilled into standing cover crop Drill date 1
7 Cover crop sprayed off Drill date 2	8 SB drilled into standing cover crop Drill date 2	9 No cover crop Drill date 2
10 No cover crop Drill date 2	11 Cover crop sprayed off Drill date 2	12 SB drilled into standing cover crop Drill date 2
13 No cover crop Drill date 3	14 SB drilled into standing cover crop Drill date 3	15 Cover crop sprayed off Drill date 3
16 Cover crop sprayed off Drill date 3	17 No cover crop Drill date 3	18 SB drilled into standing cover crop Drill date 3

Table 3. Randomisation and treatments in Bottom Boiler/Strip fields

1 No cover crop Drill date 1	2 SB drilled into standing cover crop Drill date 1	3 Cover crop sprayed off Drill date 1
4 Cover crop sprayed off Drill date 1	5 No cover crop Drill date 1	6 SB drilled into standing cover crop Drill date 1
7 Cover crop sprayed off Drill date 2	8 SB drilled into standing cover crop Drill date 2	9 No cover crop Drill date 2
10 No cover crop Drill date 2	11 Cover crop sprayed off Drill date 2	12 SB drilled into standing cover crop Drill date 2
13 Cover crop sprayed off Drill date 3	14 SB drilled into standing cover crop Drill date 3	15 No cover crop Drill date 3
16 No cover crop Drill date 3	17 Cover crop sprayed off Drill date 3	18 SB drilled into standing cover crop Drill date 3

Surveying was conducted during establishment of the following spring barley crop. Two sets of assessments are set out in the results section:

1. Crop establishment, disease and yield counts
2. Soil health measures

2.4. Results (to date)

Crop establishment, disease and yield counts

The off-combine yield map from Tile Park field (Figure 1) shows that the earlier drilled plots at the bottom of the field are visibly higher yielding. There is no effect from cover crop management at this stage.

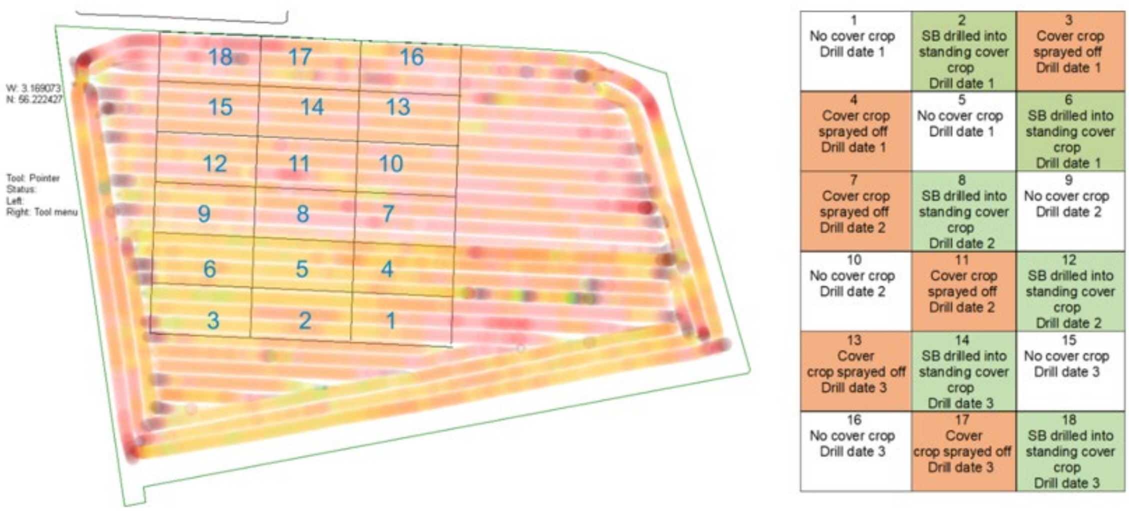


Figure 1. Yield map and treatment layout for Tile Park field (harvest 2023)

Bottom Boiler/Strip field failed to establish well and had to be abandoned and re-drilled in May 2023, so only data prior to this management decision could be gathered.

The cover crop in Tile Park Field established well in the autumn but had largely vanished by the end of March 2023 (Figure 2) from the marked-out plots before barley was drilled.

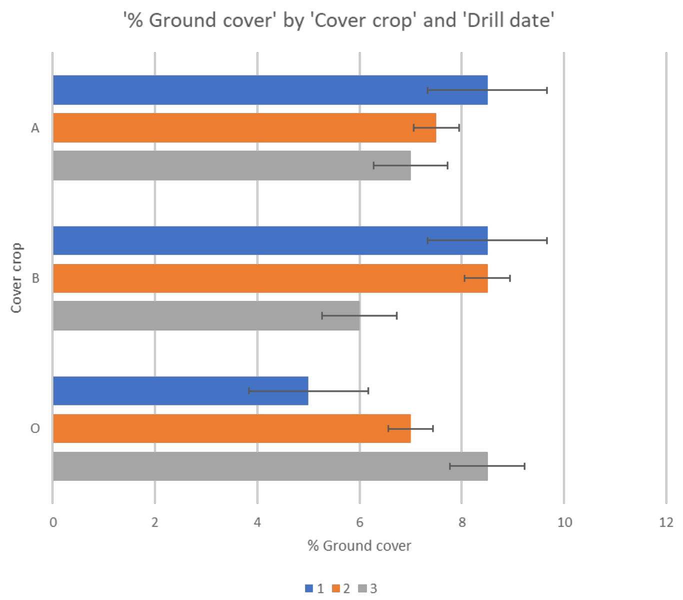


Figure 2. Tile Park 25 March 2023. Cover crop ground cover (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203).

In contrast to Tile Park, the cover crop was still well established in Bottom Boiler/Strip (Figure 3). This heavy ground cover was harder to burn off with glyphosate and so spring barley establishment was harder and slug damage was intensive.

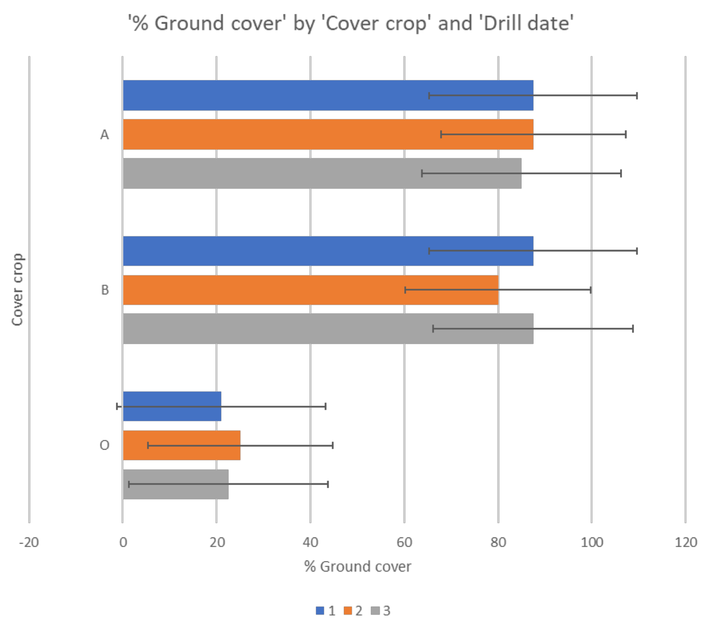


Figure 3. Bottom Boiler/Strip 25 March 2023. Cover crop ground cover (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

Early assessments show the crop emergence was broadly similar in both fields (Figures 4 and 5) for the early and second drilled treatments. This assessment was made a few days before the final sow date treatment on the 30 April.

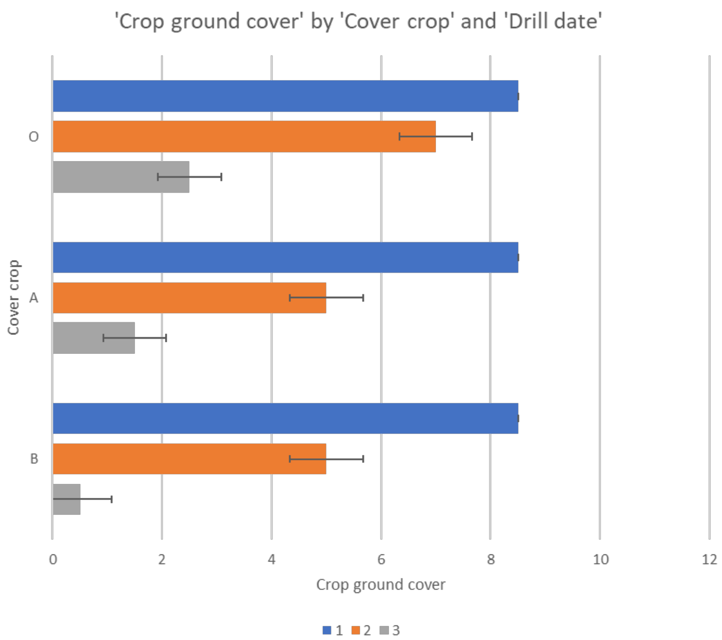


Figure 4. Tile Park spring barley % ground cover 25 April 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

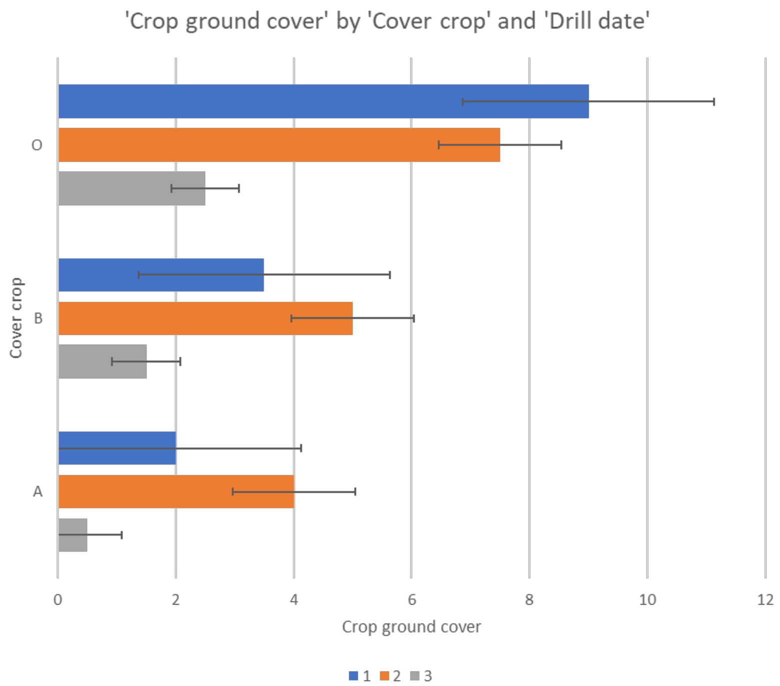


Figure 5. Bottom Boiler/Strip spring barley ground cover % 25 April 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203).

By mid-May, the early sow date was establishing well in Tile Park field (Figure 6) and was better in the plots with no cover crop. The later sow date has lower plant counts in the plots where the cover crop was burned off after spring barley drilling, which is similar to results from the previous year.

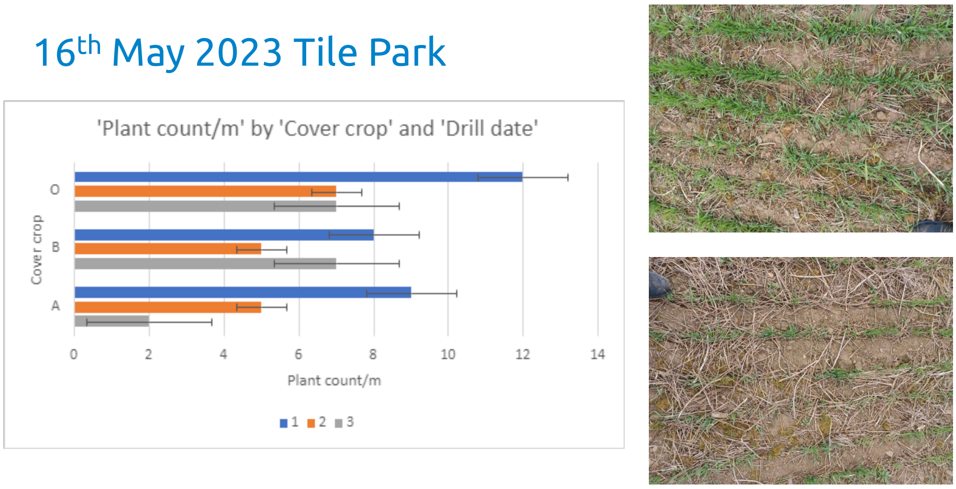


Figure 6. Tile Park plant counts per meter 16 May 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

Spring barley emergence in Bottom Boiler/Strip (Figure 7) for the early drilled no cover crop treatments was similar to that in the Tile Park Field, although it is starting to become evident at this timing that the crop in the plots with vigorous cover crop was beginning to struggle. It is particularly evident in the late-drilled treatments where the cover crop was only treated after crop drilling.

Figure 7. Bottom Boiler/Strip plant counts per meter 16 May 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

The plant counts taken in Tile Park at the start of June (Figure 8) show that plant counts from the different drilling dates were broadly similar and the crop was growing well at this stage. There was very little influence from the cover crop management options. However, plant counts were slightly lower in the second two drilling dates where the cover crop (such as it was) was burned off prior to drilling but they are not statistically different to the comparable drilling dates where the glyphosate was applied after drilling. Plant counts tended to be higher in the no cover crop plots.

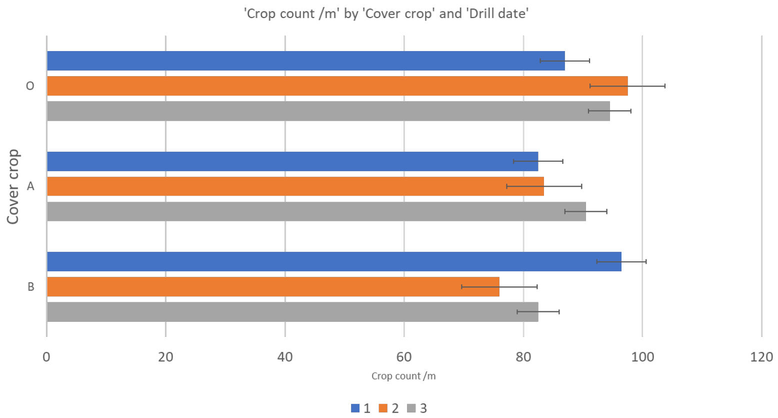


Figure 8. Tile Park Field spring barley plant counts per meter 5 June 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

In contrast, the crop in Bottom Boiler/Strip had gone backwards, even where there had been no cover crop. Plant counts were low (Figure 9).

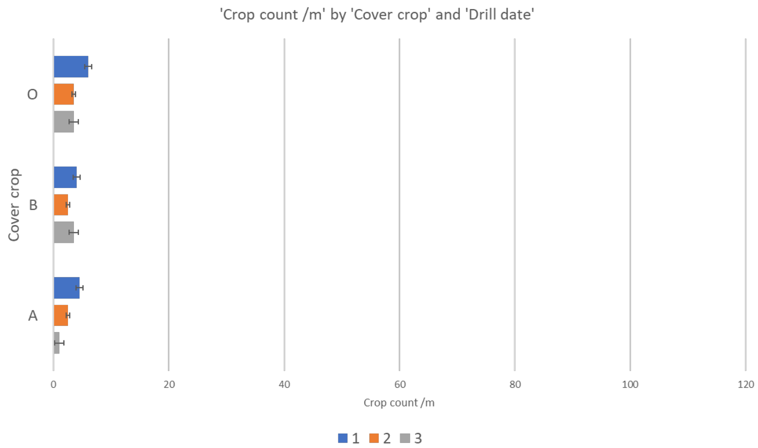


Figure 9. Bottom Boiler/Strip field spring barley plant counts per meter 5 June 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

Slug damage was evident and establishment in the two cover crop management options had always been poor. At this point, a decision was made by the farm to re-drill the crop and the plant assessments were ceased.

The ears were emerging in all drilling dates at the start of July (Figure 10), although there was a trend for the latest drilled option to be slightly behind this was not significant and there was no effect on growth stage and cover crop management option. There were traces of rhynchosporium in the crop but below 1% of plants and single lesions only where noted.

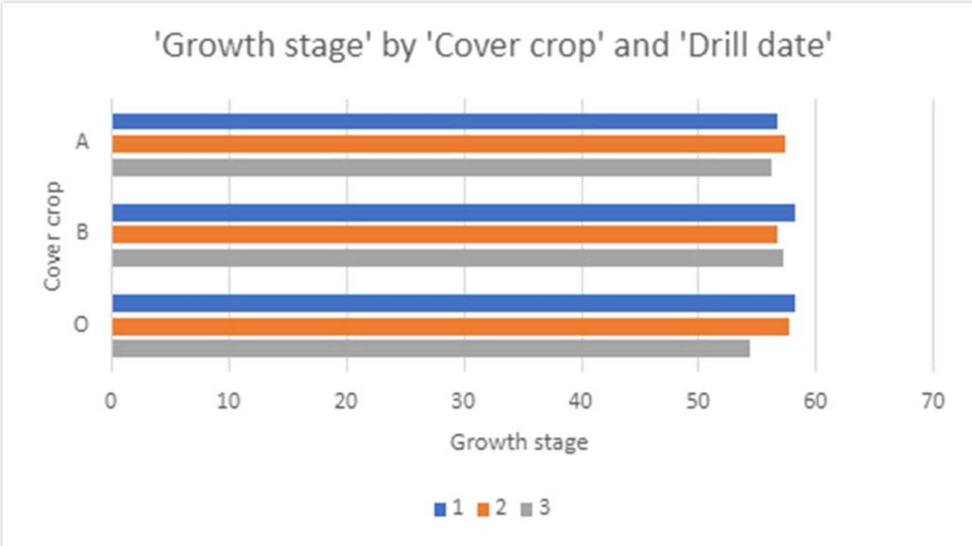


Figure 10. Tile Park Field spring barley growth stage 6 July 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

Plant counts were good in all treatments by the start of July (Figure 11). They were variable and it was hard to discern any strong trends. In the no cover crop management option, the plant counts were highest for the second drilling date and lowest for the latest drilling date but this trend was not evident in the other two management options.

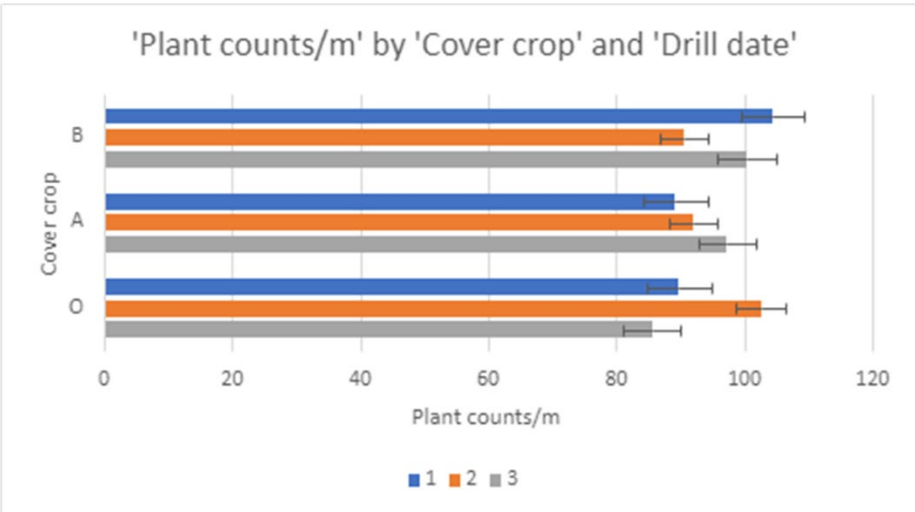


Figure 11. Tile Park Field spring barley plant counts per meter 6 July 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203).

By late July, the spring barley crop was starting to ripen and there were differences in growth stage evident between the drilling date treatments, with the earliest drilling date ripening and the later two treatments still at grain filling (Figure 12).

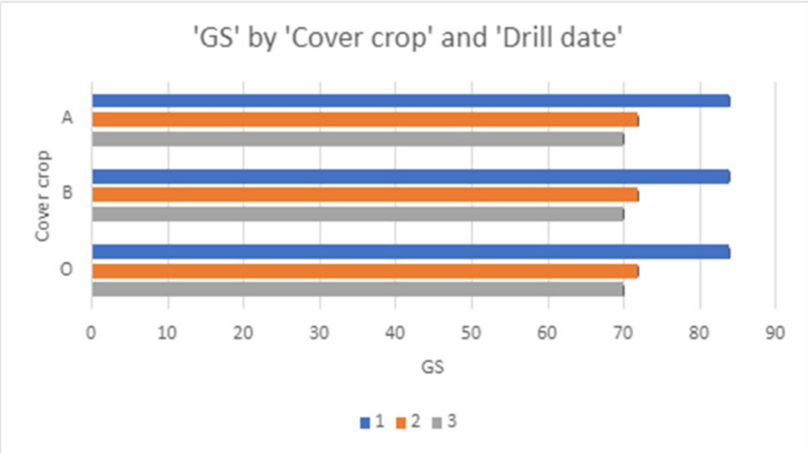


Figure 12. Tile Park Field spring barley plant growth stages 25 July 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

Plant counts were good in all plots with no strong difference between drilling date options. There was a trend for the plant counts to be lower in the no cover crop plots (Figure 13).

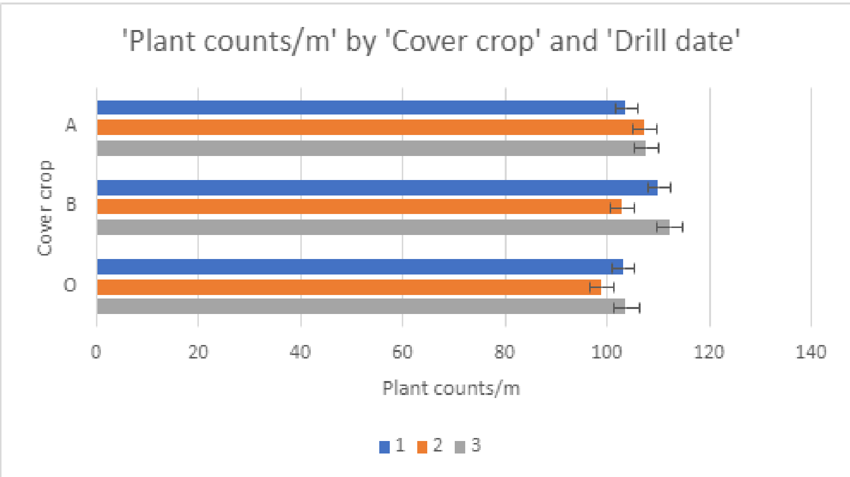


Figure 13. Tile Park Field spring barley plant counts per meter 25 July 2023 (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

The earliest drilling date was significantly higher yielding that the second or third drilling dates (Figure 14).

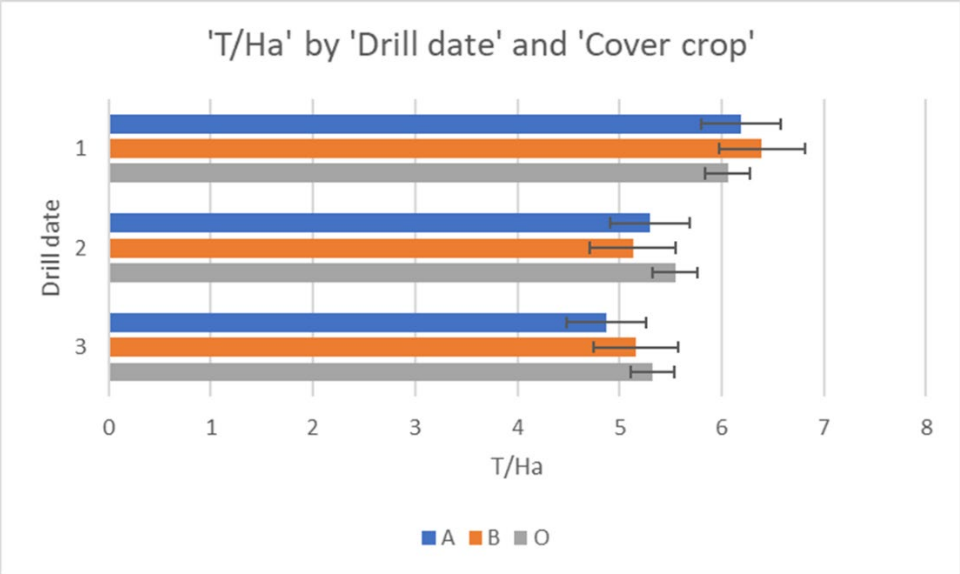


Figure 14. Tile Park Field Yield t/ha (0 = no cover crop treatment, B = burned off before crop drilling, A = burned off after crop drilling; 1 = drill date 03.04.2023, 2 = drill date 17.04.2023, 3 = drill date 30.04.0203)

There was no significant effect from cover crop management options. However, there was a trend that the latest drilled plots were lower yielding where cover crops were retained until after drilling (A). This was also observed in 2022.

Soil analysis

Tile Park field was used in a spring barley/cover crop experiment during the previous growing season (2022). The two experiments are in different locations on the farm with a sandy clay loam (Tile Park) and a sandy loam (Bottom Boiler/Strip).

Comparison between sites

In relation to the soil structure, as assessed through the VESS system, the greater mean score (although not aways statistically significant) was for Bottom Boiler/Strip for the no cover crop ($p<0.05$) and cover crop sprayed off ($p<0.002$) treatments (Figure 15). An increased score shows greater structural damage to the soil profile down to about 20 cm.

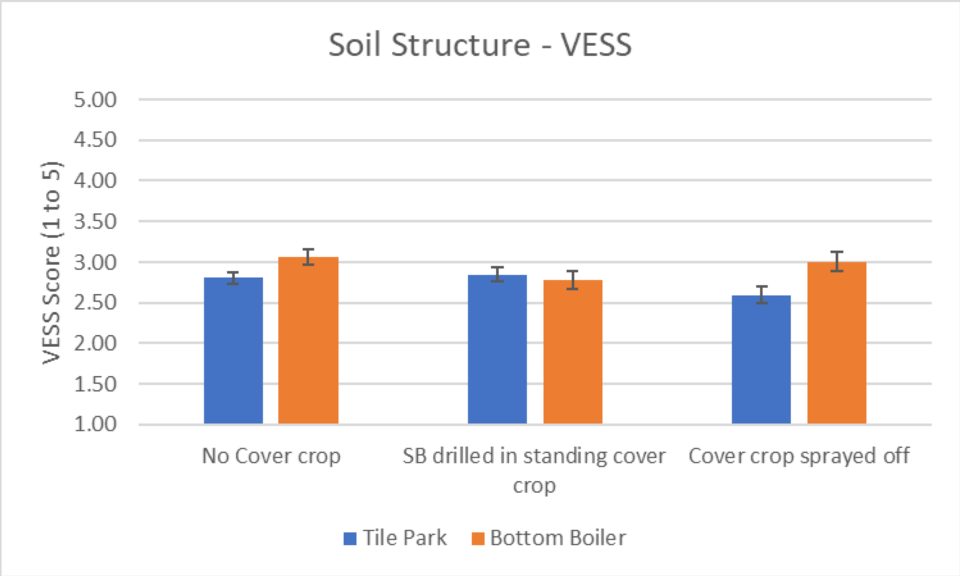


Figure 15. Mean soil structure assessment – VESS (Score 1 to 5) at the two sites, Tile Park and Bottom Boiler/Strip – for the main treatments

When the further mean of the treatments of drilling date was considered, again Bottom Boiler generally gave the greater VESS score, although this was only significant for the spring barley drilling in standing crop 1st drill (*p<0.002*) and spring barley drilling in standing crop 3rd dill (*p<0.01*) (Table 4).

Table 4. Mean VESS scores for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	2.71	3.18	n/s
No cover crop 2nd drill	2.87	2.92	n/s
No cover crop 3rd drill	2.83	3.10	n/s
SB drilled in standing cover crop 1st drill	3.07	2.48	*p<0.002*
SB drilled in standing cover crop 2nd drill	2.86	2.78	n/s
SB drilled in standing cover crop 3rd drill	2.62	3.08	*p<0.01*
Cover crop sprayed off 1st drill	2.74	2.81	n/s
Cover crop sprayed off 2nd drill	2.57	3.27	n/s
Cover crop sprayed off 3rd drill	2.46	2.94	n/s

Soil nutrients

The mean values for phosphorous (P), available potassium (K), magnesium (Mg), calcium (Ca) and soil pH gave varied results.

Soil pH

The soil pH was always greater at the Bottom Boiler site than Tile Park for the main treatments and was significantly greater for SB drilled in standing cover crop (*p<0.02*) (Figure 16).

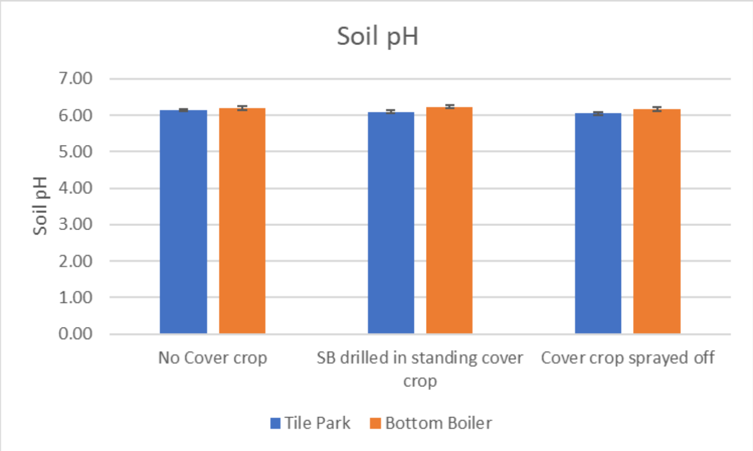


Figure 16. Mean Soil pH at the two sites for the main treatments.

The further treatments also generally gave a higher value for soil pH for Bottom Boiler than Tile Park but only the cover crop sprayed off 2nd drill was this significant (p<0.04) (See Table 5).

Table 5. Mean soil pH for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	6.12	6.28	n/s
No cover crop 2nd drill	6.13	6.02	n/s
No cover crop 3rd drill	6.15	6.25	n/s
SB drilled in standing cover crop 1st drill	6.13	6.25	n/s
SB drilled in standing cover crop 2nd drill	6.12	6.25	n/s
SB drilled in standing cover crop 3rd drill	6.03	6.20	n/s
Cover crop sprayed off 1st drill	6.00	6.27	n/s
Cover crop sprayed off 2nd drill	6.03	6.22	*p<0.04*
Cover crop sprayed off 3rd drill	6.10	6.02	n/s

However, the soil pH was below the optimum recommended value of pH 6.4 for all the treatments and sub-treatments at both the sites, with Tile Park generally requiring a greater application of lime.

Available phosphorous (P)

The mean P levels of the two sites were statistically similar but there were consistently greater concentrations of P in the soils of Bottom Boiler (Figure 17).

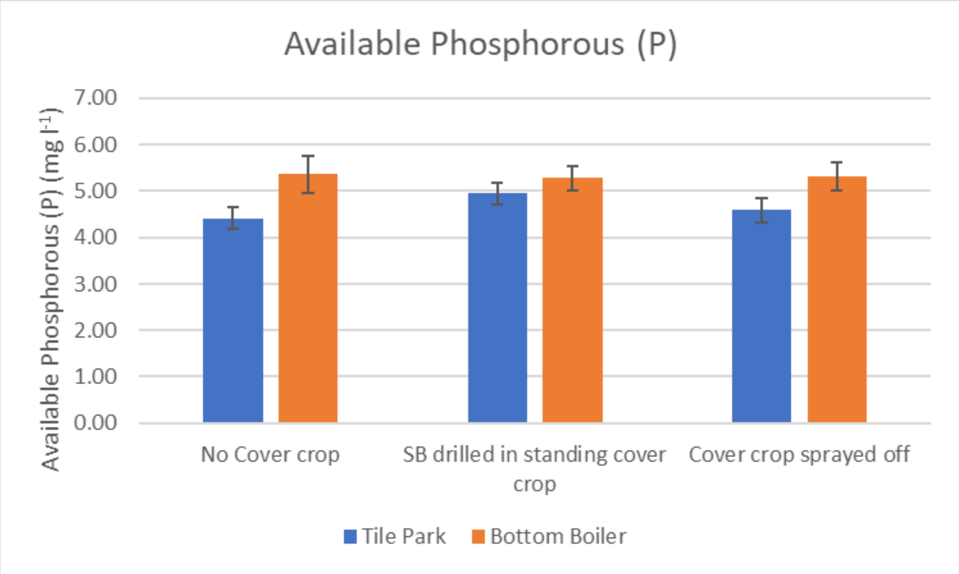


Figure 17. Mean Available P (mg l^{-1}) at the two sites for the main treatments

Considering the further treatments of drill date, again Bottom Boiler has the greater concentration in the soil although none of these were statistically significant (Table 6).

Table 6. Mean Available Phosphorous (P) (mg l^{-1}) for the drill dates for no cover crop, SB drilled in standing cover crop and xover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	4.65	4.32	n/s
No cover crop 2nd drill	4.51	6.10	n/s
No cover crop 3rd drill	4.10	5.65	n/s
SB drilled in standing cover crop 1st drill	5.52	5.04	n/s
SB drilled in standing cover crop 2nd drill	5.03	5.40	n/s
SB drilled in standing cover crop 3rd drill	4.30	5.39	n/s
Cover crop sprayed off 1st drill	5.20	4.58	n/s
Cover crop sprayed off 2nd drill	4.37	5.49	n/s
Cover crop sprayed off 3rd drill	4.21	5.90	n/s

Available potassium (K)

The concentrations of soil available potassium (K) contrasted with available P, with the Tile Park site that giving the greater values. These were statistically significant for all the treatments with the greatest significance for the cover crop sprayed off (*$p<0.01$*) (Figure 18).

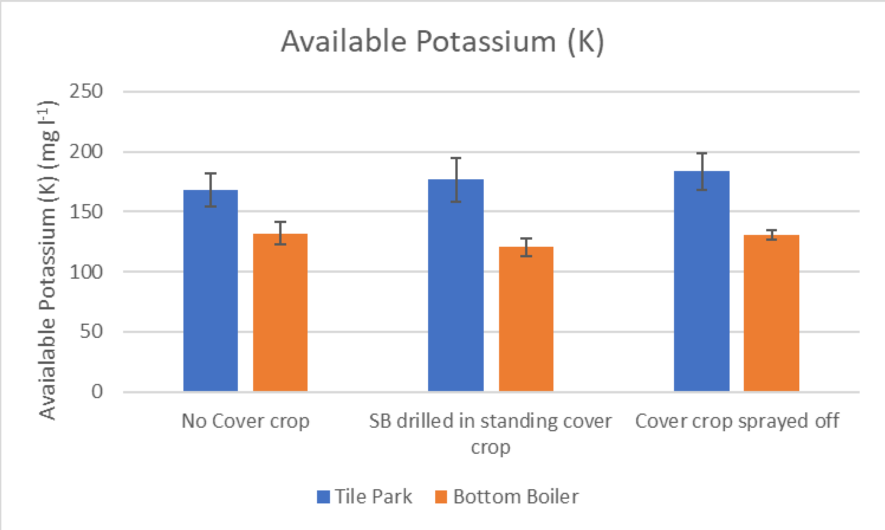


Figure 18. Mean Available K (mg l^{-1}) at the two sites for the main treatments

In considering the further sub-treatments, again the greater available K concentrations were for the Tile Park site with four treatments associated with significant differences (Table 7).

Table 7. Mean available potassium (K) (mg l^{-1}) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	138.07	113.28	*$p<0.02$*
No cover crop 2nd drill	163.62	156.88	n/s
No cover crop 3rd drill	201.95	125.98	n/s
SB drilled in standing cover crop 1st drill	140.93	111.76	n/s
SB drilled in standing cover crop 2nd drill	160.32	133.90	n/s
SB drilled in standing cover crop 3rd drill	228.17	115.45	*$p<0.04$*
Cover crop sprayed off 1st drill	143.12	119.58	n/s
Cover crop sprayed off 2nd drill	186.80	134.53	*$p<0.02$*
Cover crop sprayed off 3rd drill	220.80	137.18	*$p<0.05$*

Soil magnesium (Mg)

For this nutrient, it was the Bottom Boiler site again that had a greater concentration of soil Mg compared to the Tile Park site. This was significant for SB drilled in standing crop ($p<0.02$) and cover crop sprayed off ($p<0.01$).

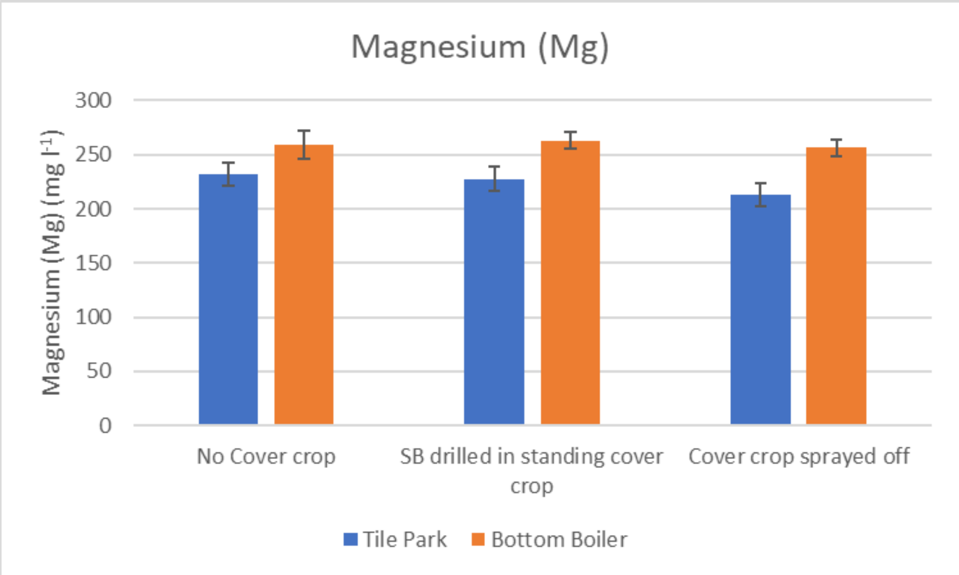


Figure 19. Mean soil magnesium (Mg) (mg l^{-1}) at the two sites for the main treatments

This pattern continued with the sub-treatments, again with Bottom Boiler having a greater concentration of Mg. However, only the no cover crop 3rd drill was statistically significant ($p<0.05$).

Table 8. Mean magnesium (Mg) (mg l^{-1}) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	255.23	291.28	n/s
No cover crop 2nd drill	233.22	231.87	n/s
No cover crop 3rd drill	208.83	252.87	$p<0.05$
SB drilled in standing cover crop 1st drill	250.37	274.58	n/s
SB drilled in standing cover crop 2nd drill	238.08	267.13	n/s
SB drilled in standing cover crop 3rd drill	194.50	247.65	n/s
Cover crop sprayed off 1st drill	239.38	269.68	n/s
Cover crop sprayed off 2nd drill	211.97	257.63	n/s
Cover crop sprayed off 3rd drill	188.30	242.37	n/s

Calcium (Ca)

There was a clear statistical difference between the greater soil calcium in the Tile Park site than the Bottom Boiler site for all the main treatments ($p<0.001$) (Figure 20). It is interesting that the soil pH values were much closer for the two sites but there were greater differences for the soil calcium content and it was Tile Park that had the lower pH values compared to Bottom Boiler.

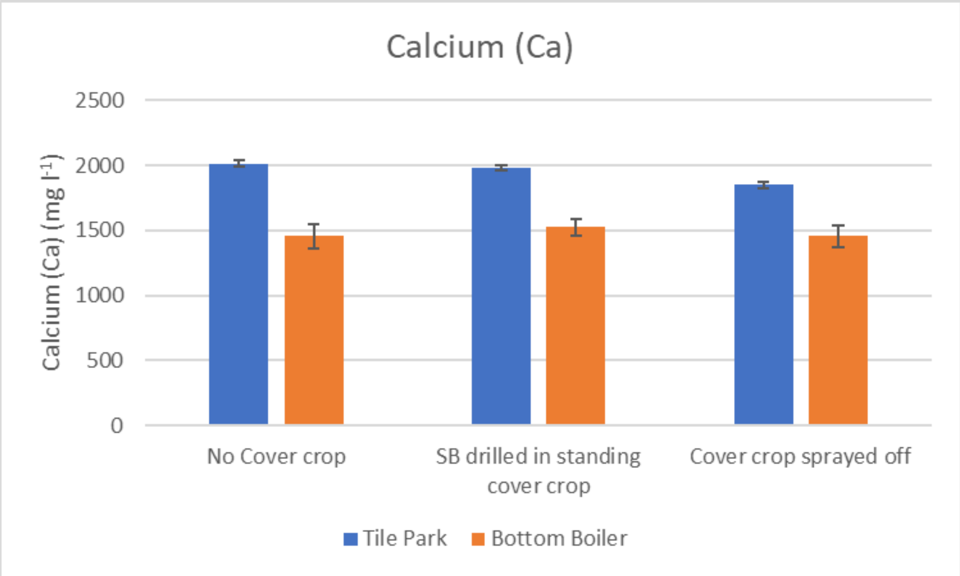


Figure 20. Mean soil calcium (Ca) (mg l^{-1}) at the two sites for the main treatments

When considering the sub-treatments, it was the Tile Park that had the greater concentration of Ca (Table 9). However, only one of these was statically significant: no cover crop 3rd drill ($p<0.05$).

Table 9. Mean Calcium (Ca) (mg l^{-1}) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	1966.67	1683.33	n/s
No cover crop 2nd drill	2000.00	1376.67	n/s
No cover crop 3rd drill	2066.67	1300.00	*p<0.05*
SB drilled in standing cover crop 1st drill	1983.33	1566.67	n/s
SB drilled in standing cover crop 2nd drill	2016.67	1616.67	n/s
SB drilled in standing cover crop 3rd drill	1933.33	1383.34	n/s
Cover crop sprayed off 1st drill	1816.67	1633.33	n/s
Cover crop sprayed off 2nd drill	1883.33	1466.67	n/s
Cover crop sprayed off 3rd drill	1850.00	1266.67	n/s

Soil organic matter

The soil organic matter (SOM) was always greater in the Tile Park site (Figure 21). These were highly statistically significant for all the treatments ($p<0.001$), including the no cover crop. The sprayed off cover crop gave the greatest difference (2.02 %). This could be due to increased inputs of organic matter (manure or crop resides) over a greater period. Additionally, if the reduced tillage system had been used at this field for longer, it could also help account for the increased SOM.

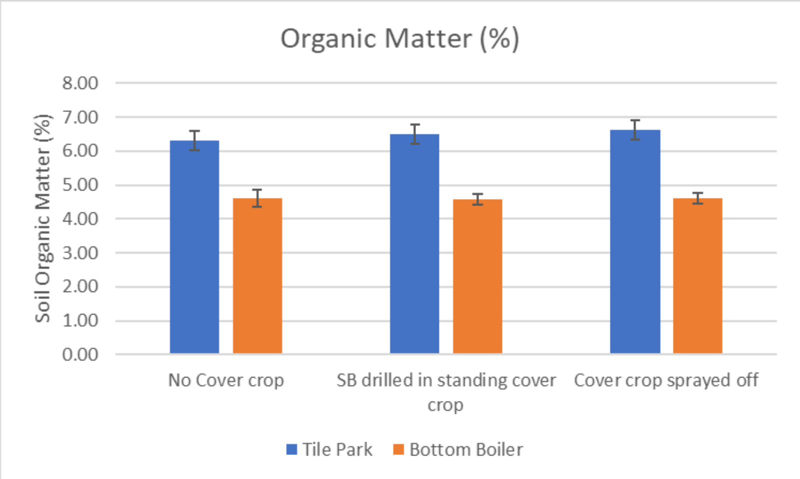


Figure 21. Mean soil organic matter (%) (mg l^{-1}) at the two sites for the main treatments

The sub-treatments also gave the greater concentration of SOM for the Tile Park site, with most of the comparisons being statistically different (Table 10). It was the SB drilled in standing cover crop 3rd drill sub-treatment that gave the greatest difference between the sites (3.19 %).

Table 10. Mean soil organic matter (%) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	5.61	5.22	n/s
No cover crop 2nd drill	6.45	4.40	n/s
No cover crop 3rd drill	6.88	4.22	*p<0.03*
SB drilled in standing cover crop 1st drill	5.87	4.78	*p<0.03*
SB drilled in standing cover crop 2nd drill	6.22	4.76	*p<0.04*
SB drilled in standing cover crop 3rd drill	7.41	4.22	*p<0.01*
Cover crop sprayed off 1st drill	5.78	4.81	n/s
Cover crop sprayed off 2nd drill	6.81	4.80	*p<0.02*
Cover crop sprayed off 3rd drill	7.32	4.24	*p<0.004*

Soil moisture (GWC)

The Tile Park site retained most soil moisture for all the treatments (Figure 22). This could have been a difference in the soil texture (however, they were similar). The increased SOM in the Tile Park site could also have contributed to the increased moisture. This would have been an advantage in the second and third soil samplings (April and May), as the soil had become drier.

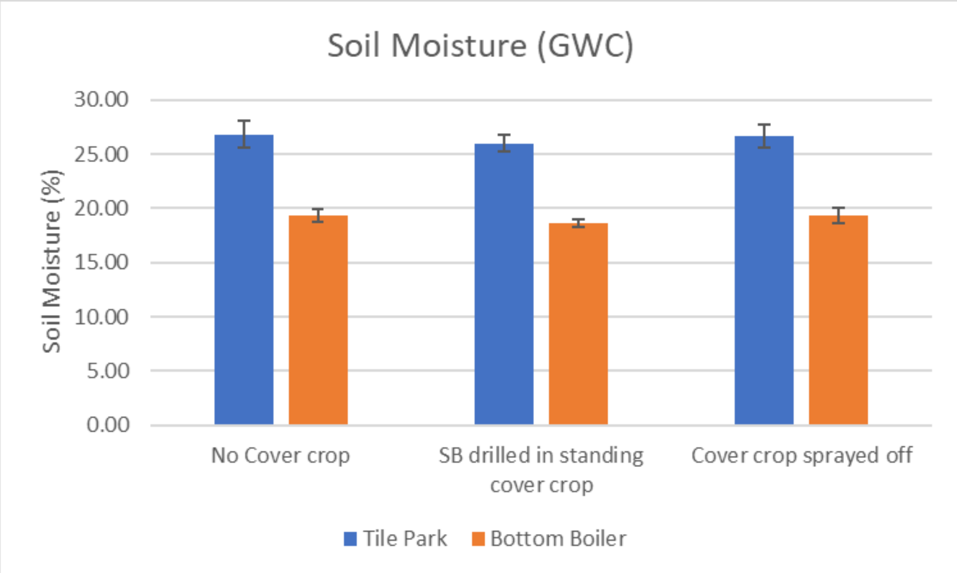


Figure 22. Mean soil moisture (GWC) (mg l^{-1}) at the two sites for the main treatments

The sub-treatments also gave the greater soil moisture for Tile Park compare to Bottom Boiler (Table 11), with many of them being statistically significant. This was especially true of the SB drilled in standing cover crop (all drilling dates), as these were the most highly significant.

Table 11. Mean soil moisture (%) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	23.83	20.87	*p<0.05*
No cover crop 2nd drill	27.33	18.13	n/s
No cover crop 3rd drill	29.31	19.01	*p<0.01*
SB drilled in standing cover crop 1st drill	24.49	19.65	*p<0.003*
SB drilled in standing cover crop 2nd drill	25.08	18.20	*p<0.004*
SB drilled in standing cover crop 3rd drill	28.35	17.98	*p<0.001*
Cover crop sprayed off 1st drill	24.21	20.21	n/s
Cover crop sprayed off 2nd drill	26.46	20.32	*p<0.02*
Cover crop sprayed off 3rd drill	29.26	17.49	*p<0.02*

Potentially Mineralisable Nitrogen (PMN)

PMN is a measure of the nitrogen that can be provided from the soil organic matter. However, this measure did not follow the pattern of the SOM closely, with significantly greater levels in the Tile Park site. The pattern was more mixed, with only the SB drilled in standing cover crop and cover crop sprayed off showing greater PMN in the Tile Park site and only the SB drilled in standing cover crop being statistically significantly greater ($p<0.03$) (Figure 23).

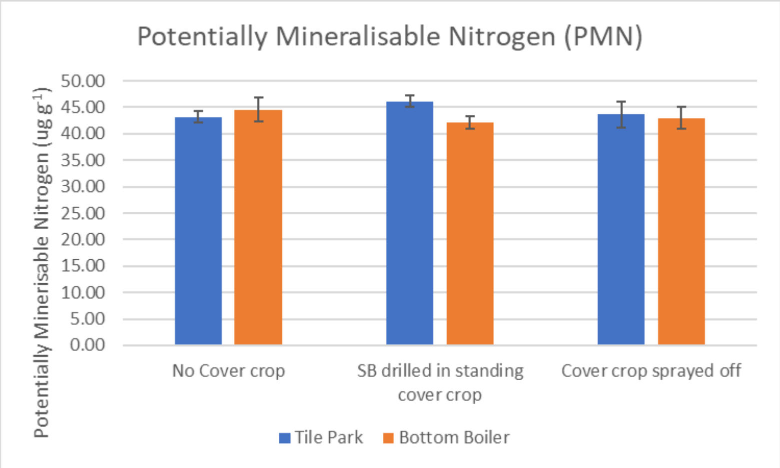


Figure 23. Mean PMN (mg l^{-1}) at the two sites for the main treatments

The sub-treatments were more consistent, with the Tile Park site providing the greater PMN results for most of the sub-treatments (Table 12). Overall, only the cover crop sprayed off 3rd drill date was statistically significant.

Table 12. Mean Potentially Mineralisable Nitrogen (ug g^{-1}) for the drill dates for no cover crop, SB drilled in standing cover crop and cover crop sprayed off (n/s = no significance)

Treatment	Site		Significance
	Tile Park	Bottom Boiler	
No cover crop 1st drill	40.45	45.94	n/s
No cover crop 2nd drill	44.24	47.29	n/s
No cover crop 3rd drill	44.78	40.51	n/s
SB drilled in standing cover crop 1st drill	44.87	40.86	n/s
SB drilled in standing cover crop 2nd drill	45.74	42.90	n/s
SB drilled in standing cover crop 3rd drill	47.91	42.46	n/s
Cover crop sprayed off 1st drill	39.19	40.25	n/s
Cover crop sprayed off 2nd drill	41.58	48.91	n/s
Cover crop sprayed off 3rd drill	50.19	39.77	*$p<0.03$*

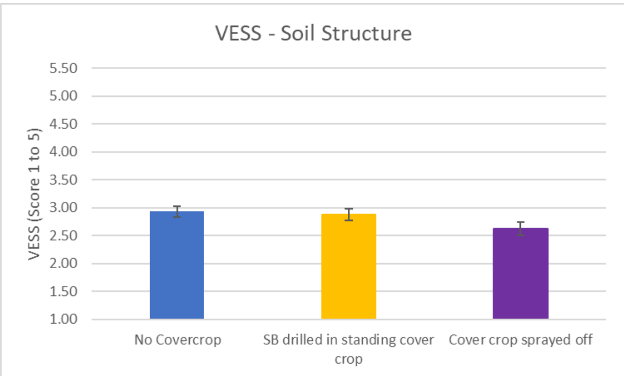
Comparisons of soil sample variables within experimental sites

The soil analysis of the treatments and sub-treatments was done through the growing season (March, April, May and September) to follow the fate of the nutrients and any changes between treatments. Certain measures would not have been sufficiently altered by the system changes, either of the use of cover crops or drilling dates over one or two seasons, such as SOM.

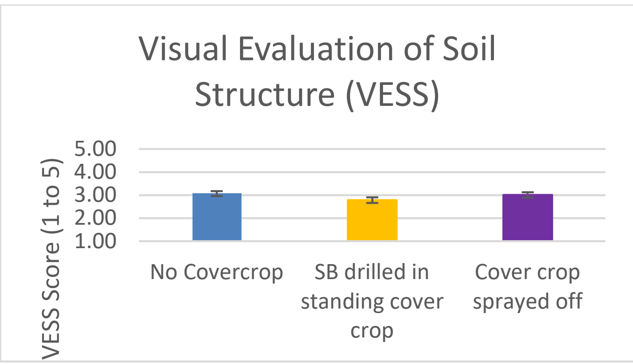
Additionally, if fertilisers were added, it was expected that these would be sufficient for crop growth and not a limiting factor to yield. This should have been the case for soil pH, with liming sufficient to be slightly above or just below the optimum for arable cereals (pH 6.4).

These above considerations were true for both Tile Park and Bottom Boiler, with less statistically significant differences between both the main treatments, relating to the use of cover crops, and the sub-treatments of drilling dates. However, there were some indications of differences (though not statistically significant).

For the main treatments, for the soil structure, it was the no cover crop that had the highest assessment score (2.93) for Tile Park, indicating that the structure was more compacted compared to SB drilled in standing cover crop and cover crop sprayed off (Figure 24a)



a) Tile Park



b) Bottom Boiler

Figure 24. Soil structure (VESS) for Tile Park (a) and Bottom Boiler (b)

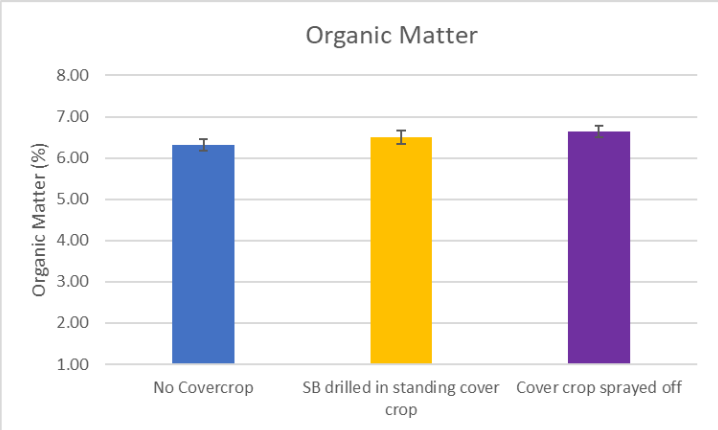
There was a similar situation for Bottom Boiler (Figure 24b), where again it was the no cover crop that indicated the greater soil structural damage (soil compaction), although these were not significant statistically.

The soil pH was very similar for all the treatments (for Tile Park and Bottom boiler) for the mean sampling over the sampling points.

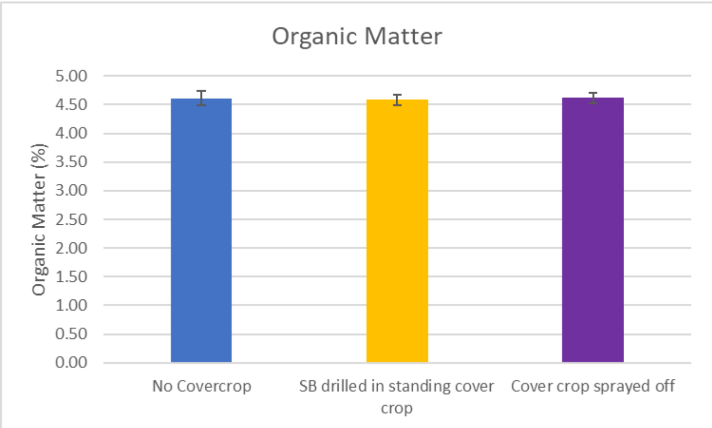
However, the available P and K gave greater P for the SB drilled in standing cover crop and cover crop sprayed off compared to no cover crop for Tile Park (not statistically significant) but again very similar for Bottom Boiler.

The available K was slightly greater again for SB drilled in standing cover crop and cover crop sprayed off compared to no cover crop for Tile Park, with Bottom Boiler very similar for all three treatments. The soil Mg for No cover crop was greater for Tile Park compared to SB drilled in standing cover crop and cover crop sprayed off whereas, the soil Mg concentrations were very similar for all three treatments for Bottom Boiler.

The mean soil Ca was statistically significantly greater for no cover crop ($p<0.004$) and SB drilled in standing cover crop ($p<0.01$) than cover crop sprayed off for Tile Park but again very similar for all three treatments for Bottom Boiler. The pattern continued with SOM, where this was greater for SB drilled in standing cover crop and cover crop sprayed off compared to no cover crop than no cover crop (not significantly) in Tile Park but more similar for all three treatments for Bottom Boiler (Figure 25).



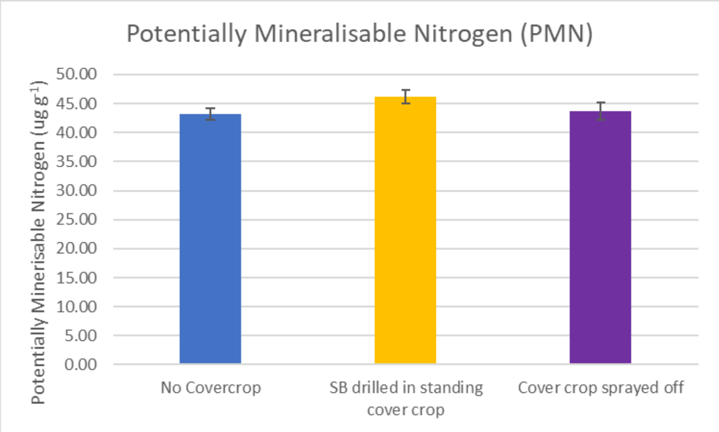
a) Tile Park



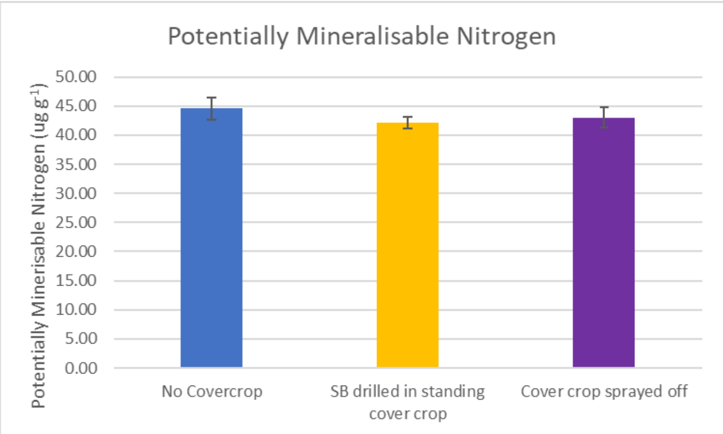
b) Bottom Boiler

Figure 25. Soil organic matter (%) for Tile Park (a) and Bottom Boiler (b)

Potentially Mineralisable Nitrogen (PMN) was greater in the SB drilled in standing cover crop in Tile Park, whereas it was the no cover crop that was the greatest value for Bottom Boiler (Figure 26). However, none of these were statistically significant.



a) Tile Park



b) Bottom Boiler

Figure 26. Mean Potentially Mineralisable Nitrogen (PMN) (ug g^{-1}) for Tile Park (a) Bottom Boiler (b)

2.5. Action points for farmers and agronomists

1) Cover crops may help with water retention and soil health
2) Drill date is a key driver of yield
3) Crop establishment might be reduced by direct drilling into a cover crop

3. Optimising nitrogen application (work package 3)

Trial leader: Steve Hoad

Start date: October 2022

End date: September 2023

3.1. Headlines

This WP modified the nitrogen (N) trial in 2021–22 and compared two methods for applying foliar N compared to an industry standard application of ammonium nitrate.

In contrast to the previous season, one of the foliar N treatments used a 30 kg/ha reduction in in total N but added trace elements, compared to the standard treatment of 160 kg/ha.

To date, yield and grain quality are not available and the report includes key crop measures such as green area index (GAI) and leaf chlorophyll (SPAD) estimates. These have become routine to our seasonal crop monitoring and informing changes in management. We continue to use a new measure of the crop N pool, as the product of GAI x SPAD.

The value of BRIX measurements remains uncertain, but we continue to test how this measurement relates to crop health and nutritional status, as well understanding how spatial and temporal change in BRIX matches with other crop measurements.

When yield data and Farmbench data are available, we will report on production, economics and efficiency of the different N treatments, and quantify differences in N fertilisation efficiency between standard granular N and foliar N.

The crop measurements in this WP were common to those in the crop nutrition trial (work package 4).

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

The timing of nutrient applications is as important as applying the right amount. Rapid development of leaves and roots during the early stages of plant growth is crucial to reach the optimum yield at harvest, and an adequate supply of all nutrients must be available during this time.

This trial compares a conventional treatment with programmes that combine standard ammonium nitrate application with smaller, more frequent applications of foliar nitrogen.

The work aims to determine whether different methods of N application, supported by live crop monitoring, including tissue testing and indicators of crop health, have an economic benefit on crop health, yield and grain quality. Our work will also indicate how changes in N impact on resource use efficiency of the crop.

3.3. How did the project address this?

Through a common measurement programme, this N trial was linked closely to the crop nutrition trial (work package 4).

A comparison of foliar N application with standard granular N application was made in a winter wheat field (Castle Park) sown with a cultivar blend of LG Skyscraper and Istabraq and using a tramline trial based on three treatments replicated twice (six tramlines) as outlined in Table 13.

Table 13. Treatments in nitrogen trial (harvest 2023)

Treatment	Tramlines
Standard ammonium nitrate (AN) 80 kg/ha on 4 March and 80 kg/ha on 2 April. Total N of 160 kg/ha.	3 and 4
Ammonium nitrate followed by urea (UAN) 80 kg/ha AN on 4 March followed by urea liquid on 4 April. Total N of 160 kg/ha.	2 and 5
Urea liquid (UAN) 80 kg/ha UAN on 4 March followed by five applications of 10 kg/ha foliar urea and three application of trace elements during the period 13 April to 7 June. Total N of 130 kg/ha.	1 and 6

Trial layout in Castle Park is presented in Figure 27. For convenience to farm N application, the standard N tramlines were placed centrally in the trial design – tramlines 3 and 4, with the farm adjusted foliar N treatments placed either side.

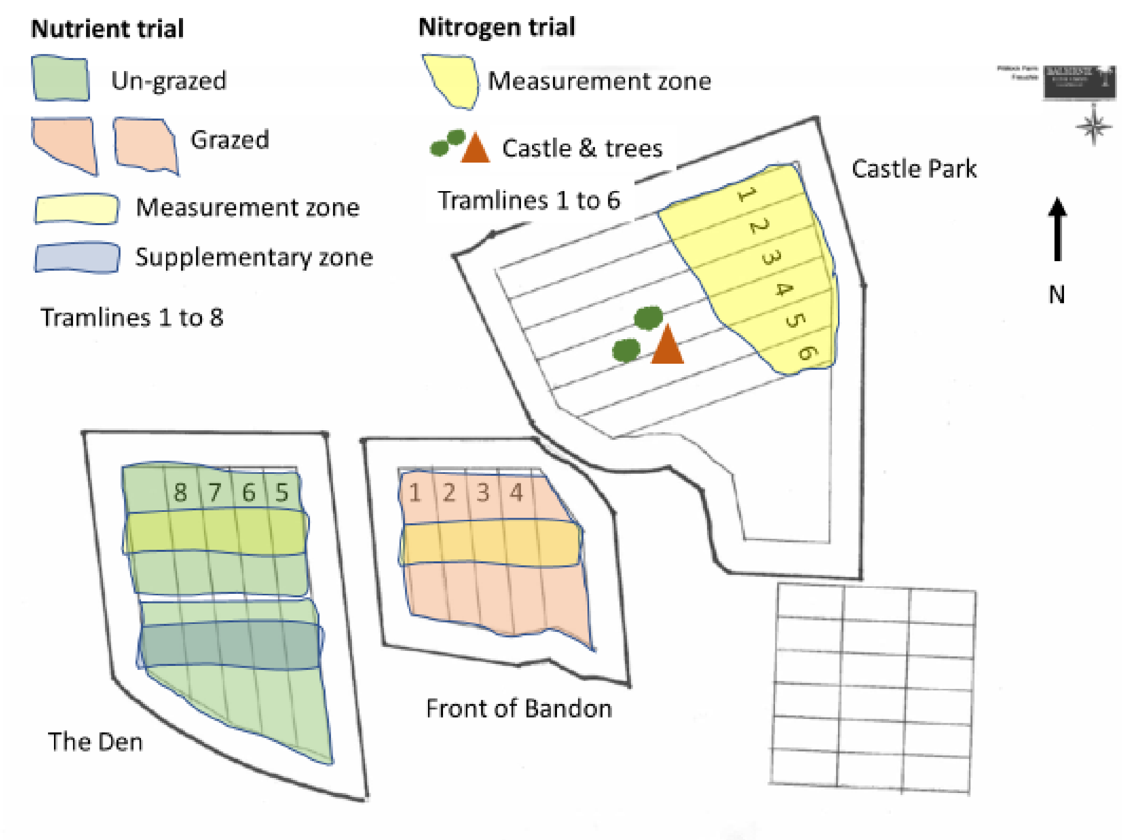


Figure 27. Field layout of the N trial with 6 tramlines in Castle Park (on east side of map). The was adjacent to the nutrition trial (in WP4) in Front of Bandon and The Den (tramlines 1 to 8)

Assessments

The measurements were taken at key crop growth stages to identify changes in crop growth and health, and to guide the farm's crop management:

- Plant growth and green (leaf) area index (GAI)
- Tissue analysis, including sap, Brix and SPAD readings
- Estimate of crop 'N pool' by a composite measure of GAI and SPAD readings
- Crop disease
- Grain yield and quality (farm data)
- Monthly trial diary, including data collected and when measurements were taken

For data analysis, differences in each crop measure among the N nitrogen treatments at five sampling times (growth stages) were tested using a nested ANOVA. Main treatment effects were analysed with treatment (standard AN, AN followed by foliar N and foliar N) at each measurement growth stage nested within date, with two replicate tramlines per treatment.

3.4. Results (to date)

To assess crop health and nutrient status, measures of GAI (Table 14) and SPAD (Table 15) were carried out at five growth stages from 1 March (GS13-14) to 28 May (GS39).

To inform on crop nutrient use and change in health, an estimate on crop N pool (Table 16) and BRIX unit (Table 17) were made at each growth stage.

GAI in the standard (AN) crop developed consistent with a wheat crop with high yield potential (Table 14). Both AN+UAN and UAN+foliar treatments resulted in smaller leaf canopies, though the difference with AN was not significant.

Table 14. Change in GAI across dates (growth stage) and among treatments in the crop N trial

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	15-21	22-30	31-32	39
	0.23	0.51	1.01	1.86	5.01
		Treatment			
Date	GS	AN	AN+UAN	AN+foliar N	
01/03/23	13-14	0.23	0.23	0.23	
26/03/23	15-21	0.53	0.50	0.50	
11/04/23	22-30	1.19	0.87	0.96	
01/05/23	31-32	2.02	1.65	1.90	
28/05/23	39	5.74	4.56	4.73	

Date F Pr. = <0.001

Treatment F Pr. = 0.201

Date.Treatment F Pr. = 0.733

SPAD values, as an estimate of leaf N uptake and leaf chlorophyll content, were constant throughout the growth phase from GS13-14 to GS39. There was no significant difference in SPAD value between N treatments.

Table 15. Change in SPAD across dates (growth stage) and among treatments in the crop N trial

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	*13-14*	*15-21*	*22-30*	*31-32*	*39*
	44.5	45.6	44.1	46.3	45.5
		Treatment			
Date	*GS*	AN	AN+UAN	UAN+foliar N	
01/03/23	*13-14*	44.3	45.0	44.3	
26/03/23	*15-21*	44.3	46.6	45.8	
11/04/23	*22-30*	43.7	43.7	44.8	
01/05/23	*31-32*	46.9	45.4	46.6	
28/05/23	*39*	47.9	44.0	44.6	
Season mean		45.4	44.9	45.2	

Date *F Pr. = 0.783*

Treatment *F Pr. = 0.945*

Date.Treatment *F Pr. = 0.952*

Crop N pool was not statistically significant among treatments, though the N pools in the AN+UAN and UAN+foliar N tramlines were on average 23% to 24% less than that of AN at GS39 (28 May).

Table 16. Change in N pool across dates (growth stage) and among treatments in the crop N trial

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	15-21	22-30	31-32	39
	1.00	2.32	4.45	8.6	23.15
		Treatment			
Date	GS	AN	AN+UAN	UAN+foliar N	
01/03/23	13-14	0.99	1.01	1.00	
26/03/23	15-21	2.36	2.33	2.28	
11/04/23	22-30	5.24	3.81	4.31	
01/05/23	31-32	9.45	7.50	8.85	
28/05/23	39	27.51	20.83	21.1	

Date F Pr. = <0.001

Treatment F Pr. = 0.373

Date.Treatment F Pr. = 0.854

BRIX values were consistent at values from 11 to 14 units from GS13–14 to GS31–32 (to 1 May) but decreased in all treatments at GS39 (28 May). There was no significant difference in BRIX values among treatments, and no interaction between date (growth stage) and treatment.

Table 17. Change in BRIX values over time and among treatments in the crop N trial

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	15-21	22-30	31-32	39
	13.9	12	13.3	11.1	7.7
		Treatment			
Date	**GS**	**AN**	**AN+UAN**	**UAN+foliar N**	
01/03/23	13-14	14.1	14.0	13.7	
26/03/23	15-21	11.6	12.6	11.8	
11/04/23	22-30	13.8	13.2	12.9	
01/05/23	31-32	11.2	11.4	10.7	
28/05/23	39	8.5	7.1	7.6	
Season mean		11.8	11.7	11.3	

Date F Pr. = <0.001
Treatment F Pr. = 0.502
Date.Treatment F Pr. = 0.870

Treatment effects on each of the crop measures in each tramline was used to guide management but also assess field variation.

From early April (before growth stage 22–30), it was evident that tramlines 5 (AN + UAN) and 6 (UAN+foliar N) were poorer in both:

- Leaf canopy development, as indicated by reduced GAI
- N uptake, as indicated by lower SPAD values and N pool

Figure 28 shows these changes, and the field gradient across the tramlines, with poorer growth (GAI, SPAD and N pool) indicated in the circled data being most prominent at the south part of the field.

Overall, SPAD was conserved across growth stages (dates), whist BRIX declined with growth stage. BRIX was also less sensitive than GAI and SPAD to the field gradient.

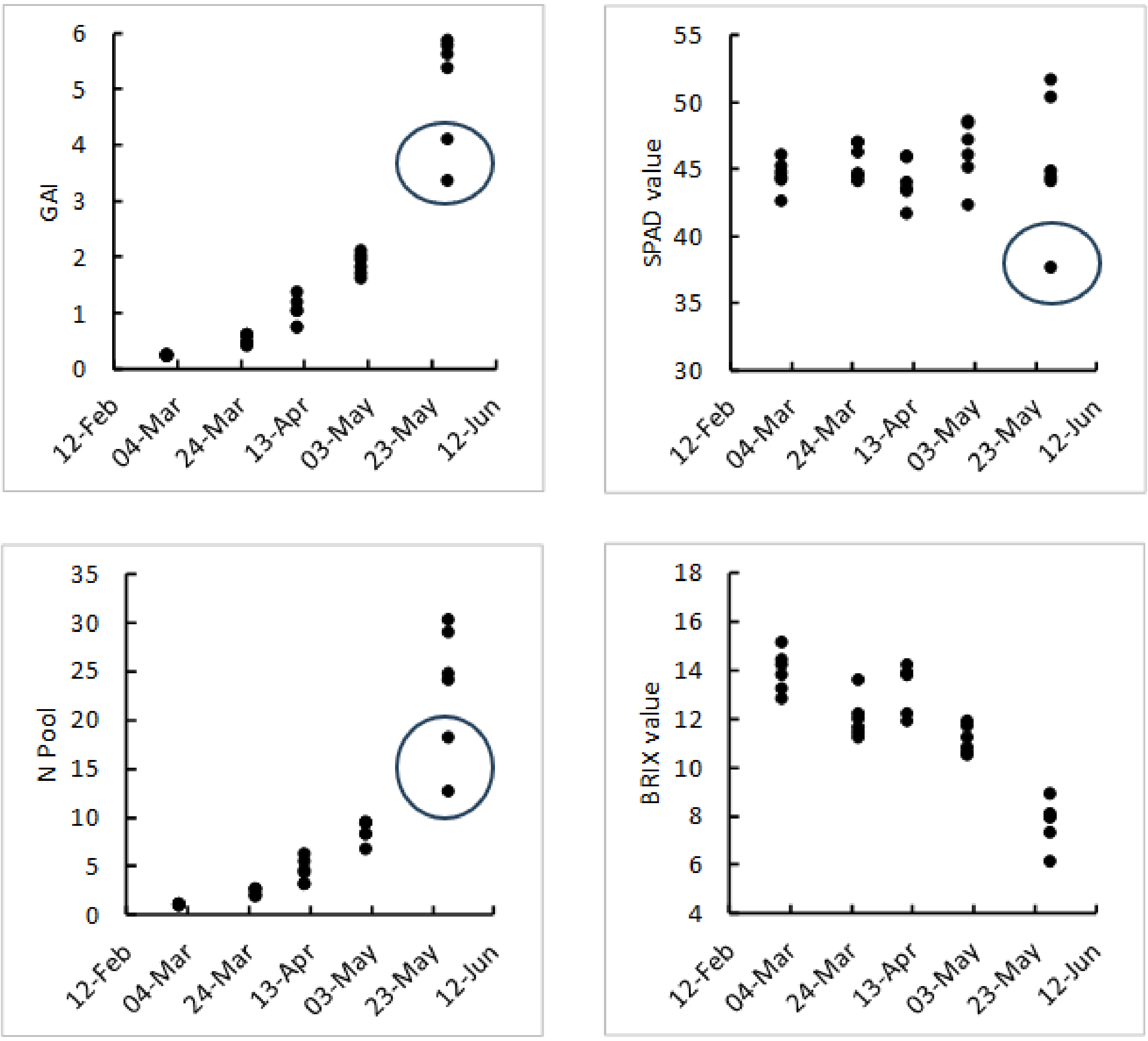


Figure 28. Change in GAI, SPAD value, N Pool and BRIX value with time (crop growth stage), from GS13–14 on 1 March to GS39 on 28 May. Circles indicate lower GAI, SPAD and N pool in tramlines 5 and 6

An aspect of work packages 3 and 4 was to explore relationships between different crop measures and their value for assessing real-time crop nitrogen and nutrient status.

The conserved pattern in SPAD, from GS13–14 to GS31–32, is shown in Figure 29. The wider spread in SPAD and GAI at GS39 highlights the field gradient that was prominent from stem extension onwards (circled).

BRIX values decreased with an increase in GAI, but there was no relationship between SPAD and BRIX.

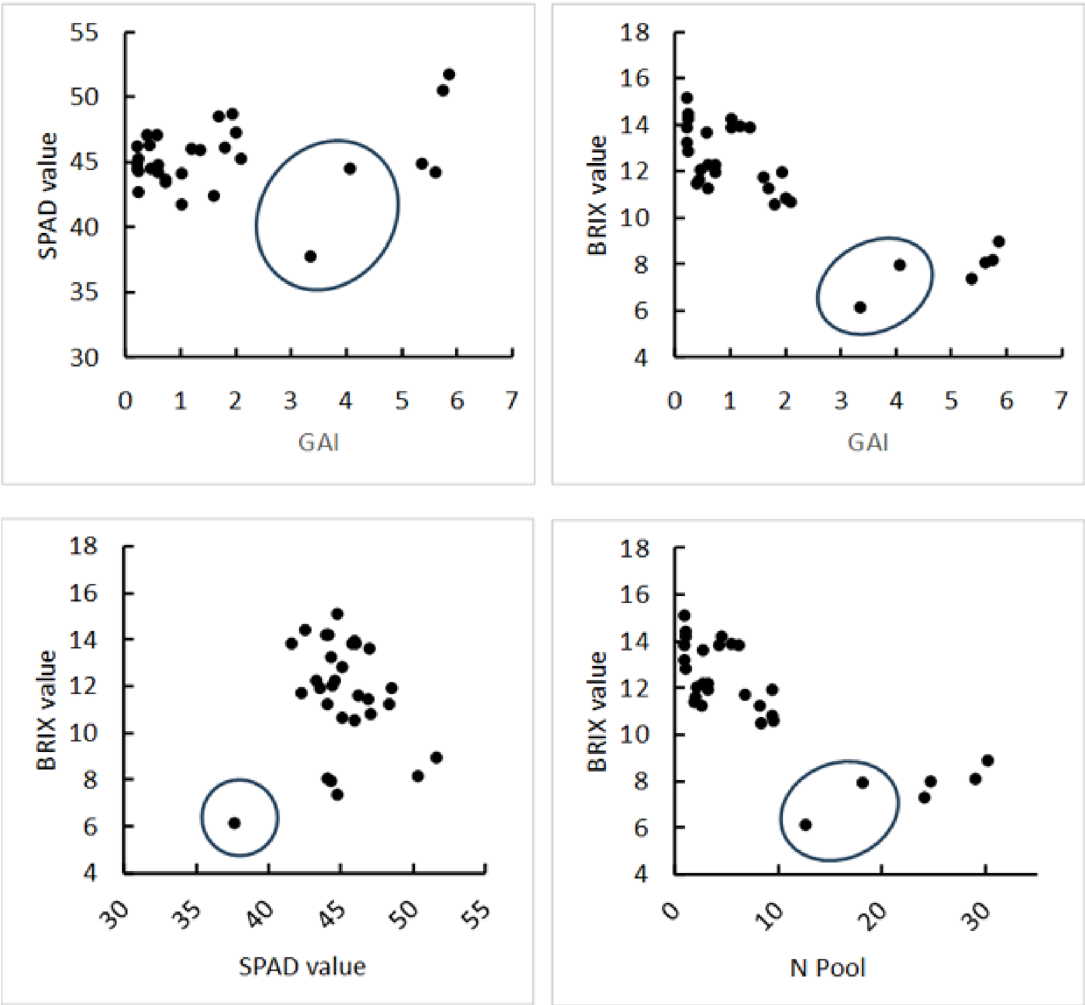


Figure 29. Exploring relationships between different crop measurements: (i) GAI and SPAD, (ii) GAI and BRIX, (iii) SPAD and BRIX (iv) N pool and BRIX. Circled data points highlight a field gradient that was most prominent at GS39, with tramlines 5 and 6 having reduced GAI and N pool, with tramline 5 indicating reduced SPAD

Application towards remote sensing to inform on field and with-in field management, both WP3 and WP4, was supported with drone flights to capture standard RGB images and vegetation indexes.

Figure 30 shows the field gradient, with lower GAI and SPAD evident in tramlines 5 and 6, but also variation between the two standard AN tramlines 3 and 4.

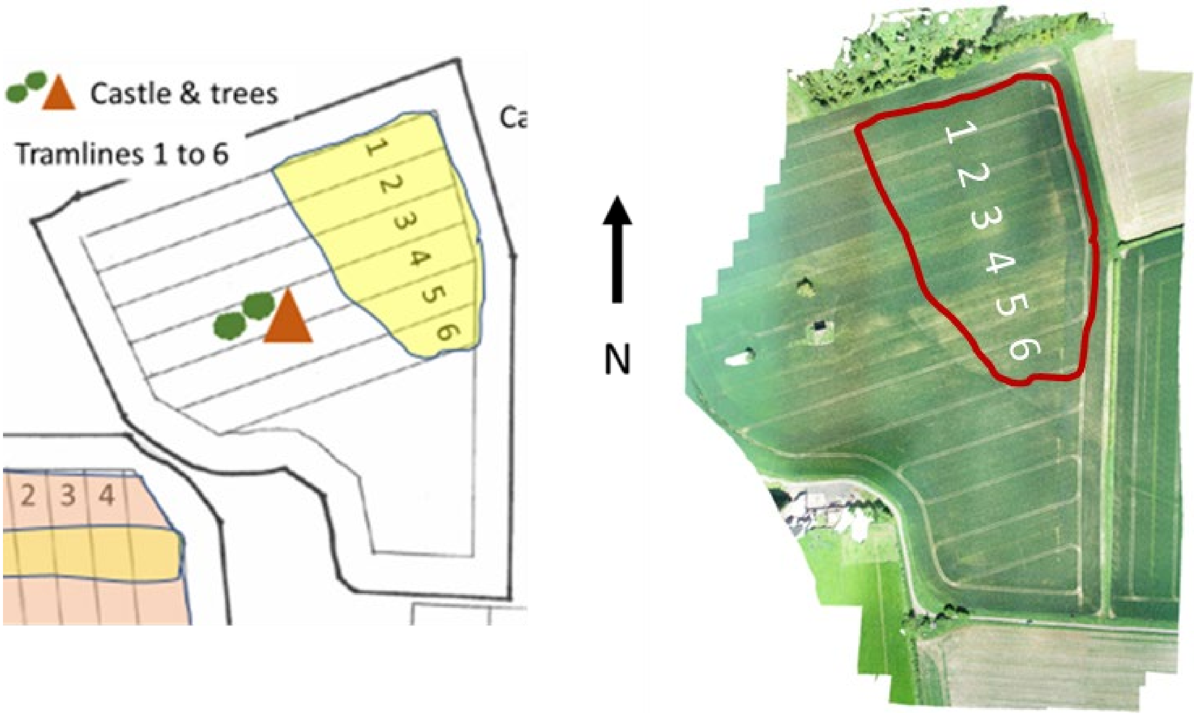


Figure 30. Whole field image for Castle Park captured by drone flight on 29 May 2023

3.5. Action points for farmers and agronomists

1) The use GAI and SPAD and an estimate of crop N pool as a composite indicator of crop potential looks promising as a guide to N management, as first reported in the 2021–22 trial
2) Further yield and grain quality data from harvest 2023 will inform on the value of this composite measure in yield forecasting and a tool in N management
3) The benefit of crop measures, including GAI, SPAD and BRIX continue to be quantified towards use of a combined tool, and eventually a remote sensing technology, that can be uses to report on crop health and yield potential
4) As reported in 2021–22, when planning for crop measurement and sampling we considered how measurement zones were representative of the full tramline length or whole field
5) With the addition of yield maps, in conjunction with representative sampling zones, we aim to identify permanent and temporary field features, such as seasonal variation in soil moisture, that may require different management to crop and/or soil

4. Adjusting nutrition application in response to crop monitoring (work package 4)

Trial leader: Steve Hoad

Start date: October 2022

End date: September 2023

4.1. Headlines

This work package repeated the trial of 2021–22 by investigating four ways to manage nutrients, including a current farm standard and two tailored treatments.

Working closely with work package 3, the nutrient trial used crop measures, such as leaf area index (GAI) and leaf chlorophyll (SPAD), as a guide to adjusting nutrition, coupled with leaf sap and tissue nutrient testing.

This work provides further support for the use of crop nitrogen (N) pool, as the product of GAI x SPAD in assessing field variation in crop yield potential and has become a key measure towards forecasting grain yield and quality.

The value of BRIX measurements was further investigated. Its potential to assess changes in crop disease levels and nutritional health, as well spatial and temporal variation in yield, is yet to be confirmed.

When crop yield and Farmbench data are available, we will report the full production, economic and efficiency of the different approaches to nutrient management.

The measurements in this work were common to the crop nitrogen trial (work package 3).

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

The timing of nutrient applications is as important as applying the right amount. Crop demand varies throughout the season and is greatest when a crop is growing quickly. Therefore, results from standard laboratory tissue testing may be quickly outdated.

Rapid development of leaves and roots during the early stages of plant growth is crucial to reach the optimum yield at harvest, and an adequate supply of all nutrients must be available during this time. Excess application of nutrients, or poor timing, can reduce crop quality and cause problems, such as lodging of cereals or increases in foliar pathogens.

This project aims to determine whether amending crop nutrition in response to live crop monitoring, including growth and development and tissue testing, will have an economic benefit on crop health, yield and grain quality. Our work will also indicate how changes in N management impact on resource use efficiency of the crop.

4.3. How did the project address this?

Trial design

Work was carried out using the same tramline treatments as in 2021–22 (Table 18). Each treatment was replicated in two tramlines, with tramlines 1 to 4 in the field, Front of Bandon (rep 1) and 5 to 8 in The Den (rep 2).

Table 18. Treatments in nutrition trial (harvest 2023)

Treatment	Tramlines
Standard fertiliser (AN) with PGR and no fungicide. With AN split and two applications of 80 kg N/ha. Total N was 160 kg/ha.	1 and 7
Standard fertiliser (AN) with PGR and fungicide. With AN split and two applications of 80 kg N/ha. Total N was 160 kg/ha.	2 and 5
Tailored agronomy 1. A Balbirnie standard, with opportunity to adjust both fertiliser and crop protection inputs. This included a single dose of 80 N/ha (as AN), preceded by and followed by three applications of foliar N and trace elements. Total N was 140 kg/ha.	3 and 8
Tailored agronomy 2. As tailored agronomy 1, but with additional ‘biology in a bag’. Total N was 140 kg/ha.	4 and 6

The experimental design was based on two adjacent fields, Front of Bandon provided tramlines 1 to 4 (replicate 1) and The Den provided tramlines 5 to 8 (replicate 2) as presented in WP3 (Figure 27). Both fields were sown with the cultivar blend of LG Skyscraper and Istabraq.

To test the effects of sheep grazing on crop health and nutrient use, the whole of one field, Front of Bandon, was grazed for two days when the crop was at growth stage, from 28 February to 1 March. The Den was ungrazed.

Assessments

The measurements were taken at key crop growth stages to identify changes in crop growth and health, and to guide the farm's crop management:

- Plant growth and green area index (GAI)
- Tissue analysis, including sap, Brix and SPAD readings
- Estimate of crop 'N pool' by a composite measure of GAI and SPAD readings
- Crop disease
- Grain yield and quality (farm data)
- Monthly trial diary, including data collected and when measurements were taken

For data analysis, differences in each crop measure among the four nutrient treatments at five sampling times (growth stages) were tested using a nested ANOVA.

Main treatment effects were analysed with treatment (standard -F, standard +F, tailored and tailored plus) at each date nested within date (growth stage) with the two fields used as treatment replicates.

The effect of grazing on crop performance was analysed with grazing versus no grazing nested within measurement date, and tramlines in each field use as four replicates.

4.4. Results (to date)

Assessment of crop health and nutrient status was used to adjust the timing of N application. The key crop measures were GAI (Table 19) and SPAD (Table 20), with further information from estimate of crop N pool (Table 21) and BRIX measures (Table 22), were carried out at five growth stages from 1 March (GS13–14) to 28 May (GS32).

Green area index was lower than that in the standard N treatment in WP3, though standard agronomy treatments with + and – fungicide were on track to achieve GAI of 5 plus units. Towards maximum leaf canopy size there was a significant difference of 0.4 to 0.6 units of GAI of between the standard and tailored agronomy (Table 19).

Table 19. Change in GAI across dates/growth stage and among treatments

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	14-15 & 15-21	22-30	31-32	39
	0.22	0.57	0.98	1.85	4.59
		Treatments			
Date	GS	Standard + F	Standard - F	Tailored	Tailored Plus
01/03/23	13-14	0.22	0.22	0.22	0.22
26/03/23	15-21	0.60	0.60	0.55	0.55
11/04/23	22-30	1.15	1.19	0.79	0.81
01/05/23	31-32	2.18	2.17	1.48	1.57
28/05/23	39	4.80	4.92	4.20	4.44

Date F Pr. = <0.001

Treatment F Pr. = <0.001

Date.Treatment F Pr. = 0.180

Compared to the N trial in WP3, there was significant drop in SPAD value at growth stages 31–32 (Table 20). This can be explained by differential crop responses to tramline treatments, including the tailored farm management.

At stem extension (GS31–32, 5 May), the whole field was paler than three weeks before, though SPAD and leaf area were much higher in standard treatment compared to the tailored agronomy. Hence, a higher N uptake in the standard agronomy than in tailored treatments (Table 21).

The increase in SPAD and N pool in the standard agronomy – from 1 March to 11 April – was interpreted as sustained high N uptake in a crop supplied with a standard recommendation for applied N. While the lower SPAD and N pool in the tailored agronomy was consistent with use of several low doses of foliar followed by a later main application of AN. The raised SPAD and N Pool in tailored agronomy at growth stage 39 was a strong response to the main N application and continued use of foliar N doses.

Responding to low, but increasing, levels of yellow rust, fungicide was applied to both standard and tailored agronomy at stem extension. Overall, disease foci were widespread but with low levels of infection at GS31–32.

By GS39, in Front of Bandon (grazed tramlines 1 to 4), new yellow rust was higher in standard (tramlines 1 and 2) than in tailored agronomy, (3 and 4), giving these tramlines a paler appearance.

Furthermore, by GS39, in The Den (ungrazed tramlines 5 to 8), a combination of leaf tipping and old or treated yellow rust contributed to a yellow colouration in standard agronomy (tramlines 5 and 7) compared to tailored agronomy (tramlines 6 and 8).

The reversal in SPAD value, between standard and tailored agronomy, during stem extension was most evident with the tailored treatment tramlines becoming greener and closing the gap to the standard agronomy in its N pool. At GS39, leaf canopy in tailored agronomy had a higher proportion of green area and fewer symptoms of stress, including leaf flecks. Healthy parts of leaves in tailored agronomy tended to have higher SPAD values than counterparts in standard agronomy.

Table 20. Change in SPAD readings across dates (growth stage) and among treatments

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	14-15 & 15-21	22-30	31-32	39
	44	44.6	46.6	40.5	45.7
		Treatment			
Date	GS	Standard + F	Standard – F	Tailored	Tailored Plus
01/03/23	13-14	44.1	44.4	43.1	44.3
26/03/23	15-21	45.6	46.5	43.4	42.7
11/04/23	22-30	49.8	48.3	42.4	46.1
01/05/23	31-32	44.0	44.3	35.7	37.9
28/05/23	39	44.3	44.3	47.2	47.0
Season mean		45.5	45.6	42.3	43.6

Date F Pr. = 0.019

Treatment F Pr. = 0.129

Date.Treatment F Pr. = 0.493

Table 21. Change in estimate N pool (as GAI x SPAD units) over time and among treatments

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	14-15 & 15-21	22-30	31-32	39
	1.01	2.64	4.62	7.59	20.93
		Treatment			
Date	GS	Standard + F	Standard - F	Tailored	Tailored Plus
01/03/23	13-14	1.01	1.02	1.00	1.02
26/03/23	15-21	2.81	2.87	2.46	2.41
11/04/23	22-30	5.70	5.75	3.32	3.72
01/05/23	31-32	9.56	9.55	5.29	5.96
28/05/23	39	21.28	21.74	19.81	20.89

Date F Pr. = <0.001

Treatment F Pr. = 0.003

Date.Treatment F Pr. = 0.262

Table 22. Change in BRIX values across dates/growth stage and among treatments

Date	01/03/23	26/03/23	11/04/23	01/05/23	28/05/23
Growth stage	13-14	14-15 & 15-21	22-30	31-32	39
	13.1	12.6	13.6	9.2	9.0
		Treatment			
Date	GS	Standard + F	Standard - F	Tailored	Tailored Plus
01/03/23	13-14	13.5	13.3	12.4	13.1
26/03/23	15-21	13.3	11.3	13.1	12.5
11/04/23	22-30	14.2	13.7	13.2	13.3
01/05/23	31-32	9.2	8.5	9.0	10.2
28/05/23	39	8.7	8.9	9.1	9.2
Season mean		11.8	11.1	11.4	11.7

Date F Pr. = <0.001

Treatment F Pr. = 0.848

Date.Treatment F Pr. = 0.995

The effect of sheep grazing on different crop measures in shown in Table 23.

Grazing significantly reduced GAI during tillering to the start of stem extension, though by the GS31–32 the difference in GAI between grazed and non-grazed was small, and by GS39 the two fields had the same GAI.

There was significant interaction between date (growth stage) and grazing effect on leaf SPAD values. Initially, SPAD was reduced by grazing, but during stem extension it was maintained at higher level.

The net effect of grazing on GAI and SPAD was to initially reduce N pool in the grazed field, only for it increase during stem extension.

Grazing significantly reduced BRIX during stem extension. Thereafter, BRIX values were comparable between the two fields.

Table 23. Effects of grazing on crop measures at each growth stage (timing)

Date	Growth stage	Non-grazed (The Den field)	Grazed (Front of Bandon field)	Comments
GAI				
01/03/23	13-14	0.30	0.15	
26/03/23	15-22	0.77	0.38	
11/04/23	22-30	1.16	0.81	Date F Pr. < 0.001
01/05/23	31-32	1.90	1.80	Grazing F Pr. 0.019
28/05/23	39	4.62	4.56	Date.Grazing F Pr. 0.647
SPAD				
01/03/23	13-14	47.0	41.0	
26/03/23	15-22	48.3	40.8	
11/04/23	22-30	46.3	46.9	
01/05/23	31-32	38.7	42.2	Date F Pr. <0.001
28/05/23	39	44.3	47.1	Grazing F Pr. 0.130
Season mean		44.9	43.6	Date.Grazing F Pr. 0.001
N pool				
01/03/23	13-14	1.41	0.61	
26/03/23	15-22	3.71	1.57	
11/04/23	22-30	5.44	3.81	Date F Pr. <0.001
01/05/23	31-32	7.49	7.69	Grazing F Pr. 0.130
28/05/23	39	20.4	21.47	Date.Grazing F Pr. 0.135
BRIX				
01/03/23	13-14	14.7	11.5	
26/03/23	15-22	15.4	9.8	
11/04/23	22-30	13.9	13.3	
01/05/23	31-32	9.7	8.8	Date F Pr. < 0.001
28/05/23	39	8.7	9.2	Grazing F Pr. < 0.001
Season mean		12.5	10.5	Date.Grazing F Pr. <0.001

As in WP3, drone flights over the two fields, Front of Bandon (tramlines 1 to 4) and The Den (tramlines 5 to 8), were made on 29 May. Images in Figure 27 indicate the greening in tailored agronomy in both fields (tramlines 3, 4. 6 and 8).

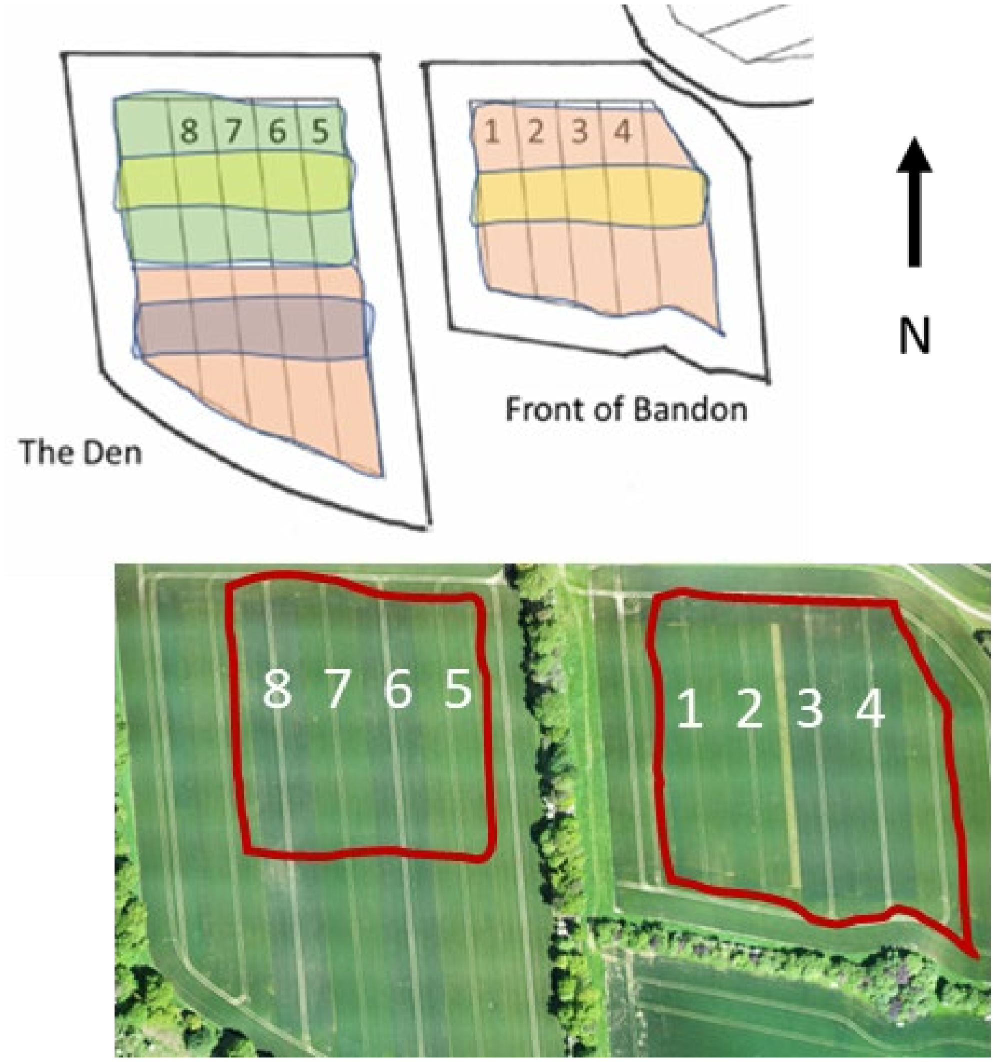


Figure 27. Whole field images for Front of Bandon (tramlines 1 to 4) and The Den (tramlines 5 to 8) captured by drone flight on 29 May 2023

There was more variation in SPAD among tramlines (grazed and non-grazed fields) than in the nitrogen trial (WP3), with low SPAD and BRIX before stem extension in grazed tramlines (circled). Generally, GAI and N pool were below values reported in the nitrogen trial. BRIX tended to decline with date (growth stage).

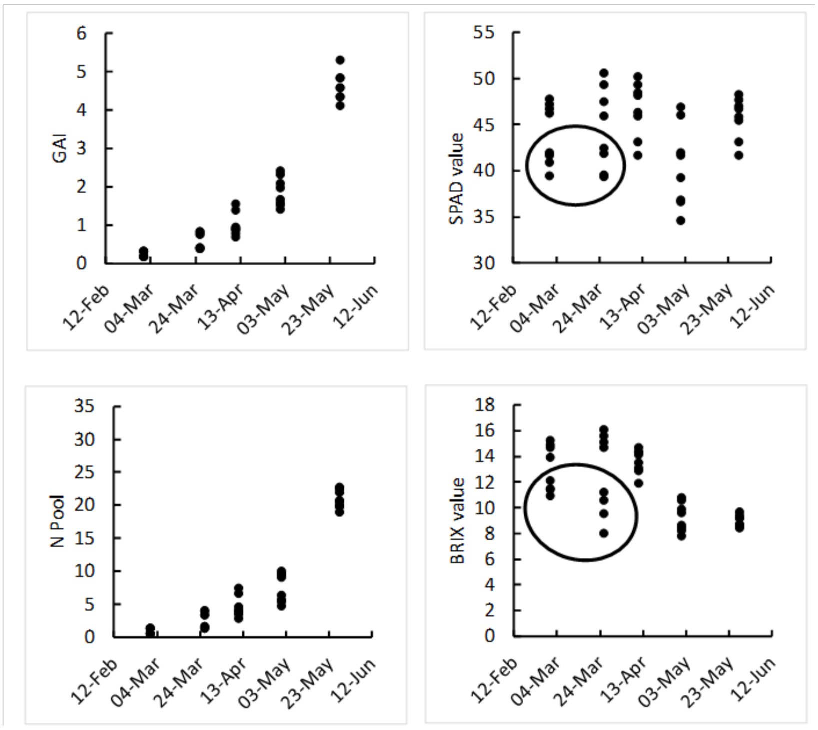


Figure 28. Change in GAI, SPAD value, N Pool and BRIX value with time (crop growth stage), from GS13-14 on 1st March to GS39 on 28th May. Circled data points highlight low levels of SPAD and BRIX units after grazing in Front of Bandon

BRIX values decreased with an increase in GAI (with growth stage), but there was more scatter in data compared to the N trial in WP3. There was no relationship between SPAD and BRIX.

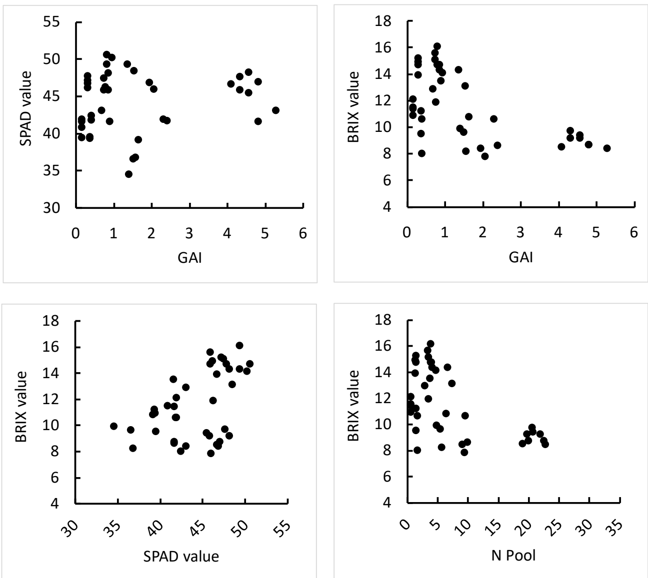


Figure 29. Exploring relationships between crop measurements: (i) GAI and SPAD, (ii) GAI and BRIX, (iii) SPAD and BRIX (iv) N pool and BRIX

4.5. Action points for farmers and agronomists

1. Work packages 3 and 4 support the use of GAI, SPAD and crop N pool as a guide to crop management
2. Use of the same crop measures in both work packages has assisted our project towards improved protocols for benchmarking the health of crops
3. Although relationships between SPAD and BRIX and crop disease or nutrient status have yet to be established, we expect that a full analysis with Farmbench data to provide the most up-to-date evaluation of these methods, as well as forming a key part of our approach towards real-time crop management
4. In both work packages, the value of crop measures, including GAI, SPAD and BRIX is being quantified to enable combined methods and technologies to inform better on crop health and nutrient status
5. If validated, these measures can be adapted for use in remote crop sensing and provide a wider opportunity for assessing spatial and temporal change in crop health and nutrient status