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Strategic Cereal Farm Scotland – Harvest 2022 report

Demonstrations

1a. Cover crops ahead of direct drilled spring barley

Trial leader: Fiona Burnett, SRUC

Key findings

The aim was to explore the effect of drilling date and cover crop management on crop establishment, biodiversity, crop health and yield.

• Sow date was the more significant driver of spring barley establishment during the season. Optimum differed between fields

• Cover crop management was also a factor in establishment and yield

• The earliest drilling dates tended to be ahead for crop cover and ultimately yield – more evident in Tile Park

• There was no yield advantage to the inclusion of cover crop and a trend that retaining the cover crop until after drilling reduced yield

• The effect of cover crop management was more evident in the latest drill date treatments where there was a trend to reduced yield and establishment in the treatment where cover crop was retained until after drilling

• Despite a trend to improved soil structure and soil chemistry, plant counts indicate that retaining the cover crop until post drilling may have negatively impacted crop establishment. Slightly lower soil nutrients may also have been a factor

• Field characteristics and timing of cover crop termination had a greater impact on pests and beneficials than simply the presence of a cover crop

• Findings indicate that later termination of cover crops could provide an important tool to support natural enemies in integrated pest management strategies

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 IPM, cover crops are thought to attract beneficial insects that overwinter in the soil and supress weeds through competing for space. However, there are also downsides to be considered 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.

Reducing artificial inputs is a long-term goal for the Strategic Cereal Farm Scotland. The purpose of this trial is to firstly quantify the benefits of establishing a cover crop prior to direct drilling spring barley. Then to see whether these benefits translate into opportunities to reduce inputs on the cash crop.

How did the project address this?

Trial design

A replicated field trial was established on two fields (Table 3.1) at the Strategic Farm Scotland (SFS) exploring the impact of the establishment and management of cover crops on crop biomass, crop yield, pest (aphids and slugs), beneficial invertebrates (i.e. natural enemies and parasitoids) and weeds. Three cover crop treatments were established following a winter wheat crop, and surveying was conducted during establishment of the following spring barley crop. The cover crop consisted of forage rye, peas, and beans and three treatments explored were:

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

Drilling dates were as follows:

- Drill date 1: Standard local practice (actual 25th March 2022)
- Drill date 2: local practice +7-10 days (actual 4th April 2022)
- Drill date 3: + 7-10 days from drill date 2 (actual 18th April 2022)

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. Exact layout and randomisation differed between fields, shown in Figures 1 and 2. (Seed was tested prior to drilling as germination 99%, Microdochium 27%, thousand grain weight 99.8g)

Table 1. *Fields included in cover crop trials.*

Field Name	Area (ha)	2022 Crop
Tile Park	12.6	Spring barley direct drilled
Tank Wilsons March	16.0	Spring barley direct drilled

Assessments

Three sets of assessments are set out in the results section

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

What results has the project delivered?

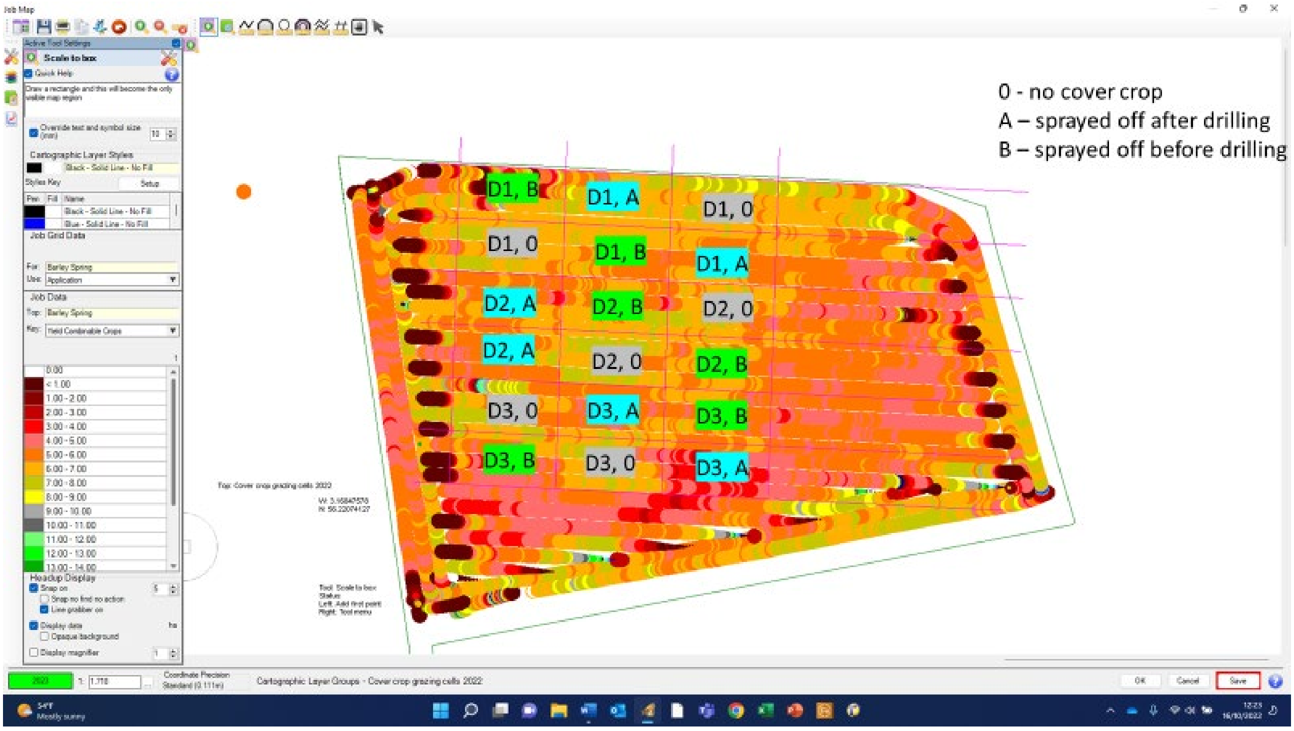

Figure 1: Yield map and treatment layout for Tile Park Field

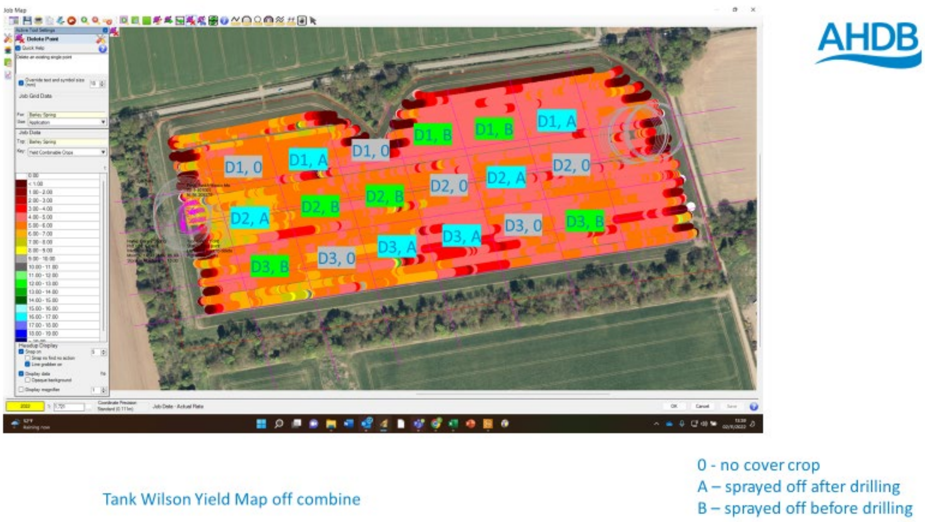

Figure 2: Yield map and treatment layout for Tank Wilson Field

The yield maps in Figures 1 and 2 show the context and locations of the trial plots within the two fields. In Tile Park the trial area appears higher yielding than the rest of the field and the plots bottom right may have been impacted by the poor yielding part of the field.

Figure 3: Emergence Tile Park field 27 May 2022 (drill date 1 - left, 2 – centre and 3 – right)

Figure 4: Emergence Tank Wilson field 27 May 2022 (drill date 1 - left, 2 – centre and 3 – right)

Figures 3 and 4 visually illustrate how plots in the two fields appeared after the final drilling date. Early drilled plots emerged well. Later drilled plots may have been more affected by the dry spring conditions. No diseases were noted at this timing.

Establishment and yield at Tile Park

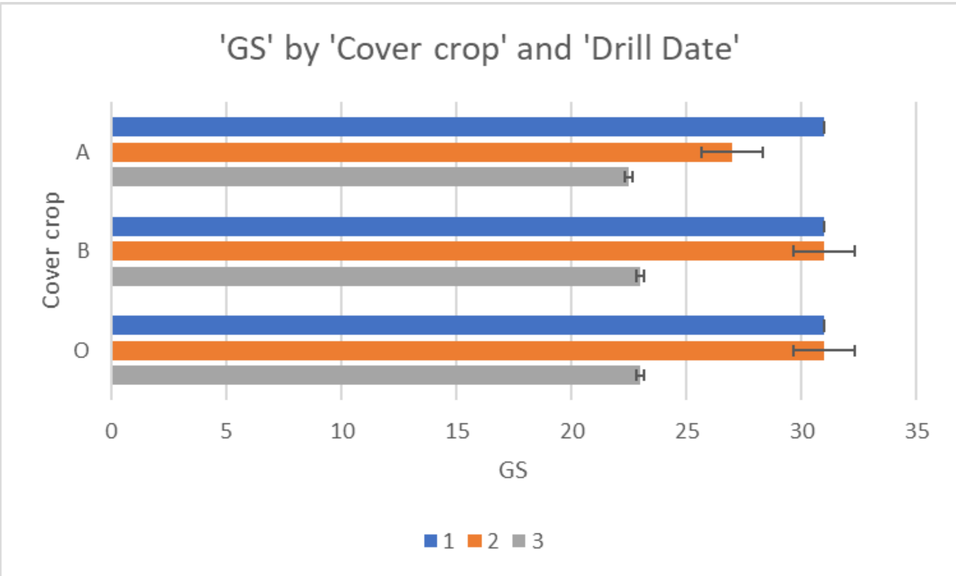

Figure 5: Tile Park 2 June 2022 Growth stage

As expected, growth stage was least advanced in later drilled plots, as seen in Figure 5. There was no influence from cover crop management.

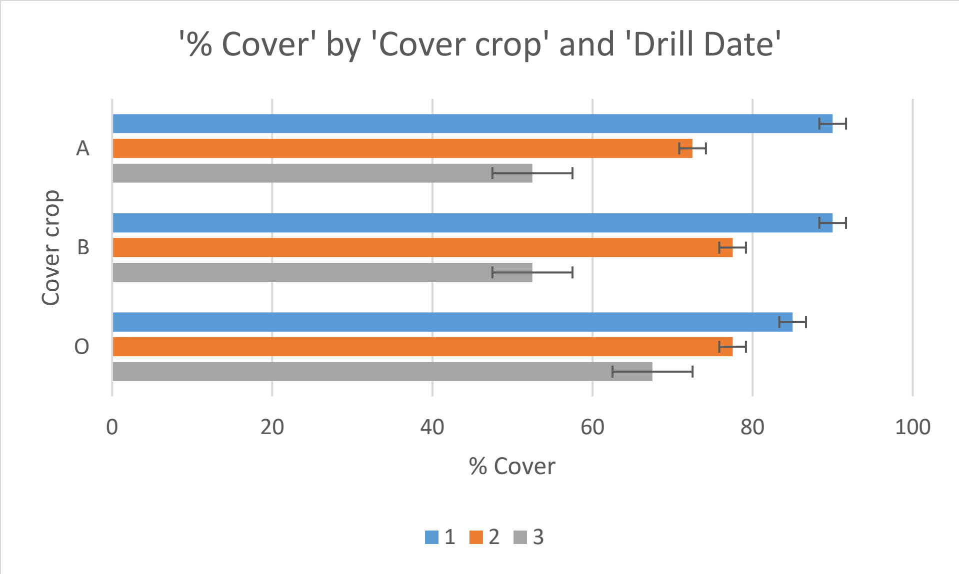

Figure 6: Tile Park % Ground cover 2 June 2022

Crop cover was lower in later drilled plots and there was no significant effect from crop cover management, although there was trend to better establishment in the earliest drill date for the two cover crop options.

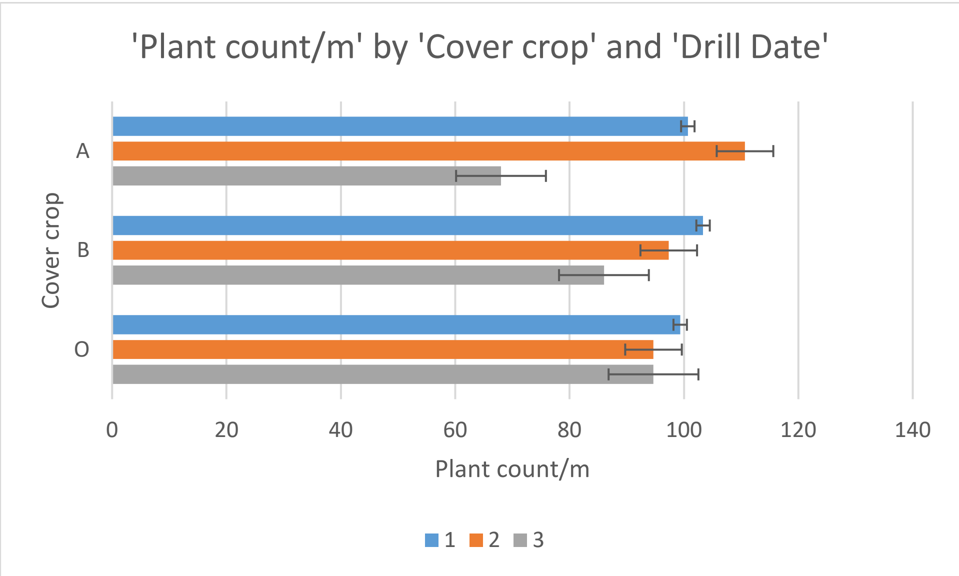

Figure 7: Tile Park plant counts per meter 2 June 2022

Plant counts were also lower in the later drilled plots and this was least obvious in plots with no cover crop, just significant where the cover crop was sprayed off before drilling and highly significant where the crop was drilled into the standing cover crop (Figure 7). By late July (Figure 8) this trend was less obvious and plant counts were lower in later drilled plots for all cover crop management options, including no cover crop, although the difference was larger in the cover crop options.

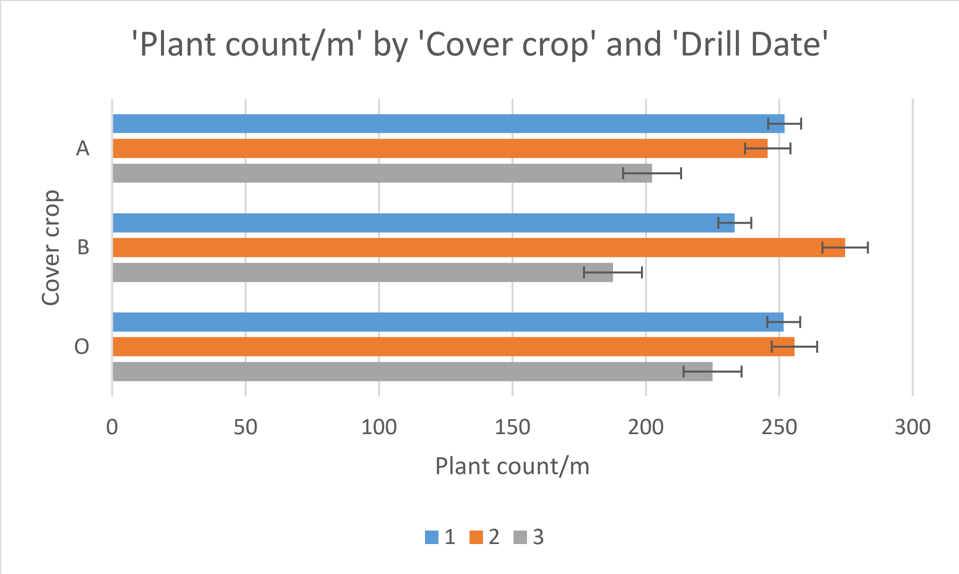

Figure 8: Tile Park plant counts per meter 26 July 2022

Disease levels were low throughout the season and rhynchosporium only infected the crop as it was starting to ripen off. Ramularia came in at low levels but there were no significant differences between treatments. There is some trend in the data for rhynchosporium levels to be higher in the later drilled plots (Figure 9) but this is skewed by them having more residual green leaf at this timing where early drilling dates had largely senesced.

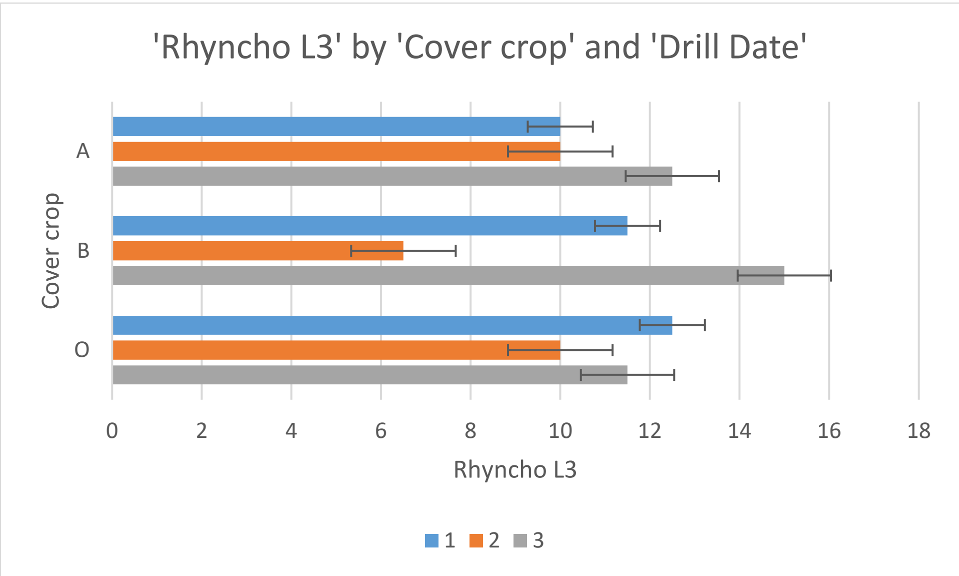

Figure 9: Tile Park disease 26 July 2022 (Rhynchosporium Final L3)

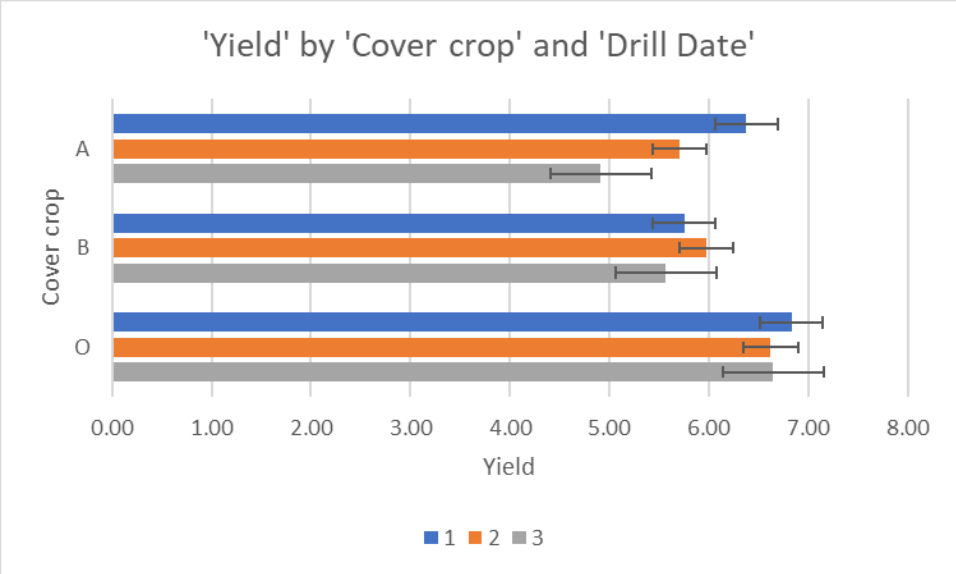

Figure 10: Tile Park Yield t/ha

The biggest influence on yield was drilling date with the earliest drilling date tending to lead although where cover crops were sprayed off just prior to drilling then the second (middle) drilling date was marginally ahead. The drilling date effect was most pronounced where the crop was drilling in to the standing cover crop, implying that this made crop establishment slightly harder. There was a trend for the no cover crop plots to yield higher and for the later drilling date the yield was significantly higher then where crop was drilled into the standing cover crop.

Tank Wilson Field

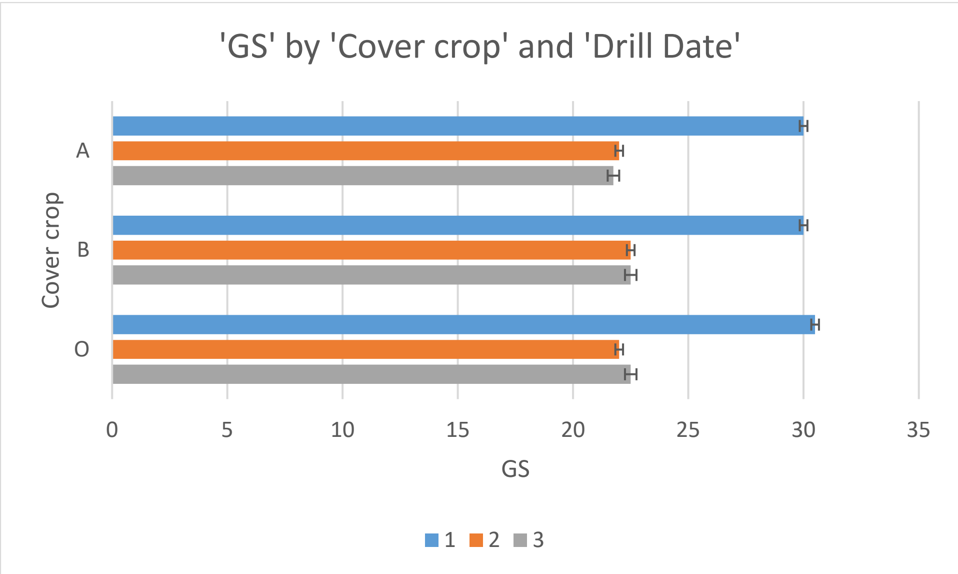

Figure 11: Tank Wilson growth stage 2 June 2022

At the June assessment timing the growth stage in the drill date 1 treatments was significantly more advanced than in the two later drill dates (Figure 11). Drill date 2 was more forward in the Tile Park Field, than here at Tank Wilson.

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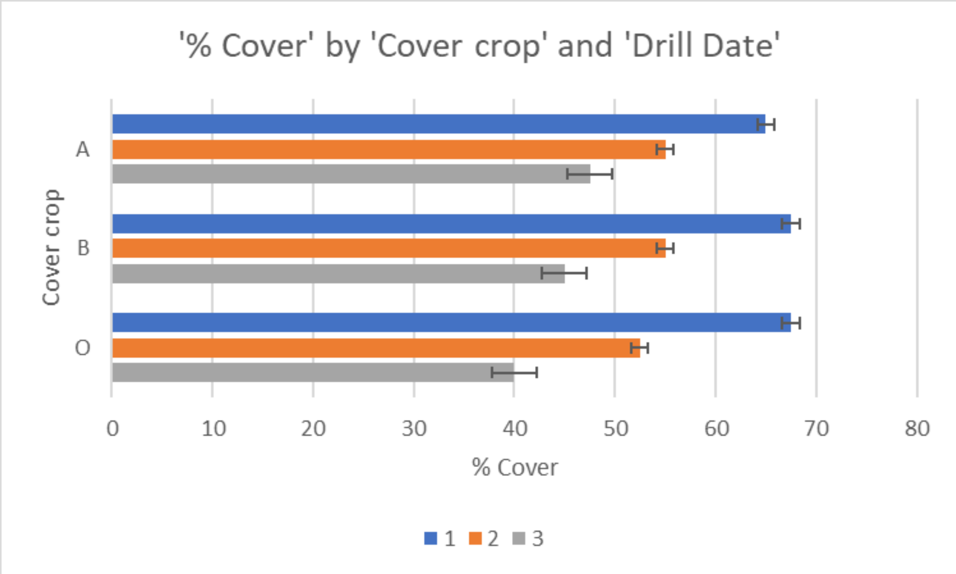


Figure 12: Tank Wilson % crop cover 2 June 2022

Again, % crop cover was higher in the earlier drilled plots with a non-significant trend for crops at the two later drill dates to be better established in the cover crop plot treatments than in the no cover crop treatment (Figure 12). This is in slight contrast to Tile Park where the earlier drill dates tended towards better establishment in the two cover crop treatments.

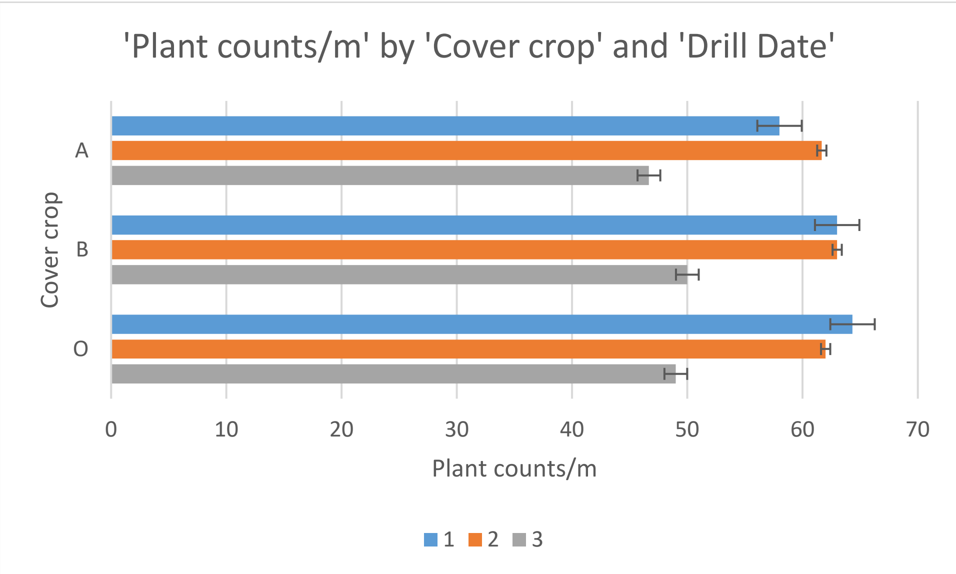


Figure 13: Tank Wilson plant counts per meter 2 June 2022

Plant counts were higher in the first two drill date treatments and lower for the latest drill date (Figure 13). Cover crop management did not influence plant counts in this field. This was in slight contrast to Tile Park where later drilling was especially penalised where it was drilled in to the standing cover crop.

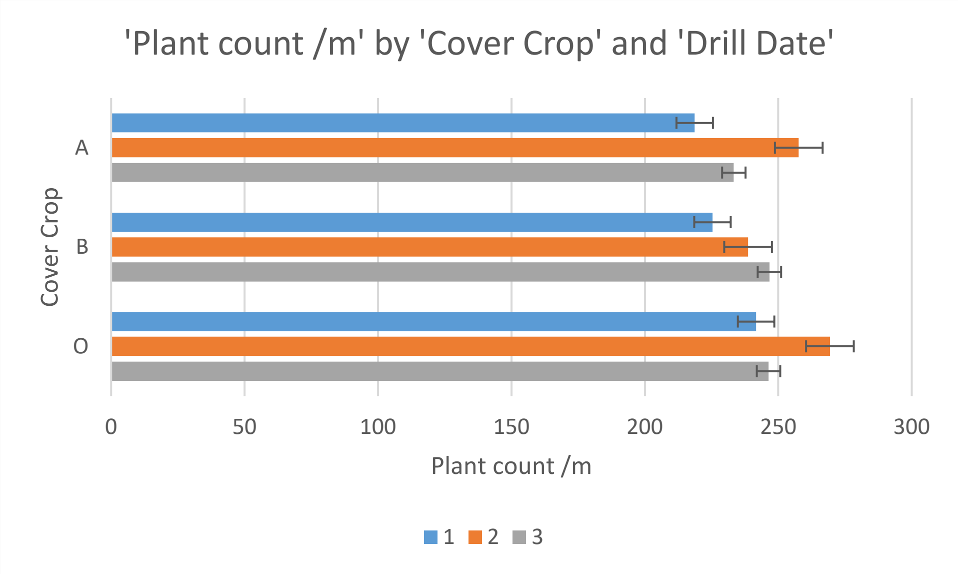


Figure 14: Tank Wilson plant counts per meter 26 July 2022

By late July, plant counts tended to be higher for the second drilling date but differences earlier had vanished so there was no significant effect on plant counst for either cover crop treatment or drill date (Figure 14). This is in contrast to Tile Park where drill date was still a significant driver of plant numbers at this timing. .

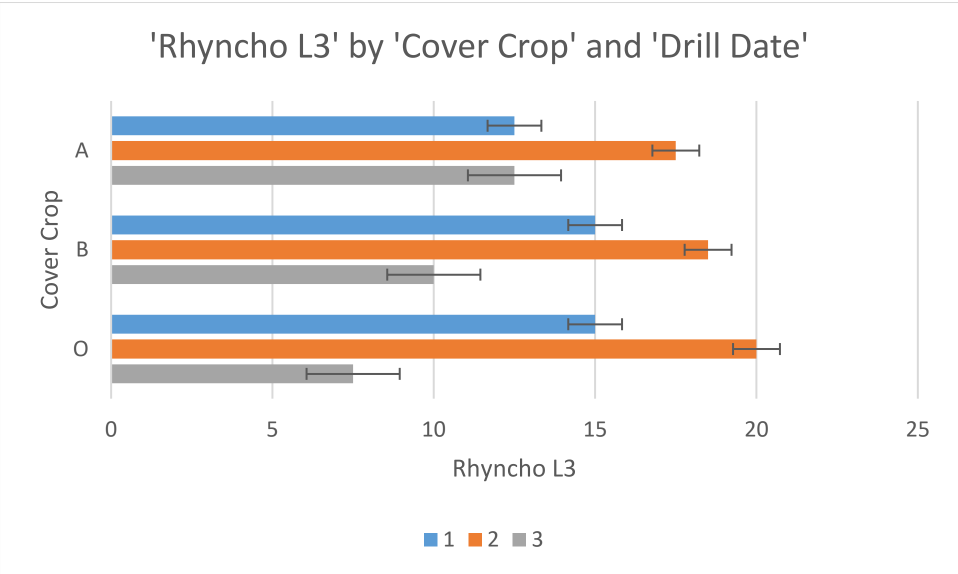


Figure 15: Tank Wilson Rhynchosporium final leaf 3 26 July 2022

Disease levels were low and rhynchosporium infected late season. Disease levels were higher in the second drill date plots and lower for drill date 2. Drill date one was more senesced which has probably reduced the disease recorded in those plots. Ramularia came in at trace levels but there were no significant differences between treatments.

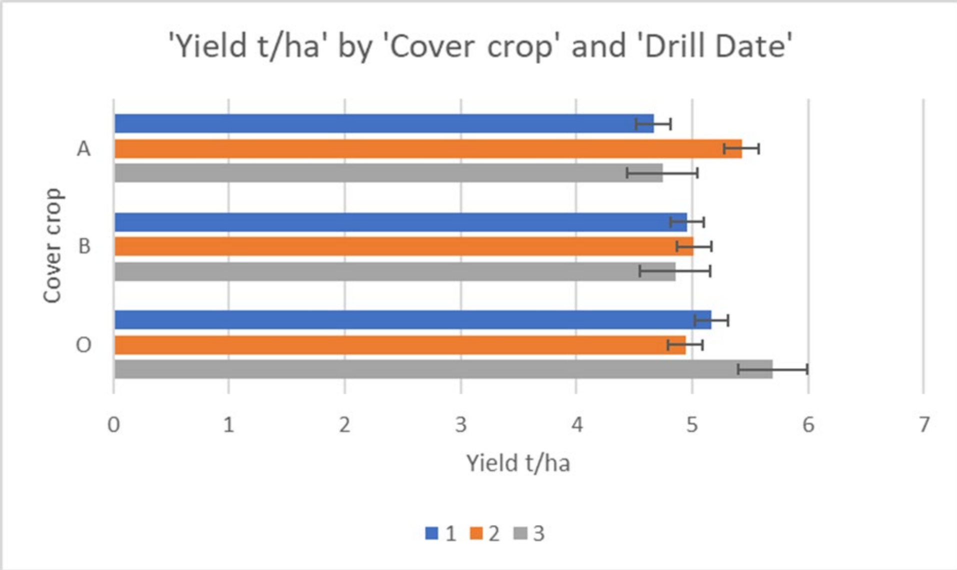


Figure 16: Tank Wilson Yield t/ha

Yield data

Average of Yield	Tile Park			
Row Labels	1	2	3	Mean
A	6.38	5.71	4.91	5.67
B	5.76	5.97	5.57	5.77
O	6.83	6.62	6.65	6.70
Grand Total	6.32	6.10	5.71	6.04

Average of Yield t/ha	Tank Wilson			
Row Labels	1	2	3	Mean
A	4.68	5.25	4.65	4.86
B	4.96	4.96	4.88	4.93
O	5.17	5.08	5.68	5.31
Grand Total	4.93	5.10	5.07	5.03

Table 2: Yield t/ha for both fields

Soil analysis

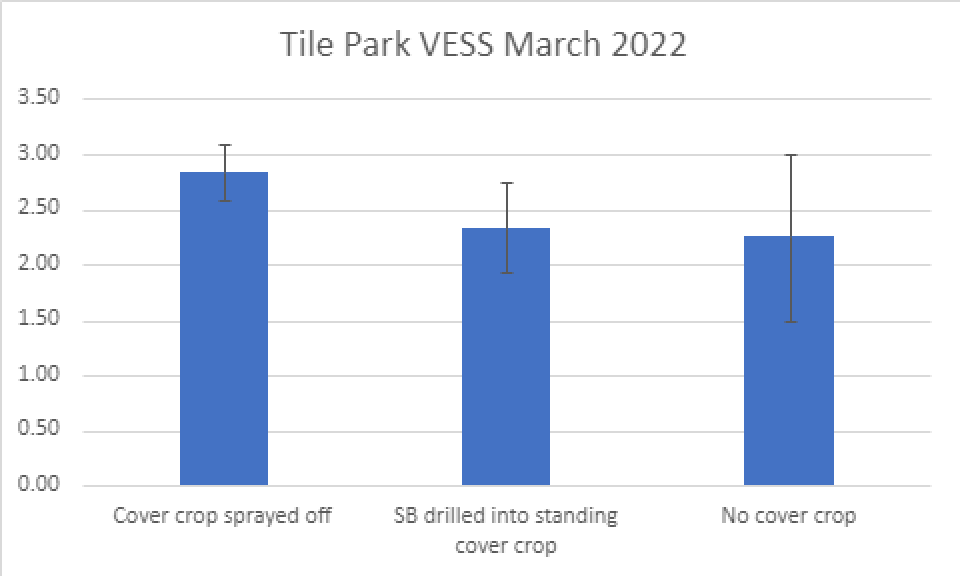


Figure 17: VESS scores Tile Park March 2022

In Tile Park there was a non-significant trend to higher VESS scores where the cover crop was sprayed off prior to drilling (Figure 17).

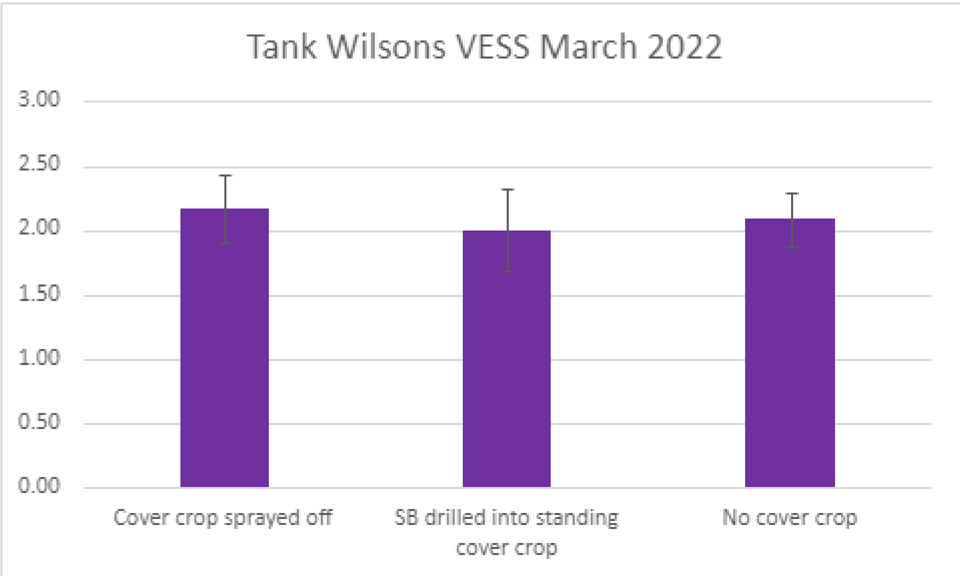


Figure 18: VESS scores Tank Wilson March 2022

The same trend is evident in Tank Wilson but differences are even smaller (Figure 18).

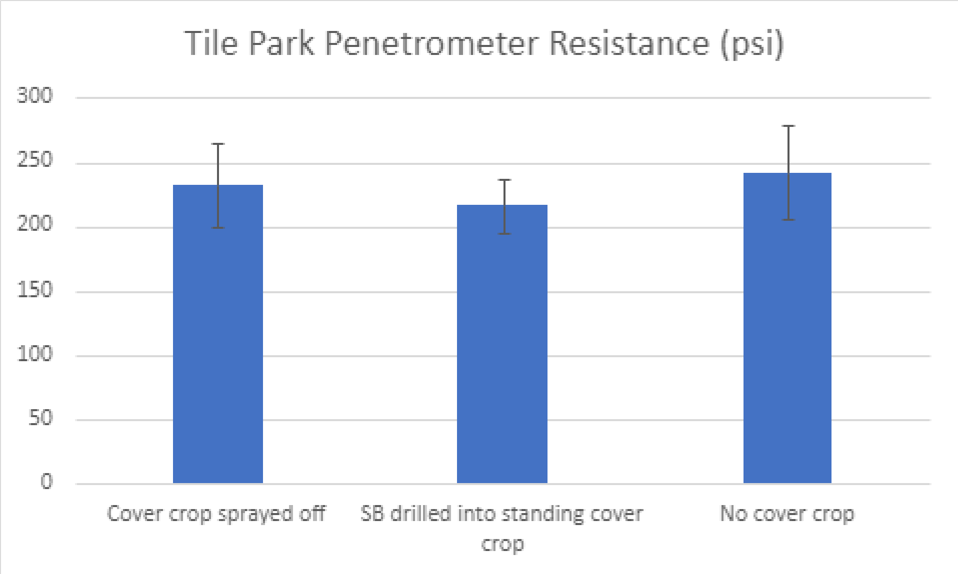


Figure 19: Penetrometer resistance (psi) Tile Park March 2022

In Tile Park there was no significant difference in penetrometer readings between cover crop management options although there was a trend to higher readings where no cover crop was established (Figure 19).

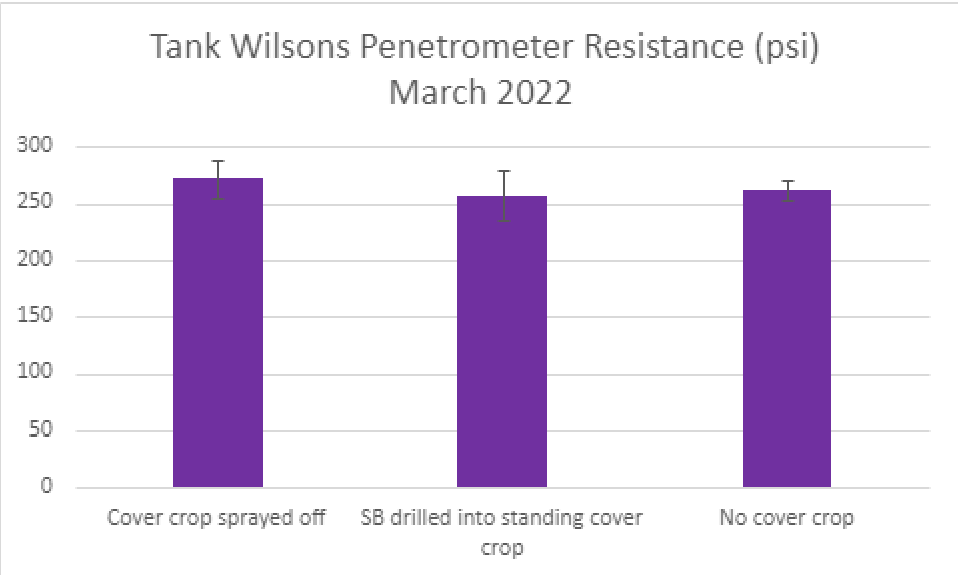


Figure 20: Penetrometer resistance (psi) Tank Wilson March 2022

In Tank Wilson penetrometer resistance was higher than in Tile Park but there were no significant differences in penetrometer readings between treatments and differences were even smaller than in Tile Park (Figure 20).

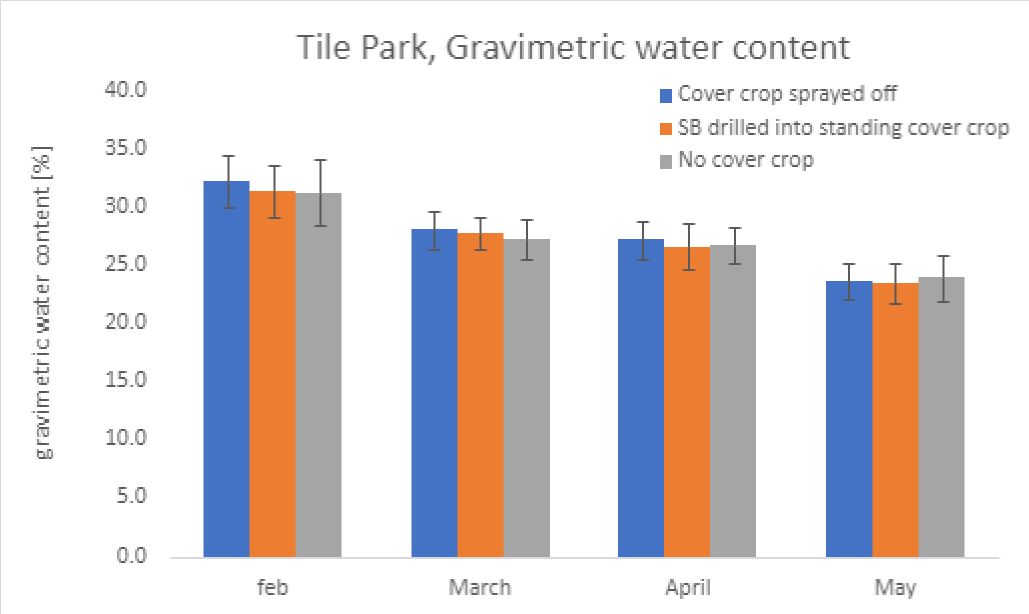


Figure 21: Gravimetric water content % Tile Park 2022

In Tile Park there was a non-significant trend to higher moisture levels where the cover crop was retained longest and sprayed off after drilling (Figure 21). This trend had disappeared by May.

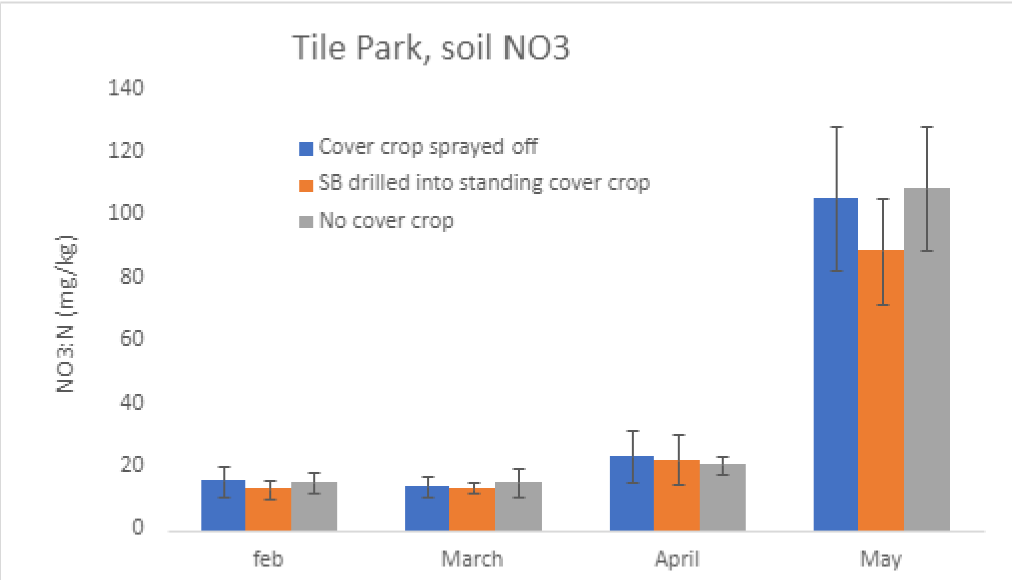


Figure 22: Soil nitrate NO_3 mg/kg Tile Park 2022

In Tile Park there were no significant differences in soil nitrate levels as a result of cover crop management options although by May there was a trend for the treatment where the cover crop had been retained until after drilling to have lower nitrate levels (Figure 22).

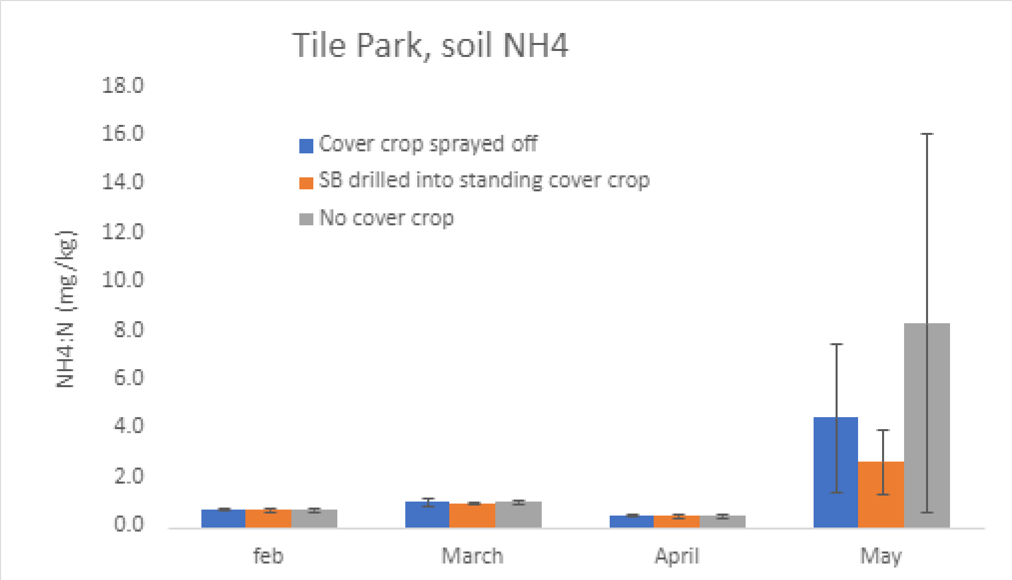


Figure 23: Soil ammonium NH_4 mg/kg Tile Park 2022

There were no significant differences in ammonium levels In Tile Park and by May they were highly variable but there was a trend for them to be lower where the cover crop was retained until after drilling (Figure 23).

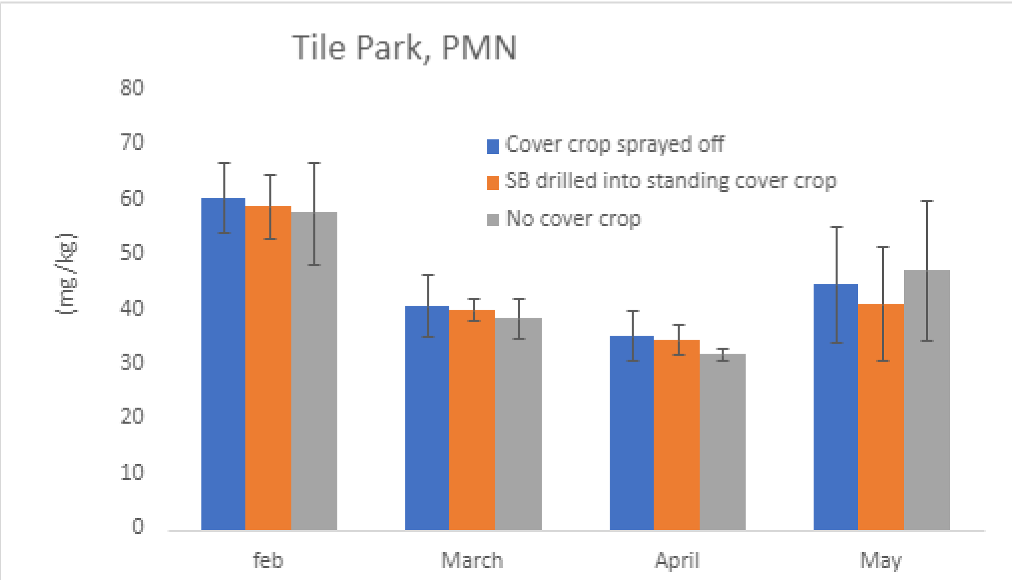


Figure 24: Soil Potentially Mineralisable Nitrogen mg/kg Tile Park 2022

In Tile Park there was a non-significant trend for higher the PMN to be higher in the two cover crop treatments and lower where there was no cover crop. This effect had disappeared by May when the lowest PMN levels were recorded where the cover crop was detained the longest and were higher (non-significant) where no cover crop had been used (Figure 24).

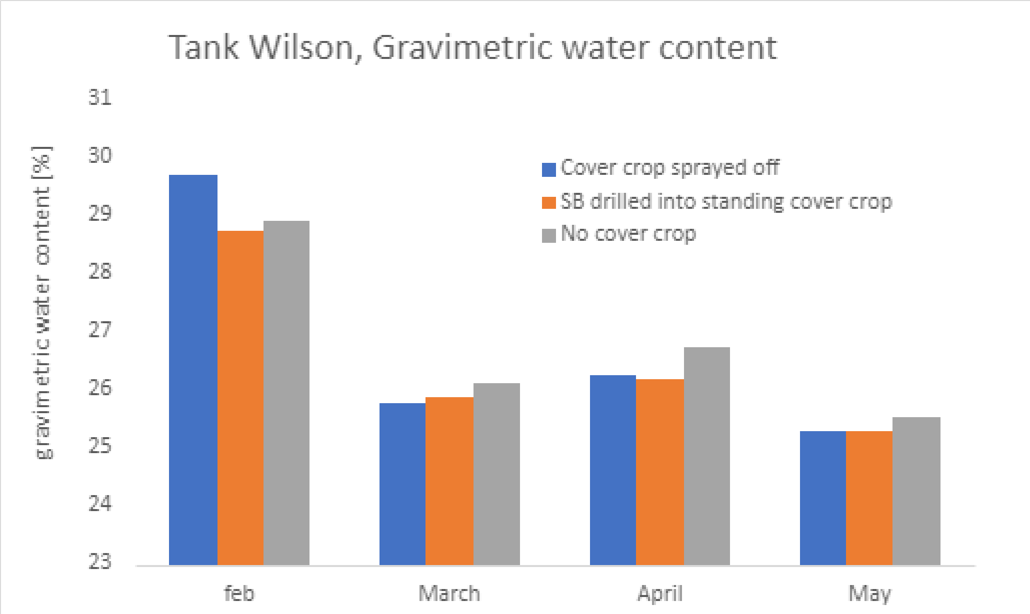


Figure 25: Soil Gravimetric water content % Tank Wilson 2022

In Tank Wilson field moisture content dropped more rapidly between February and March than in Tile Park where the decline over time was more steady. There were no significant differences in moisture between cover crop options at any timing although a trend in February (which was seen in Tile Park) for them to be higher where the cover crop was sprayed off prior to drilling (Figure 25).

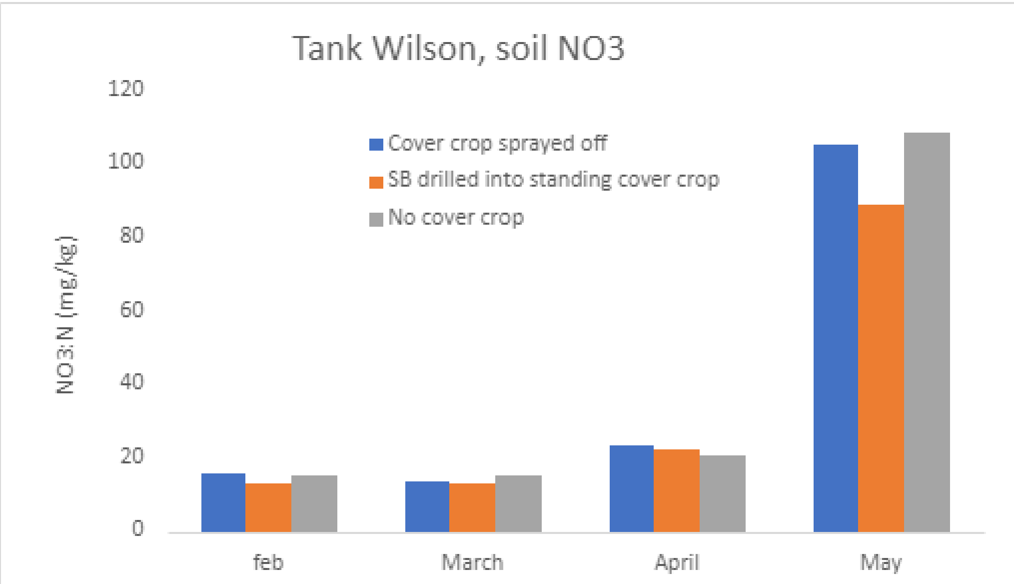


Figure 26: Soil Nitrate NO_3 mg/kg Tank Wilson 2022

In Tank Wilson there were no significant treatment effects from cover crop management on soil nirate levels although the same trend in May data was seen in this field and in Tile Park where nitrate levels were lower where the cover crop was retained the longest (Figure 26).

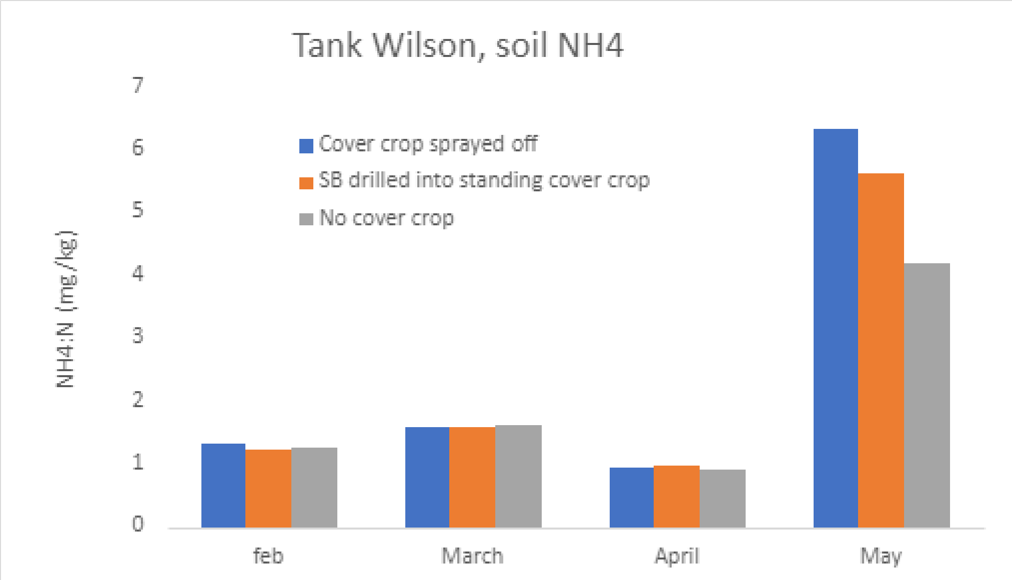


Figure 27: Soil Ammonium NH_4 mg/kg Tank Wilson 2022
There were no significant differences in ammonium levels as a result of cover crop management and the trend in the May data was the reverse of that seen in Tile Park - in Tank Wison field ammonium levels in May had a trend to be lower than in Tile Park (Figure 27).

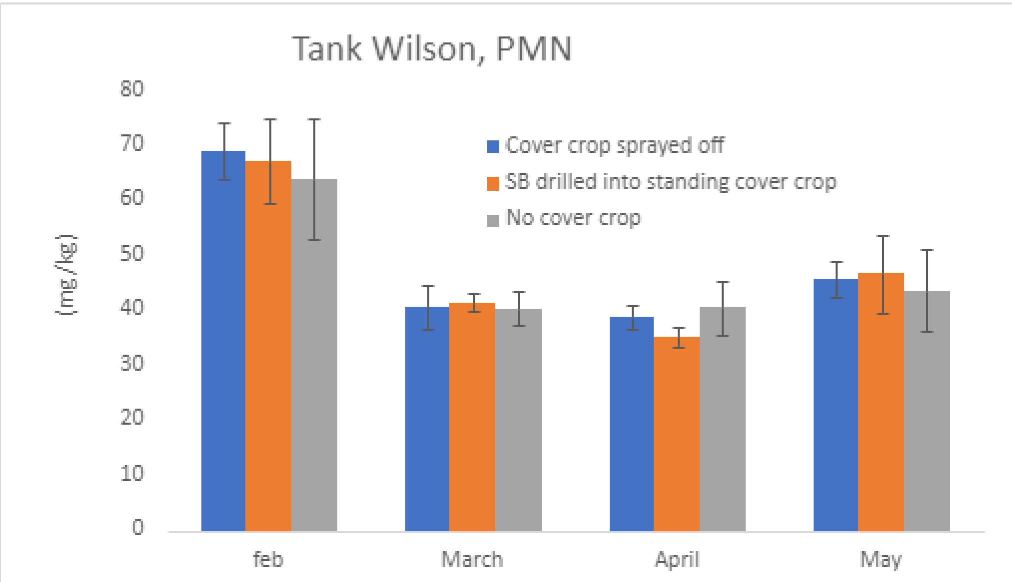


Figure 28: Soil Potentially Mineralisable Nitrogen mg/kg Tank Wilson 2022

In Tank Wilson field there was a non-significant trend for higher PMN to be higher in the two cover crop treatments at the February assessment although this was not evident in March and April as it was in Tile Park where it seemed to persist as a trend. and lower where there was no cover crop. (Figure 28).

Action points for farmers and agronomists

- Cover crops may help with water retention and soil health
- Drill date is a key driver of yield
- Crop establishment might be reduced by direct drilling in to a cover crop.

1b. Impact of Cover Crop on pests, beneficial insects and weeds

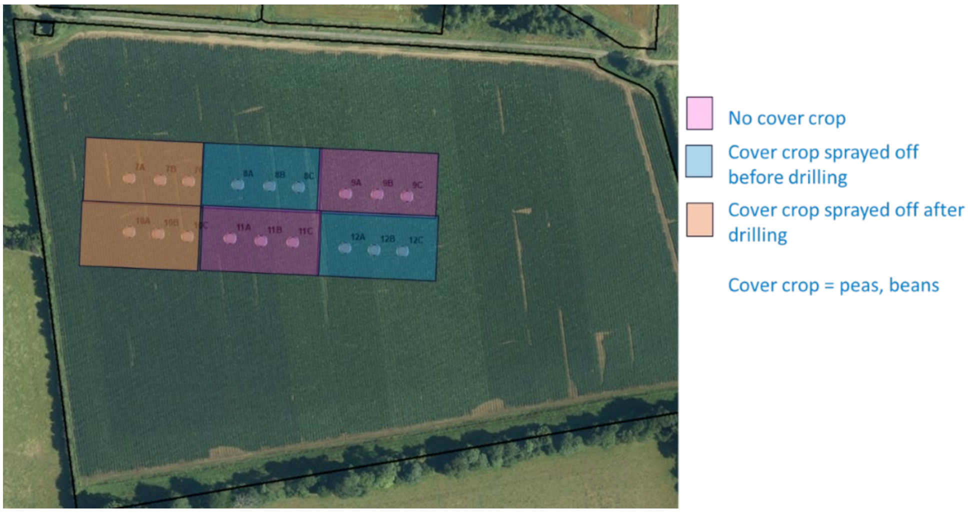
Trial leader: Lorna Cole, SRUC

How did the project address this?

A replicated field trial was established as described above (Section 1a). The wider trial additionally explored three sowing dates, however, to enable the collection of robust invertebrate data focus was on the second drill date (Drill date 2 – local practice +7-10 days). This date was selected following discussion with the land manager David Aglen who indicated that this date was standard practice at the Strategic Farm.

Table 3. *Fields surveyed including field size, crop, establishment, and adjacent field margin habitat.*

Field Name	Area (ha)	2021 Harvest Crop	2022 Crop	Habitat field margin adjacent to
Tile Park	12.6	Winter Wheat (Cultivated + livestock)	Spring barley direct drilled	Woodland
Tank Wilsons March	16.0	Winter Wheat (Direct drilled)	Spring barley direct drilled	Grass



a) Tile park

b) Tank Wilson

Figure 29. *Arial overview highlighting the six treatment plots, and three sampling locations within each plot where invertebrate surveying was conducted at Tile Park (a) and Tank Wilson (b).*

Assessments

Survey techniques for pests and natural enemies were specifically selected that could readily be undertaken by farmers with minimum training and without the use of specialised equipment. As such all techniques are easy to use and equipment easily sourced.

Surveying was conducted between 11th and 17th May during crop establishment (Growth stage: Late tillering 25-29). This targeted a period when the crop is particularly vulnerable to pests. An overview of the sampling protocol for each plot is provided in Figure 30.

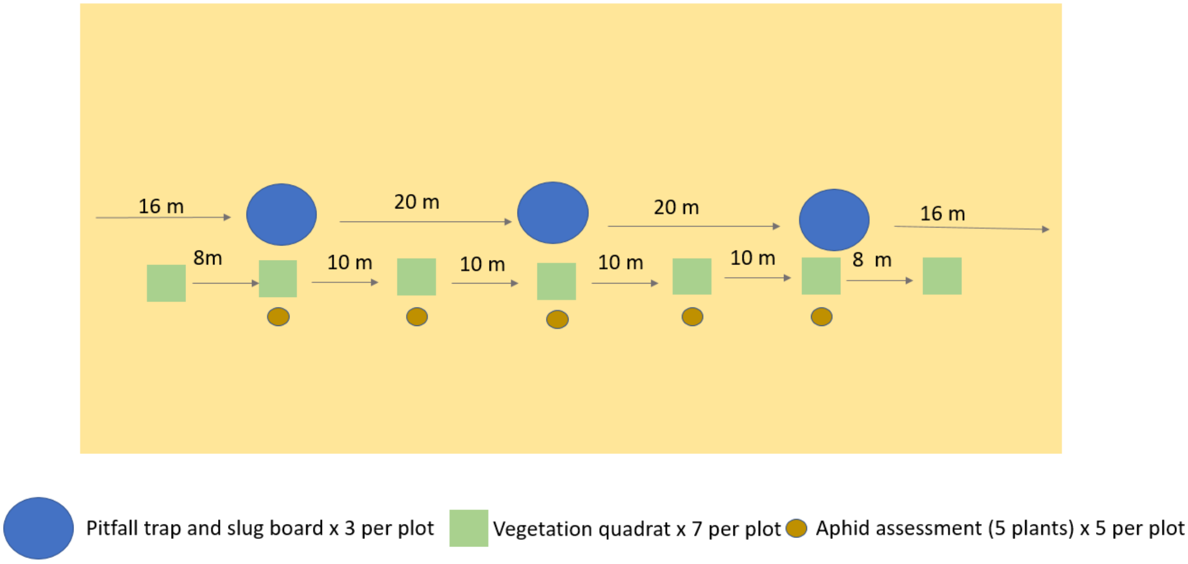


***Figure 30**. An overview of the sampling protocol adopted in each treatment plot.*

Objective one: Impact of cover crop treatments on natural enemies

Cover crops can provide food and refuge for natural enemies overwinter and thus could be a valuable tool in integrated pest management strategies (Martinez et al., 2020). To determine the impact of cover crops, and the timing of their termination on natural enemies, pitfall traps were deployed to survey ground active predators (e.g. ground beetles, spiders) and parasitoids (i.e. parasitic wasps). In each treatment plot, three pitfalls were established on 11/05/2022 and collected six days later on 17/05/2022. Traps consisted of small plastic beakers (520 ml) submerged into the ground such that the trap mouth was flush with the soil surface and contained monopropylene glycol as a preservative (saline solution can provide an effective alternative) (Figure 31). Traps were covered with chicken wire to prevent small mammals entering the trap.

Figure 31. *Photograph of the pitfall trap and slug trap. Three such sampling points were established in each plot.*

Objective two: Impact of cover crop treatments on pests

As cover crops may act as a green bridge, allowing pests and pathogens to persist overwinter (Bakker et al., 2016; Winsor, 2020) we monitored two key pest taxa: slugs and aphids.

Slugs were monitored using baited traps consisting of inverted plant saucers baited with a couple of tablespoons of poultry mash and traps were left in place for six days (Figure 31). Three slug traps were established in each plot in close proximity to the pitfall traps. Surveying at the SFS in 2021 found that crows interfered with the slug traps – lifting the traps to access the grain. To counteract this, baited traps were secured with a cane.

Aphid populations were assessed using visual counts of aphids on the establishing crop. In each plot, five distinct survey points were selected (with three of these points coinciding with the pitfall and slug sampling) and at each point five barley plants were visually inspected for aphids and natural enemies (e.g. hoverfly larvae, aphids etc.) and diseased or mummified aphids (i.e. 25 plants per plot).

Objective three: Impact of cover crop treatment on weeds

To determine if cover crop treatments influenced the weed burden in the follow-on cash crop, weed assessments were conducted. In each plot, a transect was walked in the centre of each treatment plot, and weed burdens were assessed at seven points along this transect. At each point, the surveyor's feet were placed at right angles (to form a 25 x 25 cm quadrat) and weeds were assessed in this area.

What results has the project delivered?

Objective one: Impact of cover crop treatments on natural enemies

Key findings natural enemies

- Money spiders were more abundant in pitfall traps than wolf spiders reflecting the fact they can rapidly colonise arable fields during spring (Fig 32). The abundance of wolf spiders differed considerably between the two fields (i.e.Tank Wilson average = 5 and Tile Park average = 0.94). Wolf spiders tend to be less tolerant to disturbance and differences between fields may reflect the lower incidence of soil disturbance in Tank Wilson in recent years, with Tile Park recently been cultivated for vegetables.

- In both fields, money spiders occurred in their lowest abundance in pitfalls established in plots where the cover crop was sprayed off before drilling, than cover crops that were terminated after drilling or no cover crop treatments (Fig 32). There was quite a lot of variation between the two plots in a field and further investigation will help determine if these trends are robust. Wolf spiders, on the other hand, tended to occur at their lowest abundance in plots without a cover crop, however, abundances of wolf spiders were low in pitfalls making it difficult to draw any definitive conclusions.

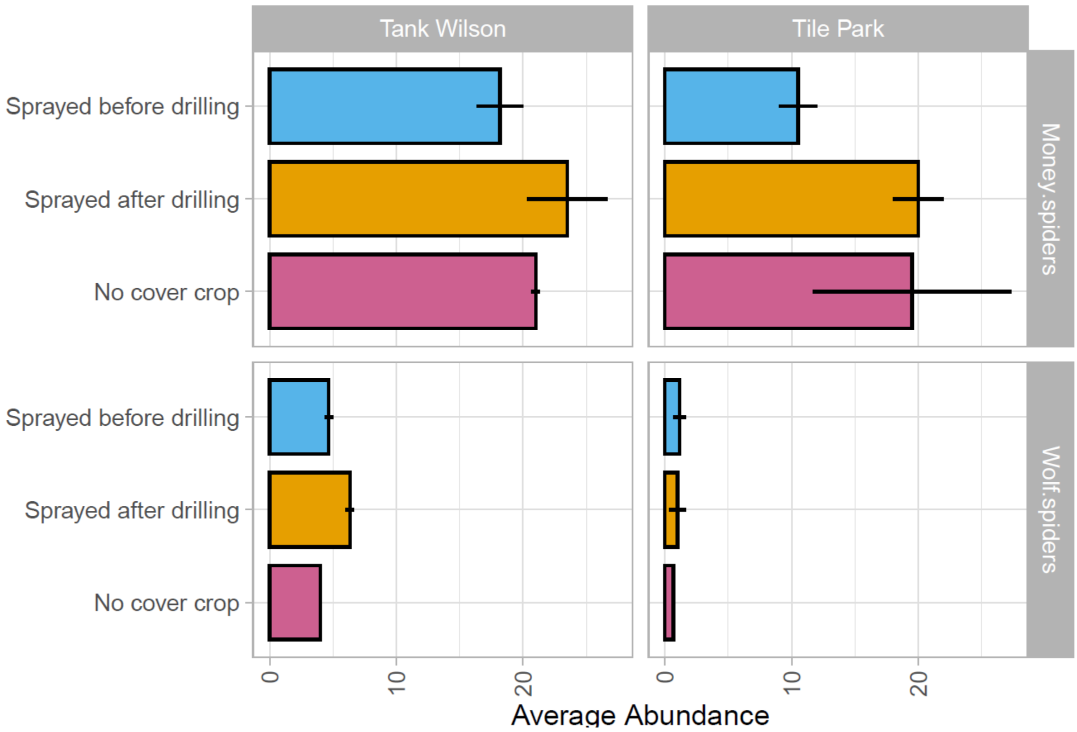


Figure 32. *Summary of the average abundance of money spiders and wolf spiders caught in pitfall traps at Tank Wilson and Tile Park in each of the three cover crop treatments.*

- No consistent trend was found with respect to the abundance of parasitic wasps recorded from pitfall traps in the three treatments. This may reflect the fact that parasitic wasps were not actively overwintering in the field, but instead wintering in the grassy field margins.

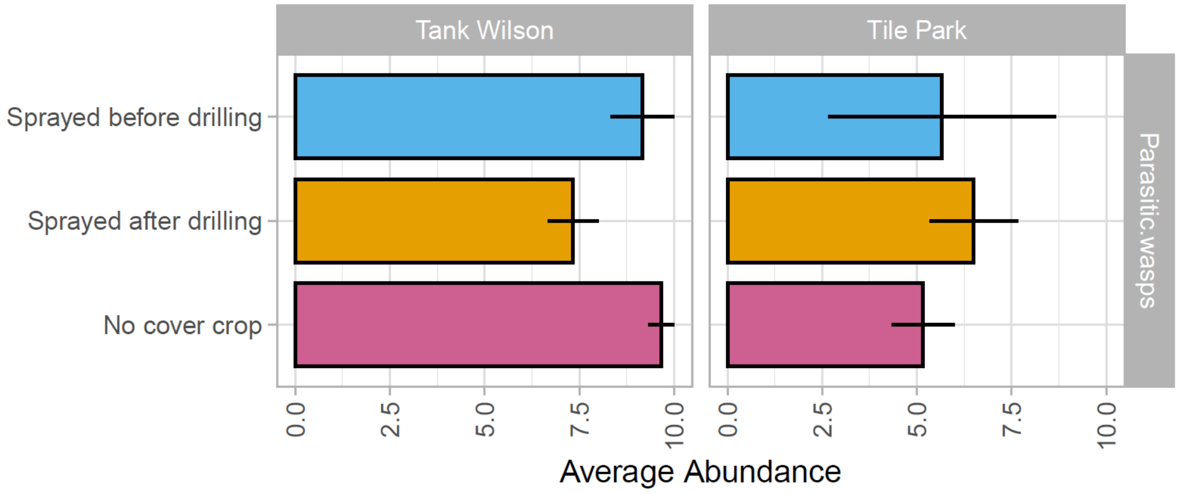


Figure 33. *Summary of the average abundance of parasitic wasps caught in pitfall traps at Tank Wilson and Tile Park in each of the three cover crop treatments.*

Key findings ground beetle assemblage structure

- A total of 510 ground beetles were recorded from pitfall traps at the SFS and these were identified to 27 different species. The average number of species trapped in pitfalls in Tank Wilson (average = 6.6) was slightly higher than Tile Park (average = 4.6). There was considerable variation between the three traps established in a specific plot highlighting that ground beetles are influenced by variations in microhabitat.

- Focussing on the key species of ground beetles recorded from the SFS, highlighted considerable differences in the assemblages in the two fields. Field had a greater impact on assemblage structure than cover crop treatment. In Tank Wilson, the community was dominated by *Bembidion lampros*, *Bembidion tetracolumn* and *Harpalus rufipes*, whereas in Tile Park the highly mobile *Nebria brevicollis* was the dominant species. It is likely that beetle populations were influenced by soil characteristics, surrounding land use and historic management. The relatively high abundance of *Harpalus rufipes* in Tank Wilson field is interesting. In Scotland this omnivorous species does not typically occur at high densities in intensively managed arable fields which may suggest it has benefitted from the low level of soil disturbance in recent years due to the adoption of conservation tillage.

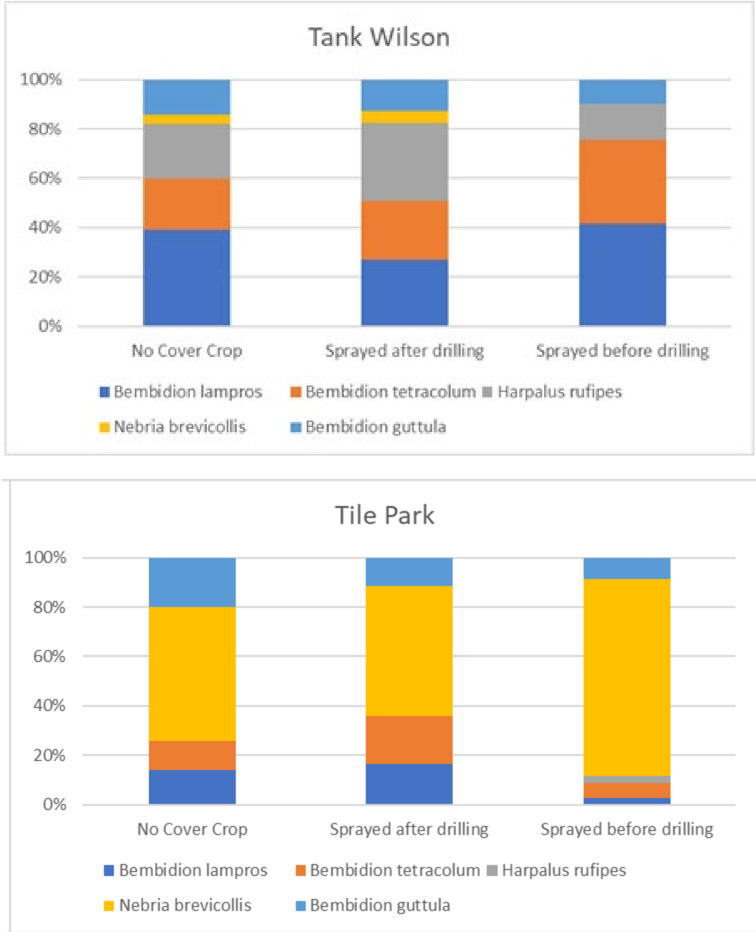


Figure 34. *Summary of the average percentage abundance of key ground beetle species caught in pitfall traps at Tank Wilson and Tile Park in each of the three treatments.*

Key findings ground beetle abundance and richness

- At Tile Park there was a tendency for the abundance and species richness (i.e. number of species) of ground beetles to be lower in the cover crop treatment that was sprayed immediately prior to drilling spring barley. This may reflect that such plots had less prey items, or that these plots were situated closer to field margins. This trend was also apparent at Tank Wilson, however, the magnitude was a lot lower, and there was considerable overlap between abundance and richness in the three treatments. Given that assemblage structures differed considerably between the two fields, such discrepancies between fields are expected.

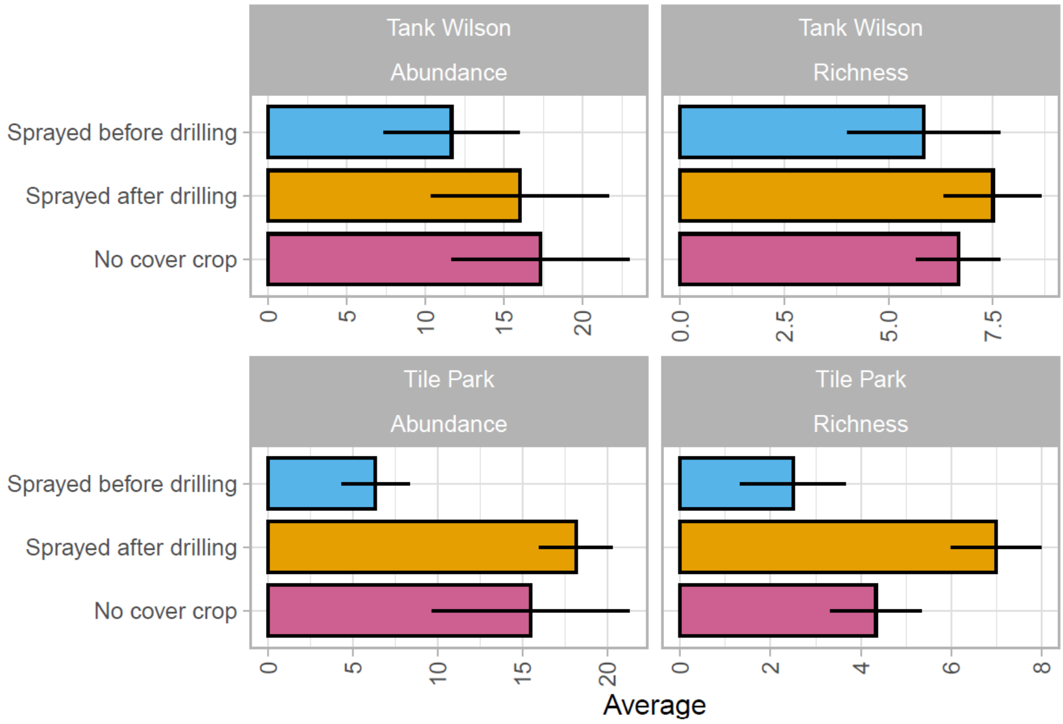


Figure 35*. Impact of cover crop treatment on ground beetle abundance and species richness*

Objective two: Impact of cover crop treatment on pests

Key findings slugs

- Slug densities were typically higher in 2022 than in 2021. The impact of establishing a cover crop varied between the two fields. In Tank Wilson slug populations were lowest in plots without a cover crop, while in Tile Park this did not hold true. This highlights that field specific factors impact on the response of slugs to cover crops.

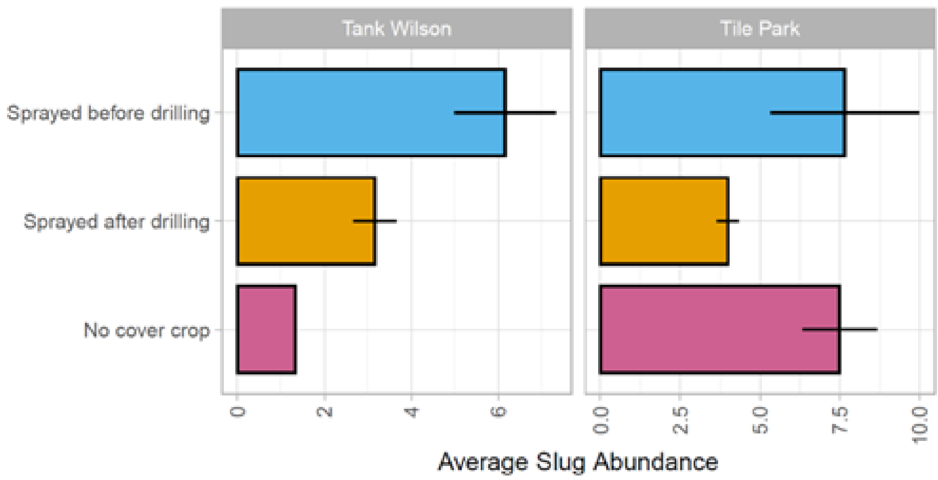


Figure 36*: Impact of cover crop treatment slug densities*

- When comparing the timing of spraying off the cover crop, both fields indicated plots that were sprayed after drilling spring barley had a lower slug abundance than crops sprayed before drilling. This may reflect that more recent spraying had resulted in reduced organic matter, directly impacting on slug densities.

Key findings aphids

- Visual searches found only four aphids in 2022 indicating that few aphids were overwintering in the fields. All four aphids were found in the cover crop treatment that was sprayed after drilling and this may indicate that spraying cover crops before drilling may reduce the green bridge effect. However, it is important to note that the low occurrence of aphids means we cannot put much weight on this result. This does leave an interesting avenue for further investigation, particularly in the South where overwintering of aphids in the crop is likely to be more prevalent due to milder conditions.

Objective three: Impact of cover crop treatment on weeds

Key findings weeds

- The occurrence of key weed species differed between the two fields with the incidence of weeds being higher in Tile Park than Tank Wilson (Table 4). The weed species present also varied with groundsel being the dominant species in Tile Park and scentless mayweed dominant in Tank Wilson.
- In both fields, weeds were most prevalent in the no cover crop treatment, reflecting spraying with glyphosate reduced the weed burden (Figure 37). There was no difference in weed prevalence in the two cover crop treatments, indicating that the timing of spraying had no impact on weed incidence.

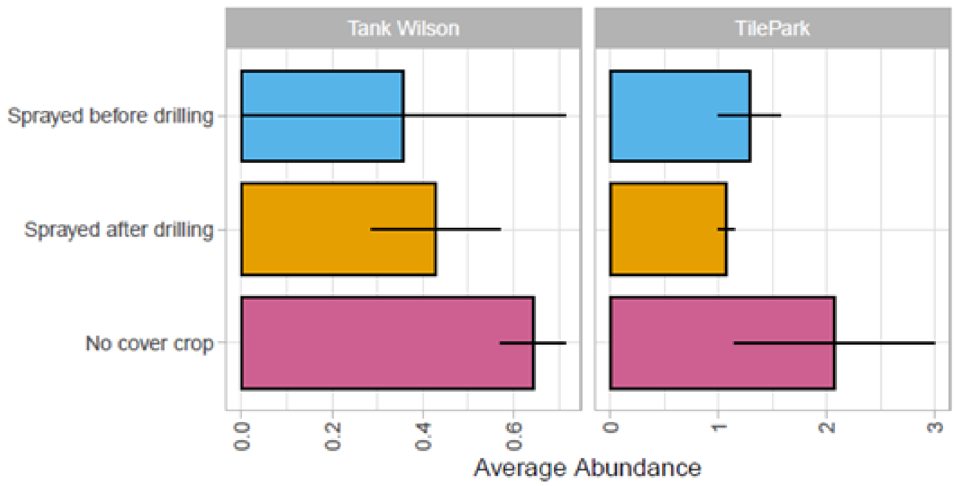


Figure 37: *Impact of cover crop treatment on weed incidence*

Table 4. *Frequency of weed species summed over the seven quadrats and two plots. Weeds are listed in order of prevalence, with the most common species listed first.*

	Tank Wilson			Tile Park		
	No cover crop	Sprayed after drilling	Sprayed before drilling	No cover crop	Sprayed after drilling	Sprayed before drilling
Groundsel ***Senecio vulgaris***	0	0	0	19	8	13
Willowherb ***Epilobium* sp.**	2	1	1	7	2	2
Annual Meadow Grass ***Poa annua***	0	1	1	1	4	0
Scentless Mayweed ***Tripleurospermum inodorum***	3	1	1	0	0	0
Cleaver ***Galium aparine***	1	1	1	0	1	0
Mouse-eared chickweed	0	0	0	0	0	1
Field forget-me-not ***Myosotis arvensis***	1	0	0	0	0	0
Creeping thistle ***Cirsium arvense***	0	0	0	0	0	1
Potato ***Solanum tuberosum***	0	0	0	0	0	1
Unidentified cotyledon	2	2	1	2	0	0
Weed incidence	**9**	**6**	**5**	**29**	**15**	**18**

Action points for farmers and agronomists

Pests and natural enemies responded to the presence of cover crops (when compared to no cover crops) differently in the two study fields. Field characteristics and timing of termination had a greater impact than simply the presence of a cover crop.

In agreement with previous research, initial findings suggest that conservation tillage may benefit in field populations of some natural enemies (Kromp 1999). Biodiversity is thought to provide an insurance against environmental change, and consequently supporting a higher diversity of natural enemies is like to ensure pest control services remain stable under a variety of situations. These results are, however, only drawn from two fields and a robust experimental protocol specifically designed to determine the impact of tillage on natural enemies is required.

Natural enemies provide an important first line of defence against pest species during crop establishment. Money spiders and ground beetles tended to occur in their lowest abundance in cover crops that were terminated before drilling, and this impact was more pronounced in Tile Park than Tank Wilson. In agreement with these findings, the higher slug populations in cover crops terminated before drilling when compared to after drilling indicates lower rates of predation. These initial findings indicate that later termination of cover crops could provide an important tool to support natural enemies in integrated pest management strategies.

Links to further information/references

Bakker, M.G., Acharya, J., Moorman, T.B., Robertson, A.E. and Kaspar, T.C., 2016. The potential for cereal rye cover crops to host corn seedling pathogens. Phytopathology, 106(6), pp.591-601.

Kromp, B., 1999. Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. Agriculture, Ecosystems & Environment, 74(1-3), pp.187-228.

Martinez, L., Soti, P., Kaur, J., Racelis, A. and Kariyat, R.R., 2020. Impact of cover crops on insect community dynamics in organic farming. Agriculture, 10(6), p.209.

Northeast, N.E., Southern, S. and Western, W., Exploring Cover Crops in an Integrated Approach to Reduce Disease Pressure and Increase Beneficial Insects in Watermelon Production.

Winsor, S., 2020. How to Anticipate Pests from Cover Crops Migrating into Cash Crops. Crops & Soils, 53(2), pp.18-23.

2. Optimising nitrogen application

Trial leader: Steve Hoad, SRUC

Overview of findings

This work investigated use of two approaches to applying foliar nitrogen (N) compared to our standard application of ammonium nitrate.

Overall, we have good link between crop measures such as leaf area index (LAI) and leaf chlorophyll (SPAD) to grain yield. This project is also testing a new measure of the crop nitrogen (N) pool, as the product of LAI x SPAD.

The value of BRIX measurements remains uncertain, but we continue to test how this measurement reports on change in crop disease levels and nutritional health, as well how spatial and temporal change in BRIX matches with differences in yield.

For yield mapping, we need to ensure that crop measurement zones are representative of the full tramline length in order to improve the relationship between crop measurements and yield.

When Farm Bench data are available, we report the full production, economic and efficiency of the different nitrogen treatments, and estimate differences in N fertilisation efficiency between standard granular N and foliar N.

The measurements in this work were common to the crop nutrition trial (Section 3).

What was the challenge/demand for the work?

Timing nutrient applications correctly 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 looks to compare a conventional treatment with programmes that combine standard ammonium nitrate application with smaller, more frequent applications of foliar nitrogen.

How did the project address this?

Trial design

Through a common measurement programme, this nitrogen trial was linked closely to the crop nutrition trial (Section 3). A comparison of foliar N application with a standard granular N application was made in a winter wheat field (Castle Heggie) sown with the cultivar LG Skyscraper and using a tramline trial based on three treatments replicated twice (six tramlines) as follows:

1. Industry standard: All nitrogen applied conventionally as ammonium nitrate (AN)
2. Farm adjusted I: First application of AN followed by 6 foliar applications at 10-15 kg/ha
3. Farm adjusted II: First application of liquid urea-AN followed by 6 foliar applications at 10-15 kg/ha

Trial layout is presented in Figure 38. For convenience of farm N application, the standard N tramlines were placed centrally in the trial design, with the farm adjusted foliar N treatments placed either side.

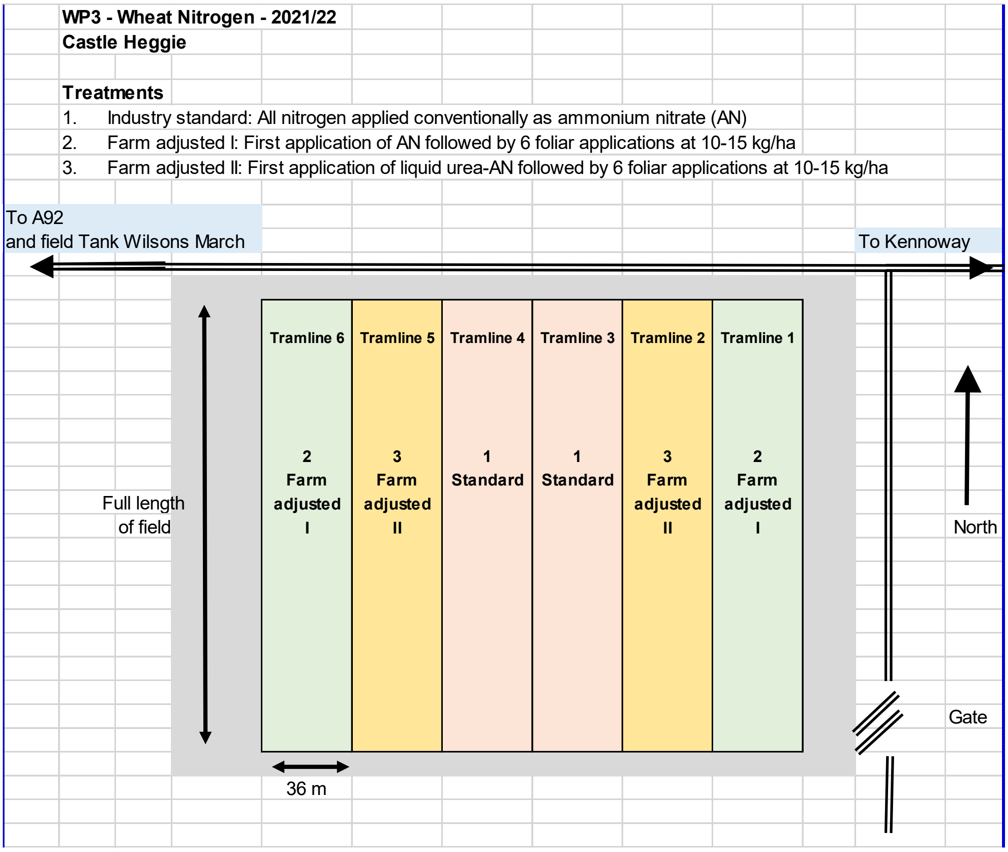


Figure 38. *Nitrogen trial layout in Castle Heggie.*

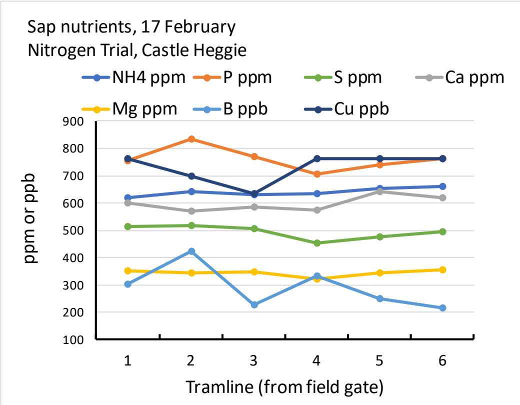
Assessments

The measurements below were be undertaken at key crop growth stages (see project assessment schedule) to identify changes in crop growth and health, and to guide the farm's crop management.

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

What results has the project delivered?

To assess base line crop health and nutrient status, sap analysis was carried out at growth stage 13-21 on 17th February prior to application of N fertiliser treatments (Figure 39). Overall, there was high uniformity in nutrient status across the sample zone. Apart from boron there was no evidence for any nutrient trends in this trial.



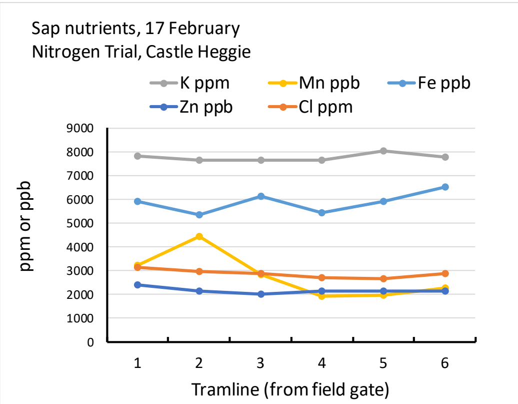


Figure 39. Left upper and lower, sap nutrients in leaves sampled at GS13-21 in Castle Heggie.

At GS13-21, BRIX and SPAD readings varied across the tramlines, with SPAD readings being greatest in the west side of the field (tramlines 4 to 6). Any trends were checked after the start of treatment applications (Figure 40).

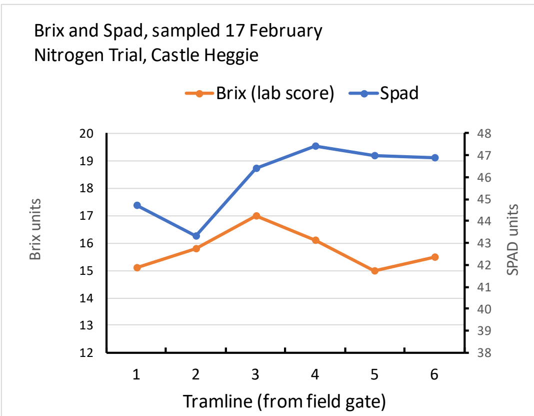


Figure 40. *BRIX and SPAD readings at GS13-21.*

BRIX, Spad, crop size and N pool were assessed at four further growth stages, including ear emergence on 31st May 2022 (Figure 41), when then was a trend across the field in both SPAD and BRIX readings. For example, the crop in tramline 2 (farm adjusted foliar N II) was thinner and paler, and had the lowest crop N pool, whilst in tramline 3 (standard N), the crop was also thin with a low crop N pool.

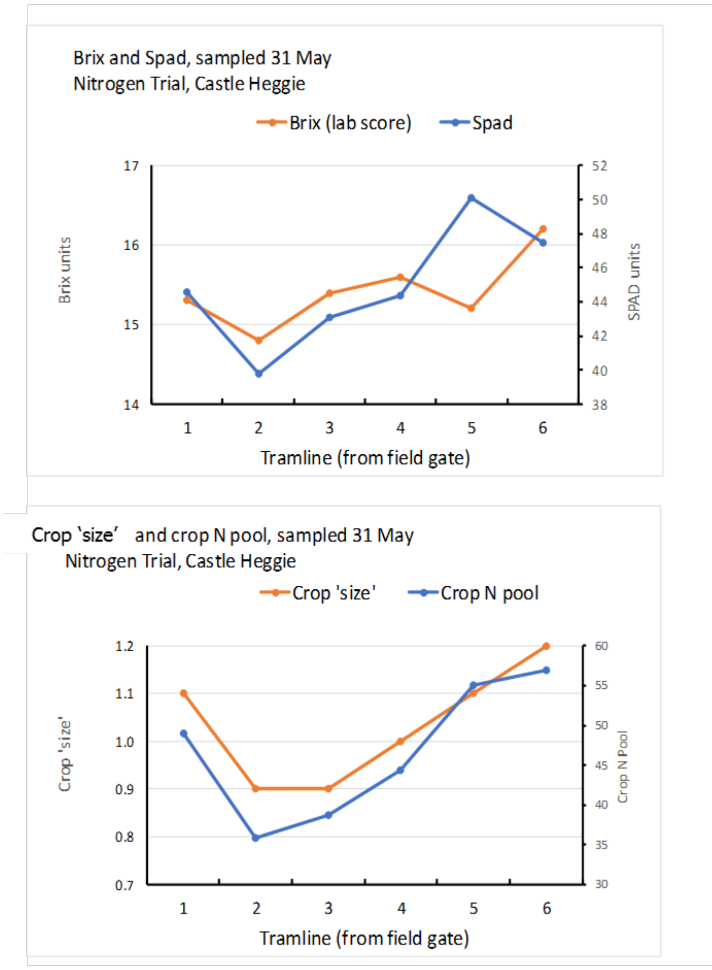


Figure 41. BRIX, Spad, crop size and N pool were assessed at ear emergence on 31st May 2022.

Grain yield for each tramline is presented in Figure 42, with a whole field yield map shown in Figure 43. Mean treatment effects indicated that the standard N treatment had a higher level of N offtake and grain yield than the two foliar N treatments (Figure 44). More interpretation of this response will be carried when Farm Bench data are available.

At harvest, it was apparent that Castle Heggie field had a north to south gradient in soil moisture, with the north end of the field being of increased soil moisture capacity and higher grain yield. This gradient needs to be considered in relation to the crop measurement and sampling zone which was in the south-central part of the field.

Subsequently, analysis of crop measurement (LAI, SPAD, BRIX and N pool) in relation to grain yield was carried in respect to (1) the full tramline and (2) an estimate of yield from the crop sample zone using the yield map.

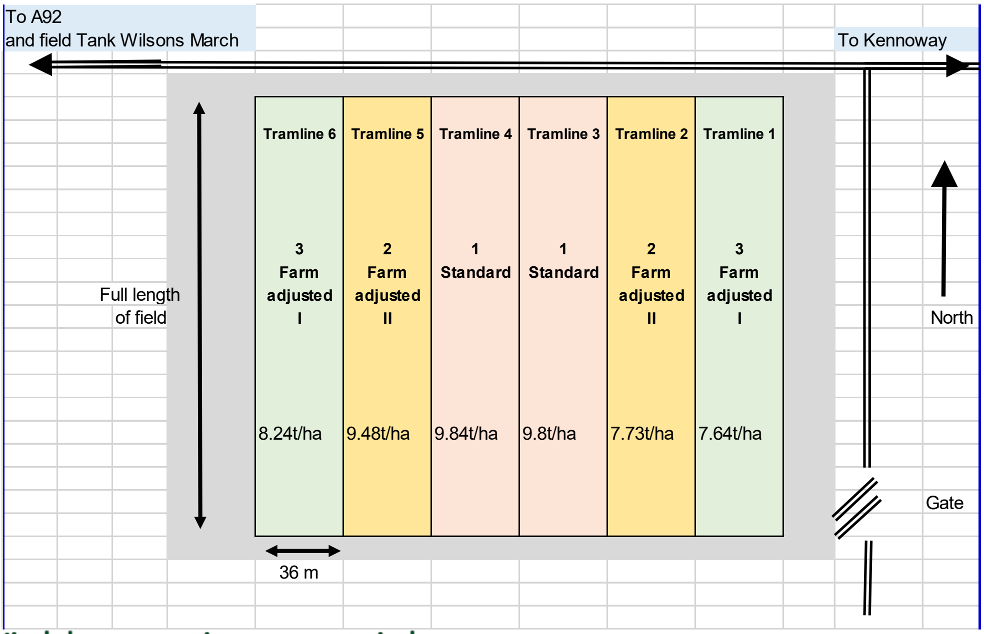


Figure 42. Grain yield in each tramline, Castle Heggie.

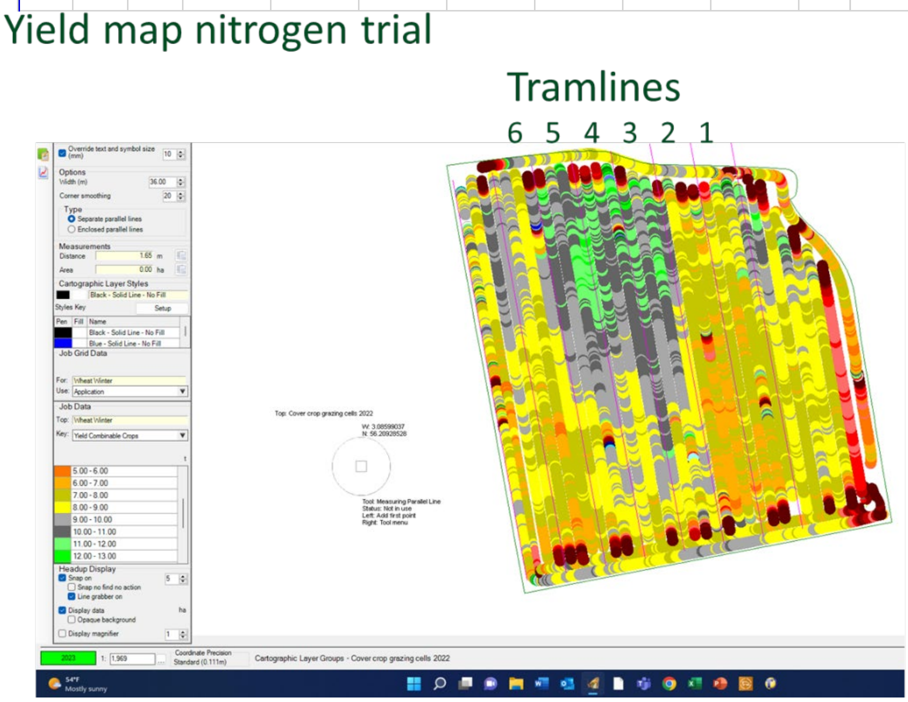
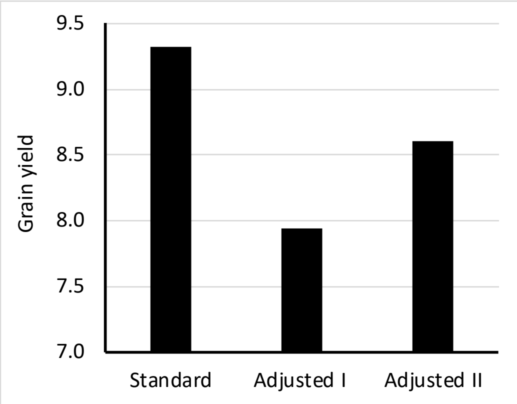


Figure 43. Grain yield map, Castle Heggie. Indicating the north to south gradient in yield, expected to be a consequence of field difference in soil moisture.



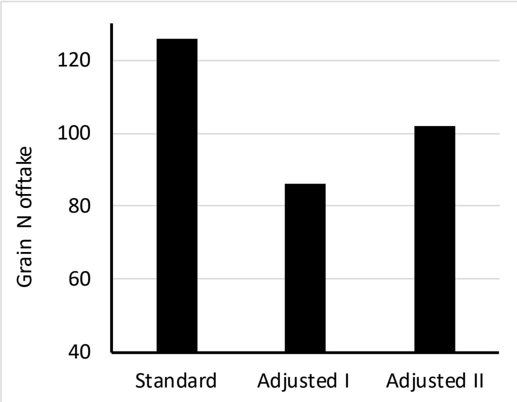


Figure 44. Grain yield and grain N offtake in three treatments in the nitrogen trial.

A weak association between the crop N pool (measurement zone) and grain N offtake (full tramline) was evident (Figure 45).

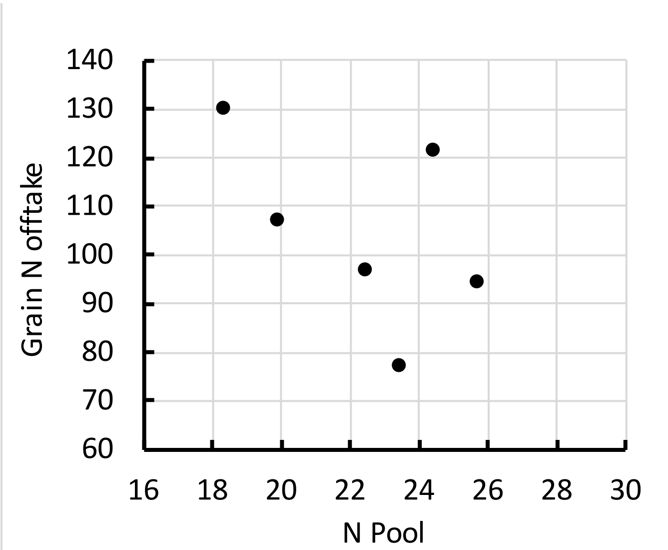


Figure 45. Relationship between the crop N pool and grain N offtake.

The relationship between the ‘N pool’ at GS 55-59 and grain yield was weak for the full tramline yield (Figure 46 LHS), but strong when using the measurement zone only (Figure 46 RHS). This differential is likely be a consequence of the moisture gradient south to north across the field, with the measurement and sampling zone being more representative of the southern to middle part of the field.

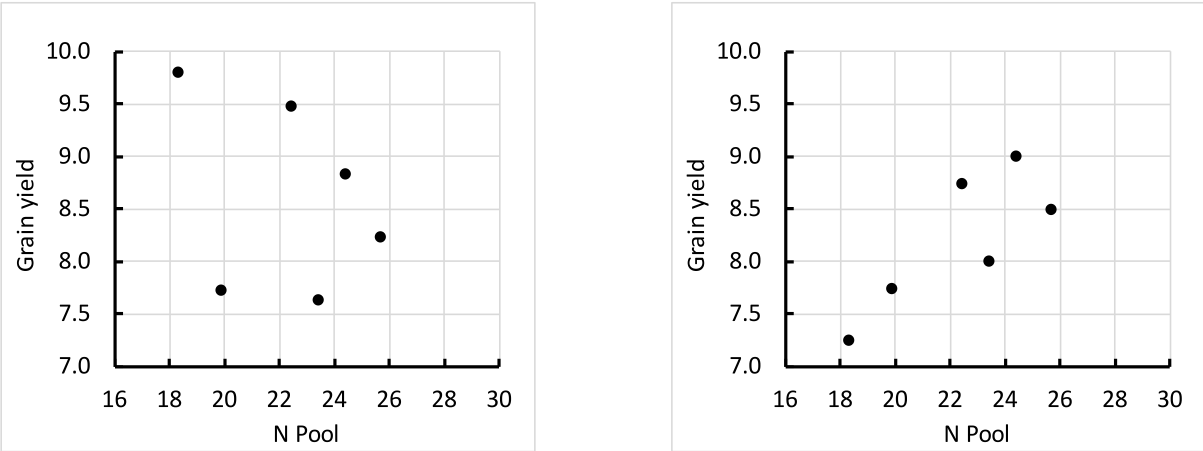


Figure 46. Relationship between the crop N pool and grain yield for the full tramline (LHS) and measurement zone in south-central part of the field (RHS).

Action points for farmers and agronomists

The use of LAI and SPAD and an estimate of crop N pool as a guide to crop potential looks encouraging.

When planning for crop measurement and sampling ensure that these zones are representative of the full tramline length or whole field.

The use of yield maps, and representative sampling zones, can be used to identify permanent and temporary field features e.g. seasonal variation in soil moisture.

The value of crop measures, including LAI, SPAD and BRIX is being quantified to enable improvements of use of combined methods or technologies that report on crop health and yield potential.

3. Adjusting nutrition application in response to crop monitoring

Trial leader: Steve Hoad, SRUC

Overview of findings

This trial investigated use of four ways to manage nutrients, including a current farm standard and two farm adjusted treatments.

Working closely with the nitrogen trial (Section 2), the nutrient trial made a good link between crop measures such as leaf area index (LAI) and leaf chlorophyll (SPAD) with grain yield. And further supported the use of crop nitrogen (N) pool, as the product of LAI x SPAD, in yield forecasting.

The value of BRIX measurements was further investigated. Its potential to assess change in crop disease levels and nutritional health, as well spatial and temporal variation in yield, is now being analysed.

Compared to the nitrogen trial (Section 2), yield mapping indicated that the crop measurement and sampling zones were representative of the full tramline length. This enables a more complete analysis of relationships between crop measurements and yield.

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

The measurements in this trial were common to the crop nutrition trial (Section 2).

What was the challenge/demand for the work?

Timing nutrient applications correctly 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 application at the wrong time, can reduce crop quality and cause problems such as lodging of cereals or increases in foliar pathogens.

This project is looking 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.

How did the project address this?

Trial design

Work was be carried out using the same tramline treatments as in 2020-21, plus additional of a 'biology in a bag' treatment. The experiment design was based on use of two adjacent and connected fields, Bottom Boiler Well (west side of the trial) for tramlines 1 to 4 and Bottom Strip (east side of the trial) for tramlines 5 to 8. Both fields were sown with the cultivar LG Skyscraper. The full design was based on the four 4 replicated treatments (see below) presented in Figure 47.

1. Standard fertiliser applied, with PGR (as Scottish Agronomy managed), but with no fungicide.

2. Standard fertiliser, PGR and fungicide (as Scottish Agronomy managed).

3. Real-time modified management I – opportunity for adjusted fertiliser and fungicide.

4. Real-time modified management II – ‘Balbirnie standard’ with biology in a bag (all main crops have trace elements, biology in a bag and urea)

WP4 - Wheat Nutrition 2021/22
Bottom Boiler Well (west) and Bottom Strip (east)

Treatments

1. Standard fertiliser applied, with PGR (as Scottish Agronomy managed), but with no fungicide
2. Standard fertiliser, PGR and fungicide (as Scottish Agronomy managed)
3. Tailored agronomy, including adjusted nitrogen and nutrients and reduced fungicide
4. Tailored agronomy, including adjusted nitrogen and nutrients and reduced fungicide, plus 'bugs in a mug'

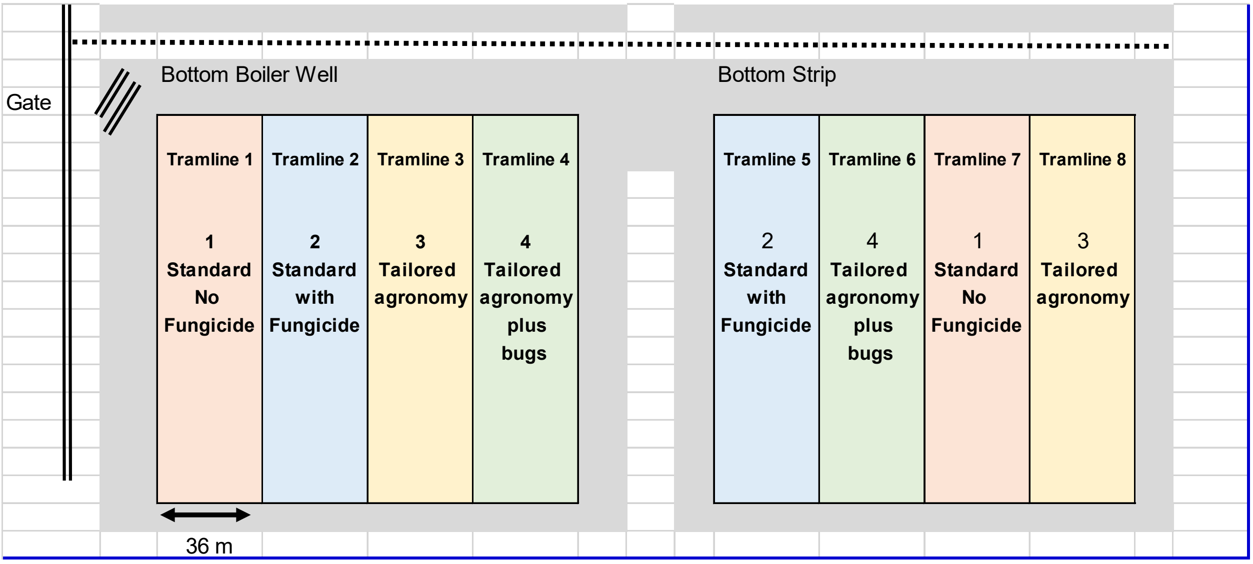


Figure 47. Nutrient trial layout in Bottom Boiler Well (west side) and Bottom Strip (east side).

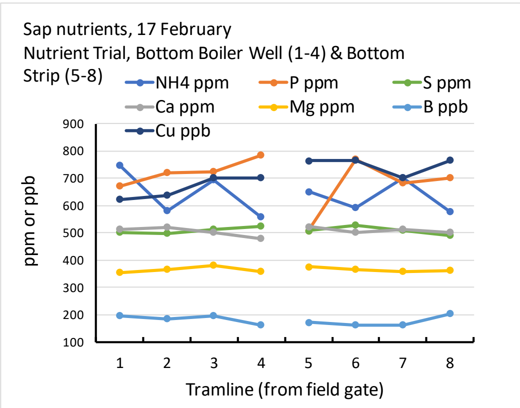
Assessments

The measurements below were be undertaken at key growth stages (see project assessment schedule) to explain changes in crop growth and health and guide crop management.

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

What results has the project delivered?

To assess base line crop health and nutrient status, sap analysis was carried out at growth stage 13-21, 17th Feb, prior to application of N fertiliser treatments. Overall, there was high uniformity in nutrient status across the sample zone (Figure 48).



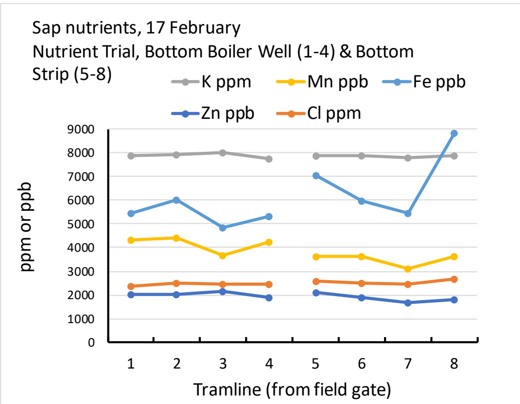


Figure 48. Left upper and lower, sap nutrients in leaves sampled at GS13-21 in Bottom Boiler Well and Bottom Strip.

At GS13-21, BRIX and SPAD readings varied across tramlines (Figure 49). Any trends would be checked after start of treatment applications. However, at this early stage before treatment application it was evident that the crop varied across the field with: (1) tramlines 1 and 7 (standard agronomy minus fungicide) showing the most consistent SPAD and BRIX, (2) tramlines 2 and 5 (standard agronomy with fungicide) had low SPAD readings, (3) tramlines 3 and 8 (tailored agronomy) varied most in SPAD readings but were consistent in BRIX and (4) tramlines 4 and 6 (both tailored agronomy plus bugs) varied in BRIX readings.

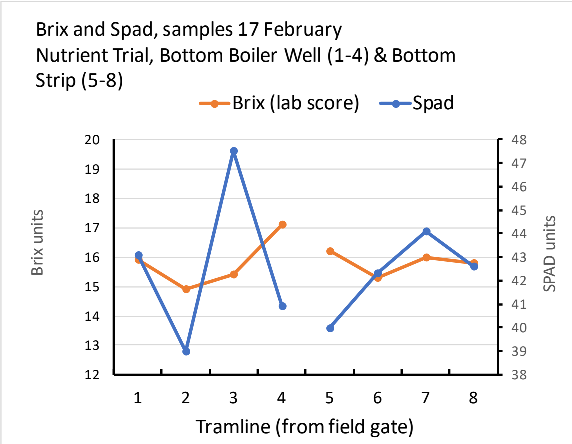


Figure 49. BRIX and SPAD readings at GS13-22.

BRIX and SPAD readings, crop size and N pool were assessed at three more growth stages, including GS31 on 31st March 2022 (Figure 50). The most striking difference between pre-treatment and GS31 was the reduction in SPAD in tramline 3 and the increased in BRIX in tramline 6. Overall, there was no consistent nutrient treatment effect on BRIX or SPAD readings. Though tramlines 3 and 8 (tailored agronomy) had variation in SPAD, but similar levels of BRIX, whilst tramlines 4 and 6 (tailored agronomy plus bugs) had similar SPAD readings, but variation in BRIX. The crop N pool was greater in Bottom Strip (east side) tramlines 5 to 8.

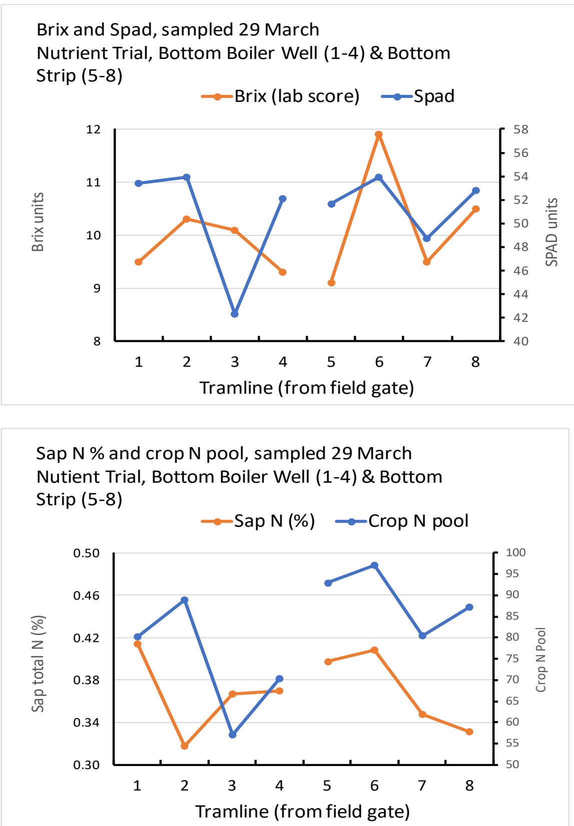


Figure 50. BRIX, Spad, crop size and N pool at GS31 on 31st March 2022.

At ear emergence on 31st May 2022 (Figure 51), one of the tailored agronomy tramlines (number 3), had a reduced SPAD reading, but a high BRIX value, whilst tramline 5 (standard agronomy with fungicide) had low BRIX (Figure 51). The paler tramline 3 is shown next to the greener tramline 2 in Figure 52 and other parts of the field in Figure 53. The interplay between BRIX, SPAD, LAI and N capture will be explored along with Farm Bench data.

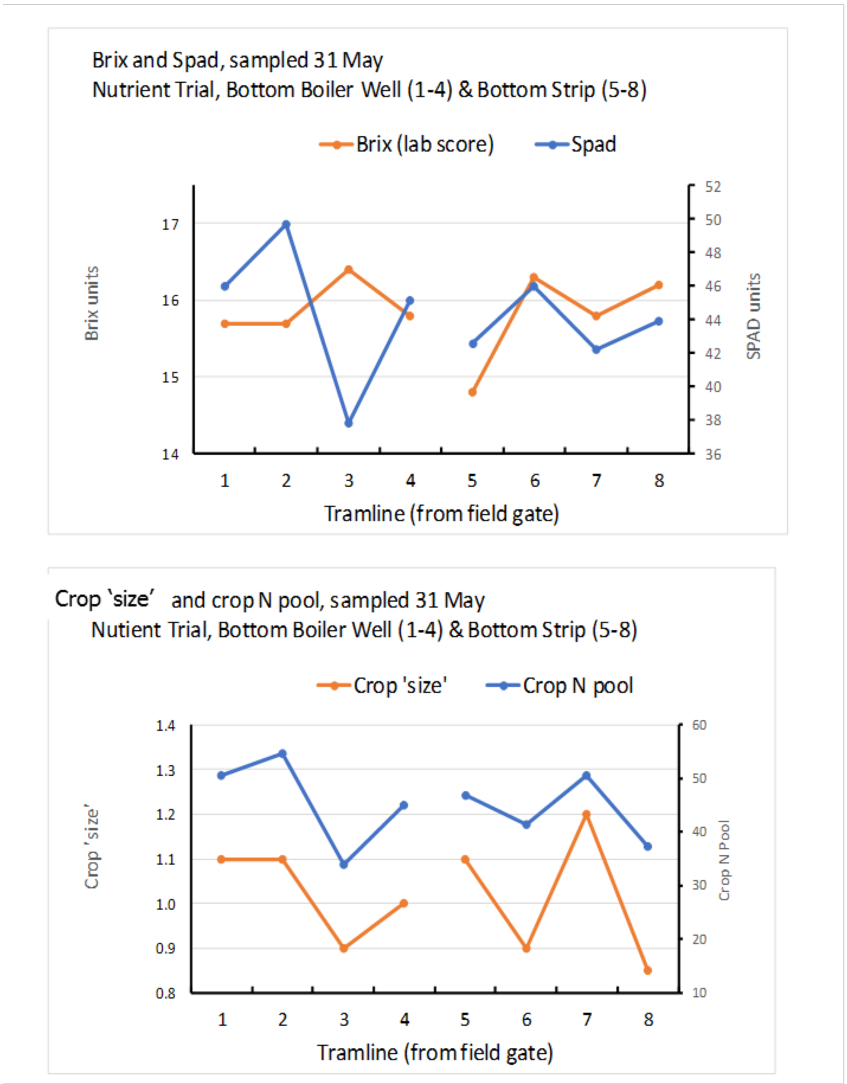


Figure 51. BRIX, Spad, crop size and N pool at ear emergence on 31st May 2022.

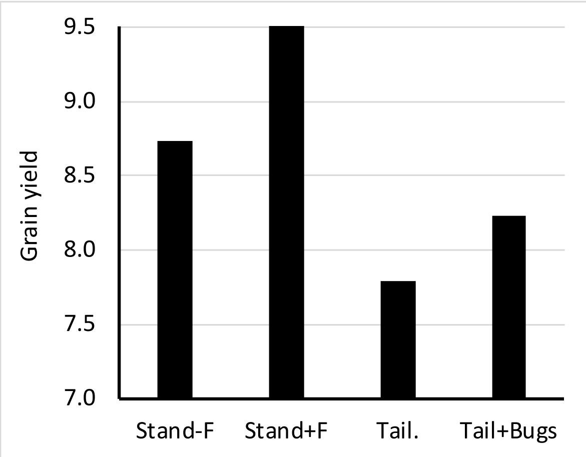
Figure 52. Bottom Boiler Well. Stem extension. Looking south. Tramline 3 tailored agronomy (left) and tramline 2 standard. Throughout spring, T3 was paler than other tramlines.

Figure 53. Bottom Boiler Well. Looking south. Ear emergence. Tramline 3 in mid frame, tramlines 1 and to RHS, tramlines 5 - 8 to LHS.

Mean grain yield for each treatment is presented in Figure 54. Compared to the nitrogen trial, the nutrient trial had a more uniform yield map along the tramlines (Figure 55), meaning that the crop sampling zone was a better representation of the whole field.

These initial data, indicate that tailored agronomy has reduced yield compared to the standard agronomy with or without fungicide. However, with tailored agronomy and its reduced N fertiliser input, it is expected that crop N use efficiency will be enhanced compared to the standard agronomy treatments. This hypothesis is supported by the crop N offtake being similar across the four treatments (Figure 54).

Crop data e.g. LAI, SPAD and N pool was analysed in relation to grain N offtake and yield. By contrast to the nitrogen trial (Section 2), the crop N pool from the measurement and sampling zone was strongly associated with grain N offtake from the full tramline (Figure 56). Likewise, yield from both the full tramline and the measurement and sampling zone was strongly associated with the crop N pool (Figure 57).



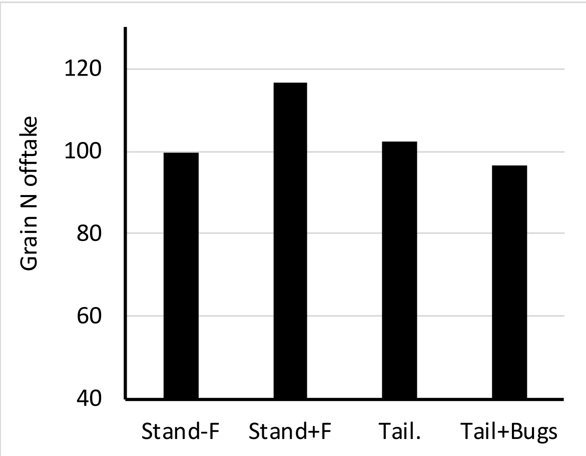


Figure 54. Grain yield and grain N offtake in four treatments in the nutrition trial.

Yield map nutrition trial

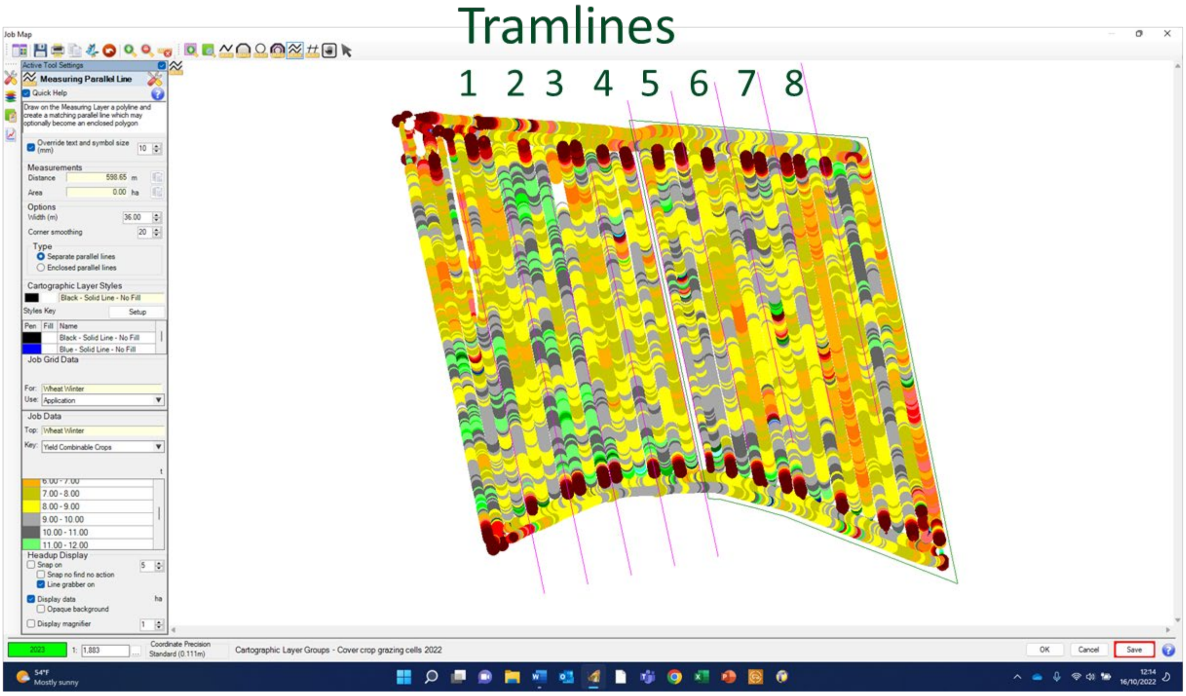


Figure 55. Grain yield map for Bottom Boiler Well / Bottom Strip.

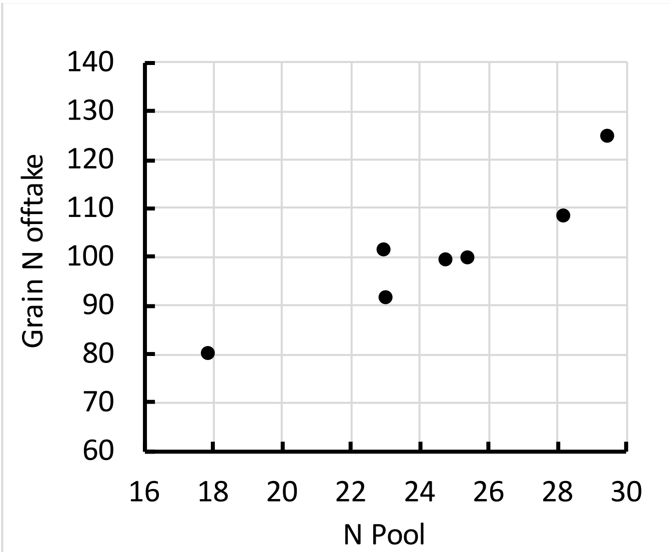


Figure 56. Relationship between the crop N pool and grain N offtake.

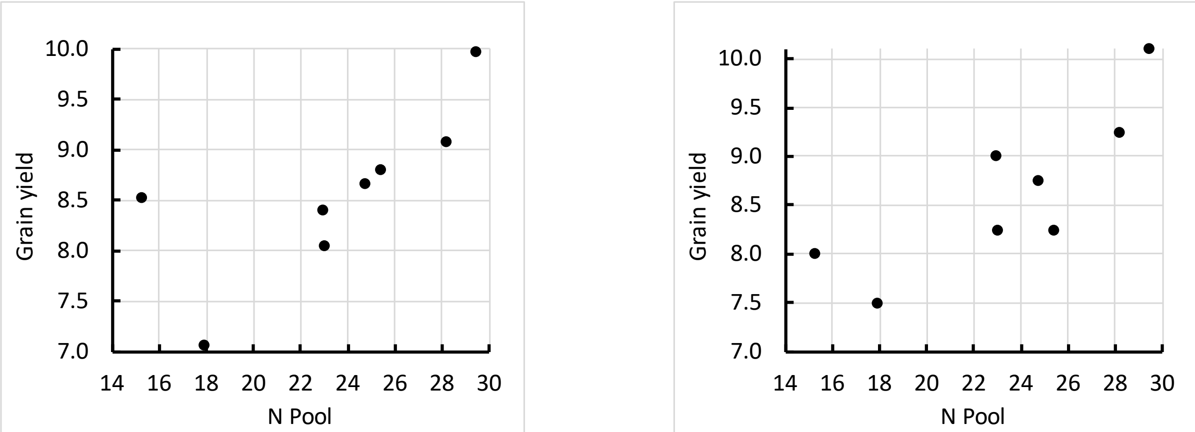


Figure 57. Relationship between the crop N pool and grain yield for the full tramline (LHS) and measurement zone in north-central part of the field, Bottom Boiler Well and Bottom Strip (RHS).

Conclusions to date

Results to date support the use of LAI, SPAD and crop N pool as a guide to crop potential.

Use of the same crop measures across trials has assisted our project towards improved protocols for benchmarking the health of crops.

Although relationships between SPAD and BRIX and crop disease or nutrient status have not yet been established, we expect that a full analysis with N input and 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.

The value of crop measures, including LAI, SPAD and BRIX is being quantified to enable combined methods and technologies to inform better on crop health and nutrient status. If validated, these measures can be adapted for use in remote crop sensing and thus provide wider opportunity for assessing spatial and temporal change in crop health and nutrient status.