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Strategic Cereal Farm Scotland – Harvest 2021 report

1. Soil health baselining

Trial leader: Christine Watson

Start date: October 2020

End date: March 2021

Headline

The project set out to baseline soil health in 5 fields across the strategic farm at Balbirnie in late 2020 and early 2021. The selected fields comprised three spring barley fields, one winter drilled spring oat crop, and a winter wheat crop. Baseline soil health data indicated that soil health was generally good overall across all fields studied in detail. Paying close attention to the three components of soil quality – chemistry, biology and physics - as highlighted from the soil scorecards is important to ensure the maintenance and enhancement of overall soil quality and yield potential. Earthworm numbers appeared to give a strong indication of soil structural quality, confirming their effective use as indicators of soil health. With a robust nutrient plan and using precision liming and nutrient applications, the soil chemistry can recover more quickly and be maintained more easily than the soil structure and biology. In the future, improving soil structure and maintaining soil biology should create the conditions for greater efficiency of soil nutrients and help reduce input costs

How did the project address this?

Trial design

The Strategic Cereal Farm Scotland (SFS) used the soil health scorecard approach, as developed by the AHDB GreatSoils Partnership, to baseline the effects of contrasting management practices on soil biology and health, in relation to plant health. In addition to the soil health scorecard assessments, the SFS should gain a better understanding about the soils capacity to retain and release water through the measure of water infiltration.

Assessments

Assessments carried out

Soil health assessments (in situ field and laboratory measurements)

5 fields with 12 zones identified using electrical conductivity maps provided. Detailed assessments were carried out for one priority (largest) zone in each field.

Category	Assessment	Number of Samples
Soil Chemistry	pH, Extractable P (Modified Morgan's), Extractable K and Mg, Na and Ca.	1 Bulk sample per field taken from priority zone.
Soil Biology	Soil Organic matter (Loss on Ignition)	1 Bulk sample per field taken from priority zone.
	Potentially mineralisable nitrogen	1 Bulk sample per field taken from priority zone.
	Microbial Biomass (chloroform fumigation)	1 Bulk sample per field taken from priority zone.
	Earthworms from soil block (numbers, mass and identification)	3 worm counts per zone (12 zones across 5 fields). Earthworm mass and identification for priority zones (1 per field).
Soil Physics	Moisture holding capacity	1 Bulk sample per field taken from priority zone.
	Infiltration Rates	1 measurement per field taken from priority zone.
	Penetrometer resistance and maximum depth	20 measurements per zone (12 zones across 5 fields).
	Bulk Density (10-15 cm)	3 cores per priority zone (1 per field).
	Visual evaluation of soil structure (VESS)	3 VESS scores per zone (12 zones across 5 fields).

Grid sampling

Soil sampling (4 pH/ha and 1 P,K and Mg and LOI per field) for Modified Morgans P, K, Mg, pH and loss on ignition was carried out on 9 fields (106 ha) using grids through Soil Essentials. Treaton East Bank (14 ha) could not be sampled due to issues with waterlogged conditions and cows/calves so will be sampled later.

What results has the project delivered?

Results

Soil health scorecards for fields using key measurements of soil health indicators

Monitoring Criteria	Bottom Strip Oats	Tank Wilson Winter Wheat	Treaton Spring Barley	Castle Park Spring Barley	Horse Park Spring Barley
pH -SAC (mg/l)	6.5	6.1	6.8	5.9	6.3
lime required arable (t/ha)	0	1.9	0	3.2	0
Ext P -SAC (mg/l)	8.3	3.4	7.8	3.6	3.7
Ext K -SAC (mg/l)	139	181	345	272	179
Ext Mg -SAC (mg/l)	293	106	159	267	177
Ext Na -SAC (mg/l)	9.3	8.9	12.4	10.7	10.3
Ext Ca -SAC (mg/l)	1700	1500	2800	1500	1800
Ca:Mg SAC (ratio)	5.8	14.2	17.6	5.6	10.2
LOI - SAC (%w/w)	4.2	7.7	4.7	6.7	6.2
org carbon (DUMAS)	2.5	2.9	2.7	1.8	2.7
Calculated SOM from dumas	4.3	5.0	4.7	3.2	4.7
Microbial biomass C in soil DM (μg C/g)	361	461	303	379	459
PMN -SAC (mg/kg)	43	35	64	30	28
Earthworms (total no)	3	4	5	7	3
VESS	3.3	2.7	4.0	3.2	2.8
Cone penetrometer (MPa)	2.1	1.9	2.0	1.9	2.2
Bulk density (g/cm^3)	1.7	1.3	1.6	1.4	1.3

Photograph of VESS soil block showing poor structural quality Sq 3.5 at Castle Park field (Nov, 2020)

Grid sampling results (maps for pH and nutrients available on request)

Loss on Ignition (LOI)

LOI

Standard Texture Categories

<15% Mineral

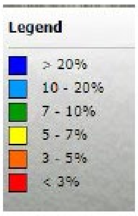
15-20% Organic

21-35% Peaty

36-50% Peat

>50% Peats

LOI Mg/l



Grid sampling results confirm that organic matter levels are high in all 9 fields (with the exception of relatively low values in top strip field).

Summary of grid sampling pH and nutrient status results

Field	pH	Phosphate	Potassium	Magnesium	Calcium	Ca:Mg Ratio	Sodium
	mg/l	mg/l	mg/l	mg/l	mg/l	Ratio	mg/l
Bottom Strip	6.5	8.1	181	295	1700	5.8:1	10.1
Castle Heggie	6.3	4.2	260	125	1700	13.6:1	13.4
Castle Park	6.0	4.3	327	319	1700	5.3:1	14.6
Front Bandon	6.6	3.3	241	229	2400	10.5:1	12.3
Horse Park	6.3	4.0	303	229	2000	8.7:1	14.8
Tank / Wilsons	6.2	3.1	200	100	1400	14.0:1	14.1
Tile Park	6.5	4.8	257	290	2600	9.0:1	14.2
Top Strip	5.9	9.6	306	85	1100	12.9:1	11.5
East Myres	6.3	7.2	339	319	2300	7.2:1	23.5

Very Low	Low	Medium Low	Medium High	High	Very High

Detailed grid sampling results indicate that some fields/areas of fields would benefit from precision lime and nutrient applications to maintain optimum pH and nutrient levels for crop nutrition. Improving pH and nutrient status would improve financial efficiency and optimise crop performance as well as avoid negative environmental impacts such as diffuse pollution.

Action points for farmers and agronomists

Paying close attention to the three components of soil quality as highlighted from the soil scorecard, as developed through the AHDB GreatSoils partnership, is important to ensure the maintenance and enhancement of overall soil quality and yield potential.

Earthworm numbers appear to be a strong indication of soil structural quality and are a useful indication of the soil biology and therefore overall soil health.

With a robust nutrient plan and using precision liming and nutrient applications, the soil chemistry can recover more quickly and be maintained more easily than the soil structure and biology. However, maintaining healthy soil structure and soil biology should create the conditions for the greater efficiency of soil nutrients and help reduce input costs.

Soil health in the five fields that were assessed could be increased through future improvements in soil physical conditions. Soil physical conditions could be improved through management interventions that will alleviate compacted soils and prevent any future compaction issues.

2. Crop health baselining

Trial leader: Fiona Burnett

Start date: October 2020

End date: September 2021

Headline

Plant health was assessed in 5 fields across the farm – three spring barley crops, one winter sown spring oats crop and one wheat crop where a tramline trial evaluated lower input fertiliser approaches. The farm adopts low input strategies, so the fields were untreated with fungicides, with the exception of the winter wheat where yellow rust infected in the spring and was managed at T1.

Disease levels across the farm in the 2021 season were relatively low, following a dry spring, although wetter weather from May onwards created more conducive conditions. There were moderate levels of mildew in the oats. The spring barley crops remained clean and ramularia levels were lower than those seen on other sites.

In the wheat field monitored, a full fungicide programme was applied to the standard treatment tramline in this field and Septoria levels remained relatively low and were not significantly different across the three tramlines. The standard farm treatment stayed slightly greener for longer and had lower levels of yellow rust by the end of the season. Yields were higher in the standard treatment (7.7 t/ha compared to 5.0 t/ha in the UT tramline. There were only trace levels of yellow rust in the standard treated tramline at the end of the season but in untreated tramlines levels were between 2 and 3% on the flag. Septoria levels remained low in all tramlines, demonstrating some potential for reduced inputs if that is the only target but yellow rust was problematic in this trial and challenged the low input approach.

How did the project address this?

The project set out to baseline plant health in 5 fields across the strategic farm at Balbirnie and in 2021 the selected fields comprised three spring barley fields, one winter drilled spring oat crop, and a wheat crop where a tramline trial was carried out to evaluate the potential for reduced input crop protection programmes.

The fields monitored for plant health in 2021 were as follows:

Field Name	Area (Ha)	2019 Harvest	2020 Harvest	2021 Harvest	Zones
Horse Park	9	WO	SB	SB	2
Bottom Strip	11.5	WW	Cauliflower	Spring Oats Winter sown	2
Tank/Wilsons	13.5	Cover crop after carrots	WO	WW	3 tramlines (trial)
Treaton East Bank	20	WW	Kale summer cover crop	SB	2
Castle Park Heggie	12	Cabbages	SB	SB	2

The tramline trial carried out in Tanks / Wilsons field is described more fully in WP4 but was as follows:-

1. untreated or unfertilised
2. standard farm fertiliser (nutrient) management
3. real-time crop-soil nutrient adjusted fertiliser

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Assessments

Winter wheat Assessments:

	Category	Timing	Assessment	Number of Samples
1	**Soil**	All soil analysis	**Done in other WP**	**-**
2	**Physiological**	GS 10 Crop Emergence	Tiller/Plant Counts	10 quadrat counts (plants/m2) 5 per zone
3	**Disease**	GS 30 (T0) Stem Extension	Foliar Disease	40 plants per field i.e. 20 per zone
4	**Physiological**	GS 31 Stem Extension	Tiller/Plant Counts Tissue Testing Brix Testing	10 quadrat counts per zone 40 plants sampled across field (20 per zone) 100g tissue across field per zone
5	**Biomass**	GS 31-33 Stem Extension	Fresh Weight	40 plants across zones (20 per zone)
6	**Disease**	GS 31-33 (T1) Stem Extension	Foliar Disease Stem Disease	40 plants across zones (20 per zone) 25 plants across field (per zone)
7	**Disease**	GS 39 (T2) Flag Leaf Emergence	Foliar Disease	40 plants across zones (20 per zone)
8	**Physiological**	GS 61 Flowering	Tiller/Plants Counts Brix Testing	10 quadrat counts (plants/m2) per zone 100g tissue per zone
9	**Disease**	GS 61-65 (T3) (T2 + 3 weeks)	Foliar Disease	40 plants across zones (20 per zone)
10	**Disease**	GS 87 (T2 + 6 weeks)	Foliar Disease Stem Disease Ear Disease	40 plants across zones (20 per zone) 25 Plants per zone 100 plants across zones (50 per zone)
11	**Physiological**	GS 87/Harvest Grain filling/Harvest	Tiller/Plant/Ear Counts	10 quadrat counts (plants/m2) 5 per zone
12	**Biomass**	Harvest	Yield mapping	From the combine

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Spring barley Assessments:

	Category	Timing	Assessment	Number of Samples
1	**Soil**	All soil analysis	**Done in other WP**	**-**
2	**Physiological**	GS 21 Tillering	Tiller/Plant Counts	10 quadrat counts (plants/m2) 5 per zone
3	**Disease**	GS 25-30 (2 wks <T1) Mid Till/Stem Exten	Foliar Disease	40 plants across zones 20 per zone
4	**Disease**	GS 30-31 (T1) Stem Extension	Foliar Disease Stem Disease	40 plants across zones 20 per zone
5	**Physiological**	GS 31 Stem Extension	Tiller/Plant Counts Tissue Testing Brix Testing	10 quadrat counts 5 per zone 40 plants sampled across field 20 per zone 100g tissue per zone
6	**Biomass**	GS 31-33 Stem Extension	Fresh Weight	40 plants across zones 20 per zone
7	**Physiological**	GS 39 Flowering	Tiller/Plants Counts Brix Testing	10 quadrat counts (plants/m2) 5 per zone 100g tissue per zone
8	**Disease**	GS 39-49 (T2) Booting	Foliar Disease	40 plants across zones 20 per zone
9	**Biomass**	GS 39-49 (T2) Booting	Fresh Weight	40 plants across zones 20 per zone
10	**Physiological**	GS 59 Ear Emerged	Tiller/Plants Counts Brix Testing	10 quadrat counts (plants/m2) per zone 100g tissue per zone
11	**Disease**	GS 61-65 (T3) (T2 + 2-3 weeks)	Foliar Disease	40 plants across zones 20 per zone
12	**Physiological**	GS 71 Grain Filling	Tiller/Plant/Ear Counts	10 quadrat counts (plants/m2) per zone
13	**Disease**	GS 87 (T2 + 5-6 weeks)	Foliar Disease Stem Disease Ear Disease	40 plants across zones 20 per zone 25 Plants per zones 100 plants across zones 50 per zone
14	**Physiological**	GS 87/Harvest Grain filling/Harvest	Tiller/Plant/Ear Counts	10 quadrat counts (plants/m2) 5 per zone
15	**Biomass**	Harvest	Yield mapping	From the combine

Spring oats Assessments:

	Category	Timing	Assessment	Number of Samples
1	**Soil**	All soil analysis	**Done in other WP**	**-**
2	**Physiological**	GS 10 Crop Emergence	Tiller/Plant Counts	10 quadrat counts (plants/m2) per zone
3	**Disease**	GS 25-30 (2 wks <T1) Mid Till/Stem Exten	Foliar Disease	40 plants across zones 20 per zone
4	**Disease**	GS 30-31 (T1) Stem Extension	Foliar Disease Stem Disease Clubroot	40 plants across zones 20 per zone 40 plants areas poor growth across zones, 20 per zone
5	**Physiological**	GS 31 Stem Extension	Tiller/Plant Counts Tissue Testing Brix Testing	10 quadrat counts 5 per zone 40 plants sampled across field 20 per zone 100g tissue per zone
6	**Biomass**	GS 31-33 Stem Extension	Fresh Weight	40 plants across zones 20 per zone
7	**Disease**	GS 37-39 (winter) GS 49-55 (spring) Flag-Ear Emergence	Foliar Disease	40 plants across zones 20 per zone
8	**Biomass**	GS 39-49 (T2) Booting	Fresh Weight	40 plants across zones 20 per zone
9	**Physiological**	GS 59-61 Ear Emerg-flowering	Tiller/Plants Counts Brix Testing	10 quadrat counts (plants/m2) per zone 100g tissue across field per zone
10	**Disease**	GS 61-65 (T3) (T2 + 2-3 weeks)	Foliar Disease	40 plants across zones 20 per zone
11	**Disease**	GS 87 (T2 + 5-6 weeks)	Foliar Disease Stem Disease Ear Disease	40 plants across zones 20 per zone 25 Plants per zones 100 plants across zones 50 per zone
12	**Physiological**	GS 71/Harvest Grain Filling	Tiller/Plant/Ear Counts	10 quadrat counts (plants/m2) per zone
13	**Biomass**	Harvest	Yield mapping	From the combine

hat results has the project delivered?

Results show that the low input approaches adopted on the Strategic Farm at Balbirnie can be successful in low pressure seasons. We will need to collate data over a number of seasons to begin to correlate disease levels to other risk parameters such as soil health status or weather data.

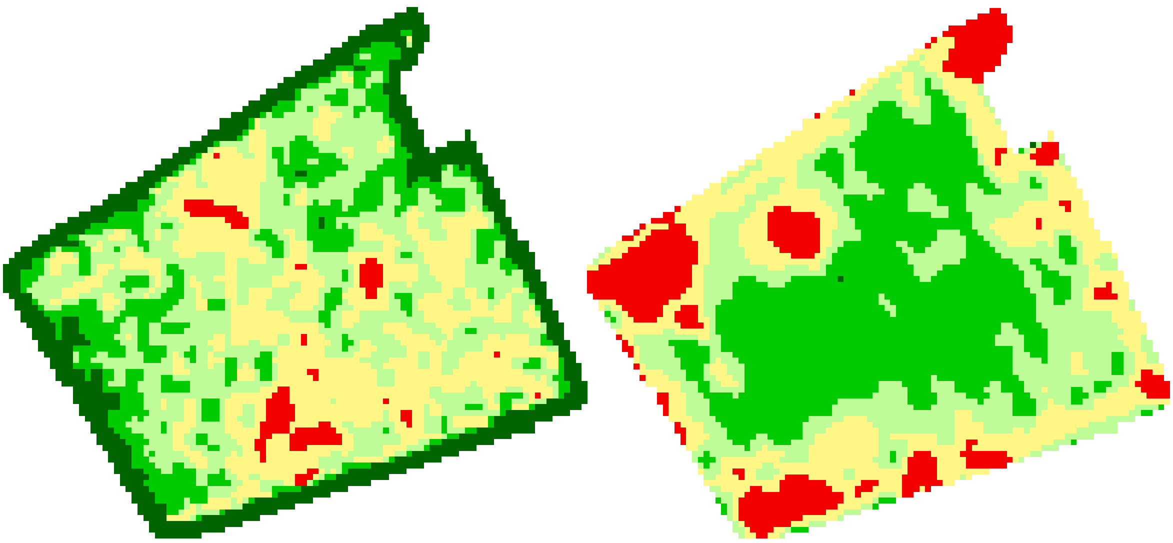
Spring barley results

Three spring barley fields were monitored and the plant and tiller counts and Brix level shown below.

	Castle Park	East Treaton	Horse
28th April 2021			
GS	10-11	-	10-11
Plant count	26.6	-	30.0
19th May 2021			
GS	13-14	11-14	13-14
Plant Count	26.6	30.36	31.4
Tiller count	72.0	Not yet tillering	77.3
16th June 2021			
GS	55-65	55-65	55-65
Plant Count	27.13	38.7	32.7
Tiller Count	49.6	68.23	58.46
Brix	9.8 and 8.9	11.6 and 10.5	10 and 9.5
23rd July 2021			
GS	71-75	71-75	71-75
Ear count (quadrat)	51.36	72.26	64.4

Castle Park field had lower plant and tiller numbers and lower ear counts than the other two fields. Brix levels were also slightly lower. East Treaton, although slower developing at the start of the season had the highest ear count and Brix levels.

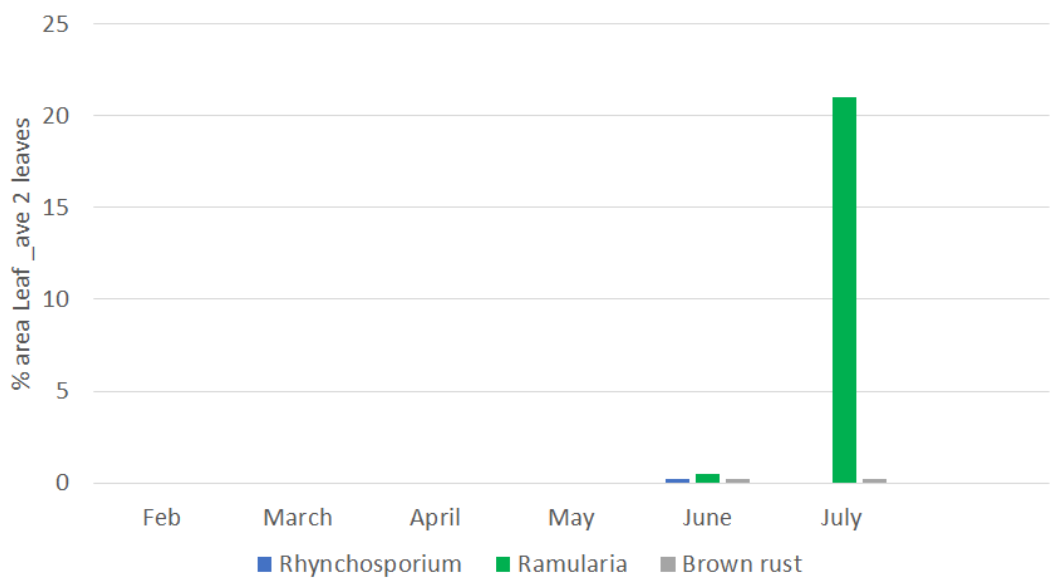
Castle Park Field



Crop biomass image generated in Climate Fieldview (red low, green high) 22nd April and 6 June 2021

By the later assessment timing the thinner area around the crop margins are more evident and relate to wheeling compaction.

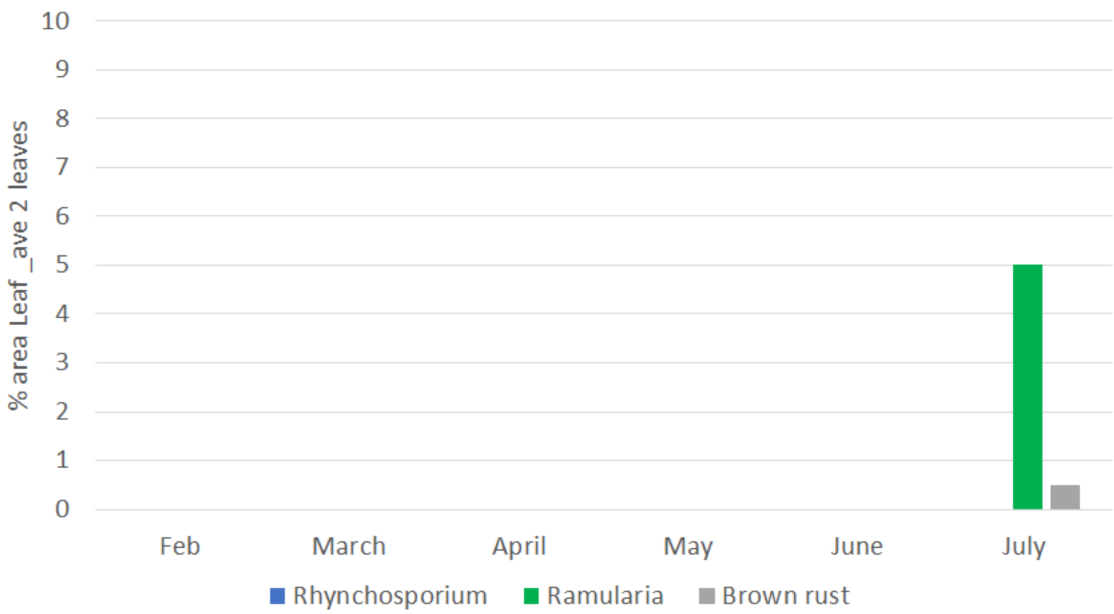
Figure 1 Castle Park Field April 2021



Graph 1 Disease levels Spring barley Castle Park Field

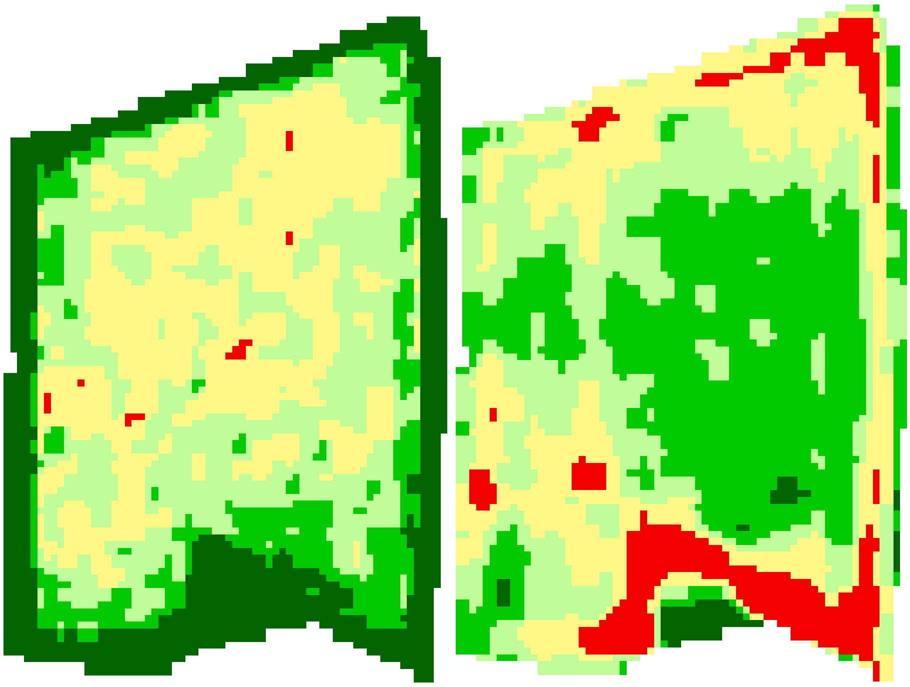
Disease levels were very low with only a trace of rhynchosporium, mildew and ramularia detected. Ramularia levels were slightly higher than in the other two fields monitored.

Spring barley East Bank Treaton Field 28 April 2021



Graph 2 Disease levels Spring barley East Bank Treaton Field

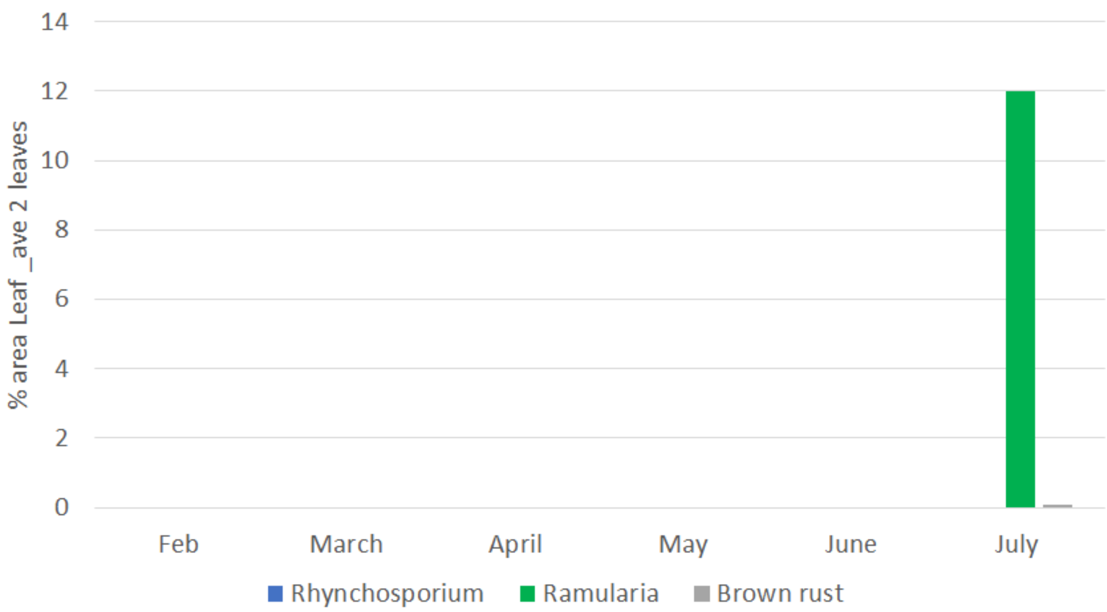
Disease levels in this field were very low throughout with low levels of ramularia even at the end of the season. A trace of brown rust was detected at the final assessment.



Crop biomass image generated in Climate Fieldview (red low, green high) 22nd April and 1st July 2021

This shows an area of poor growth, bottom right, where the crop was thinner and senesced slightly earlier.

Spring barley Horse Park 19 May 2021



Graph 3 Disease levels Spring barley Horse Field

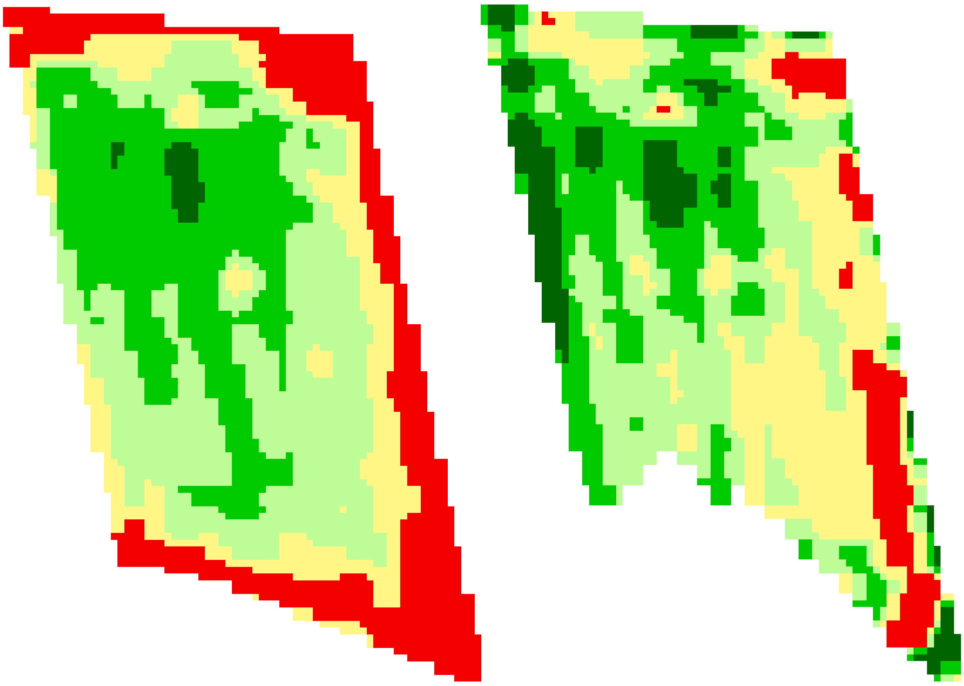
A trace of brown rust was picked up in this field at the latest assessment timing and some ramularia on leaves 1 and 2. Shown here as averaged over the top two leaves.

Spring oats Bottom Strip Field

Growth stage, plant, tiller and Brix levels were recorded as below

	Bottom strip
25th February 2021	
GS	22-23
Plant count	98.4
Tiller count	81.5
21st April	
GS	32
Brix	15.1 and 19.4
Plant count	31.1
Tiller count	66.2
19th May 2021	
GS	55
Plant count	32.2
Tiller count	72.6
16th June 2021	
GS	73-77
Ear count	30.56

These growth stages broadly align with other monitored commercial crops in the area.

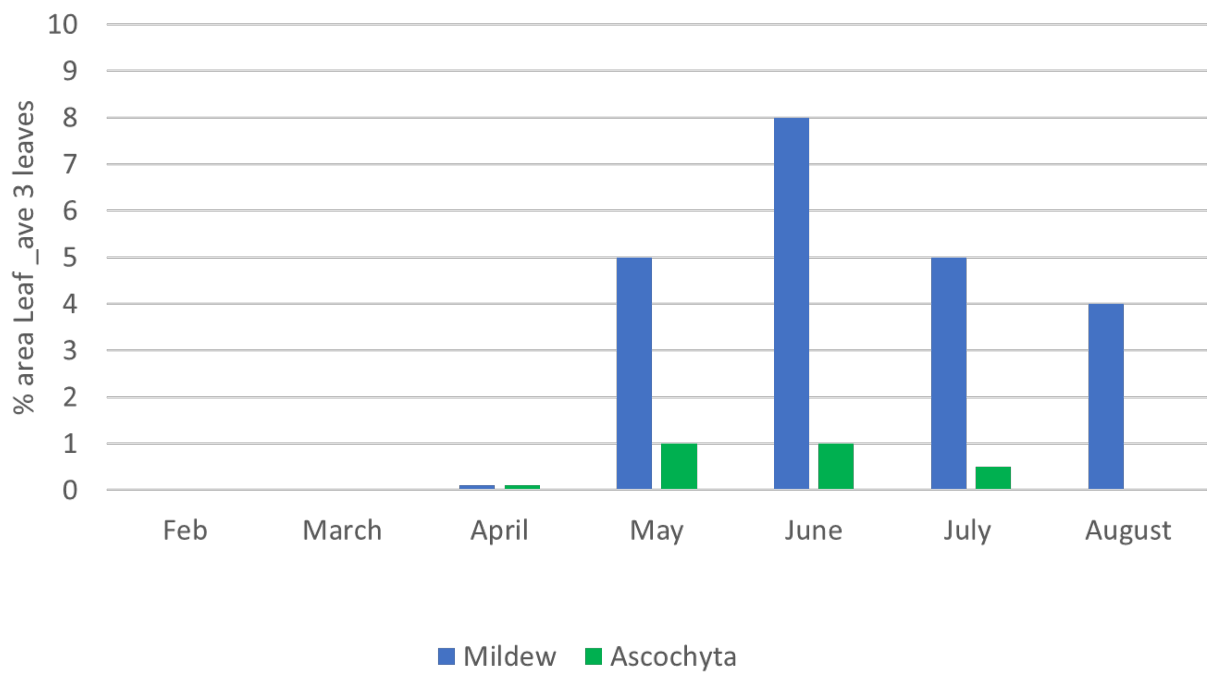


Crop biomass image generated in Climate Fieldview (red low, green high) 22 April and 1st June 2021

The biomass images in the spring oats reflect uneven growth and different tramline widths are evident in the field, and are also evident in earlier photographs.

Spring Oats: Tramline widths visible in the field in May 2021

Spring oats – Bottom strip field



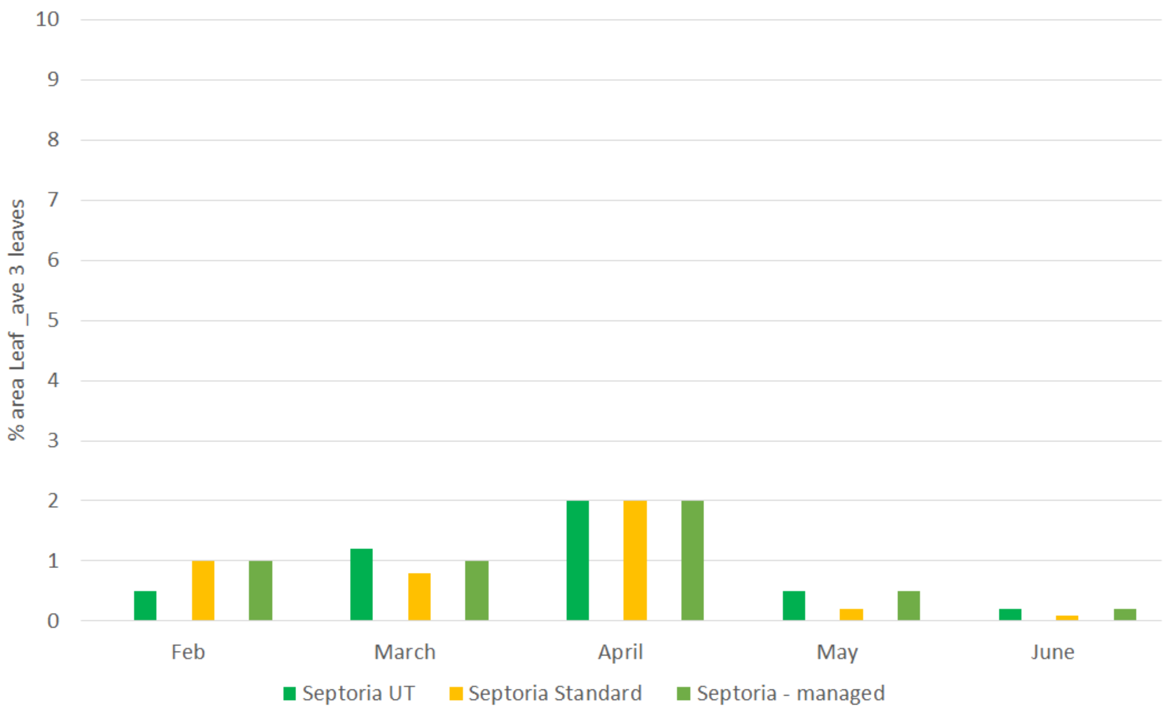
Graph 4 Disease levels in oats in Bottom Strip Field

Mildew was the main disease detected in this field with trace levels of Ascochyta leaf spot also picked up at very low levels.

Winter wheat – Tanks Wilson Field

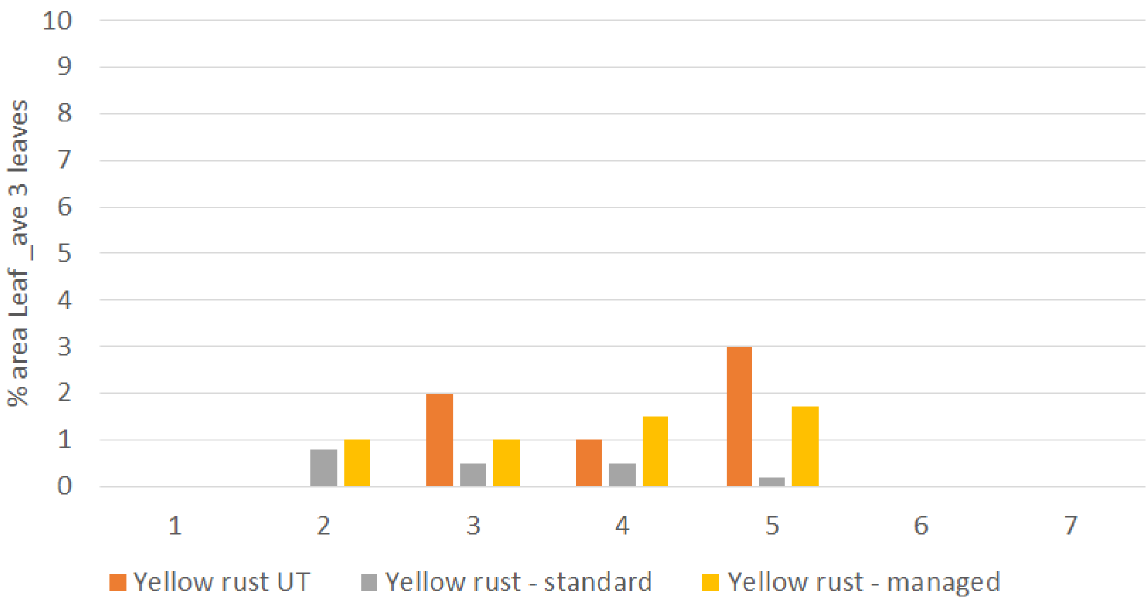
The winter wheat in Tanks Wilson Field had low levels of disease as the crop approached stem extension. The weather remained dry until late May.

Winter wheat – Tanks Wilson Field on 21st April and 19th May 2021



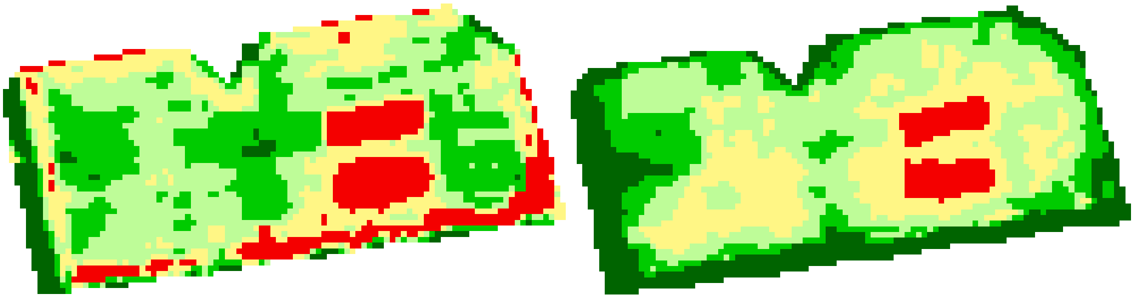
Graph 5: Septoria levels on top 3 leaves emerged at assessment for the UT tramline, the standard input treatment and the managed input programme.

Septoria levels were low even although no fungicides were applied in two of the tramlines and there were no significant differences in septoria levels between treatments.

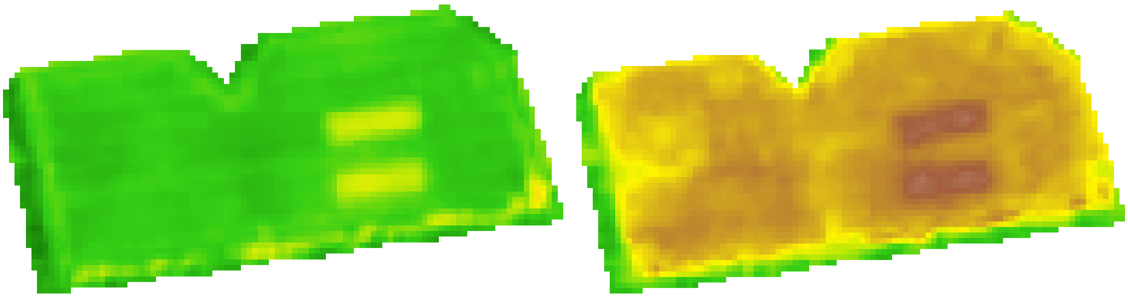


Graph 6: Yellow rust in the winter wheat tram line trial

Yellow rust infected the field and started to increase rapidly. It was managed with fungicides at T1 and no further fungicide inputs were applied to the field. At an assessment on 10th June it had climbed to leaf two and the flag, and was significantly lower in the standard 2 treated tramline where fungicides were applied.

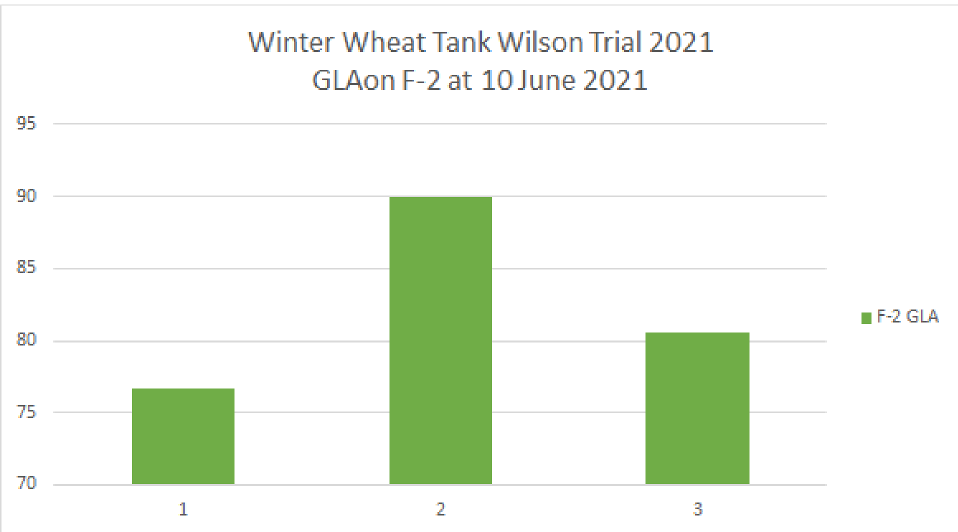


Images of crop biomass (low red to green high) generated in Climate Fieldview 1st July and 2nd August 2021. Untreated tramline shows red.

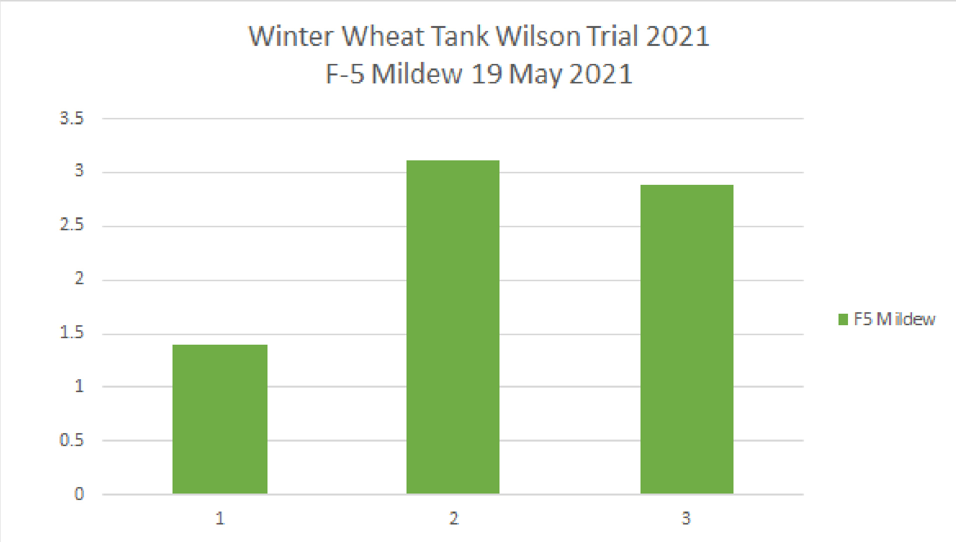


Images of crop vegetation colour generated in Climate Fieldview 1st July and 2nd August 2021. Untreated tramline is visible in both shots.

This is reflected in the Green Leaf Area assessment of final leaf 2 taken on 10th June below. The standard farm nutrient treatment stayed greener for longer than the managed input treatment.



Graph 7: Green leaf area 10th June 2021



Graph 8. There were low levels of mildew on leaf 5 at this assessment timing with lower levels in the untreated plots. This may link with lower leaves of green leaf in this tramline.

Stem base and ear disease assessments were made but no significant differences between tramlines observed. The growth stages and plant counts per tramline are recorded below but no significant differences were noted.

	UT	Standard	Managed
25th February 2021			
GS	14	14	14
Plant count	50.4	50.4	50.4
19th May 2021			
GS	32-37	32-37	32-37
Plant Count	31.4	31.4	32.4
Tiller count	77.3	77.9	73.4
16th June 2021			
GS	55-65	55-65	55-65
Plant Count	43.0	42.9	41.9
23rd July 2021			
GS	71-75	71-75	71-75
Ear count (quadrat)	44.2	43.1	42.6

Action points for farmers and agronomists

The results from the plant health monitoring this year show that the low input fungicide approaches adopted on the strategic farm can be successful in low pressure disease seasons such as 2021. Key actions are therefor as follows:-

- React to key risk indicators such as sow date, variety and weather to modify crop protection plans as the season progresses.
- Pay attention to drilling date in winter wheat, as a driver of yellow rust. Yellow rust is already visible in early drilled wheat on the Balbirnie Strategic Farm (November 2021). This does not need managed until T0 in the spring when an accurate assessment of treatment need can made based on the disease levels that have survived the winter.
- IPM planning is key in reducing the risk of disease with key strategies being the selection of more resistant varieties where these are available and the introduction of more diverse rotations, as used at Balbirnie. Complete an IPM plan to help with assessing your practices and exploring what to alter to increase your IPM score and reduce your disease risks.

for Scottish growers here

For English and Welsh growers here

3. Pests and natural enemies baselining

Trial leader: Lorna Cole

Start date: March 2021

End date: August 2021

Headline

Baseline data were collected for key pests and natural enemies in eight fields using targeted, user-friendly, survey techniques. The techniques were successful at monitoring a diversity of natural enemies. Pest and natural enemy populations varied across the farm, and the observed variation was not directly related to location on the farm or crop type and instead appeared driven by a variety of factors. Ground active predators dispersed into the field at different rates in spring highlighting the potential for infield overwintering habitats to enhance populations of less mobile species.

Many natural enemies taxa occurred at higher densities in field margins (e.g. harvestmen, rove beetles and parasitic wasps) when compared to field centres, and this was reflected in higher predation rates. Predatory hoverfly larvae, which specialise on aphids, were the only natural enemy investigated that occurred at a higher abundance in field centres - highlighting their potential as a biocontrol agent.

Different natural enemies appeared to be driven by different environmental factors and consequently they have the potential to complement each other. For example, low hoverfly populations could be compensated for by higher abundances of money spiders.

How did the project address this?

Surveying in 2021 focussed on the collection of baseline data on target pest species and beneficial insects across the Strategic Farm Scotland (SFS). Robust baseline data will help us determine the impact of any future changes to management on populations of pests and beneficials. We monitored natural enemies, insect pollinators, floral resources and key pest species at specific points in the season using targeted survey techniques.

Focus was to obtain baseline data for both the fields, and adjacent field margins and to explore the variation in populations at the farm scale. To achieve this, eight fields were selected across the farm to cover the key crops grown on the farm and to explore field margins with different adjacent habitat (Figure 3.1, Table 3.1).

Figure 3.1: The eight fields where pest and natural enemy baseline sampling was conducted.

Table 3.1: Fields surveyed including field size, crop, establishment, and adjacent field margin habitat.

Field Name	Area (ha)	2021 Harvest Crop	Habitat field margin adjacent to
Castle Park	15.1	Spring Oats (Direct drilled)	Woodland
Tile Park	12.6	Winter Wheat (Cultivated + livestock)	Woodland
Horse Park	9.5	Spring Barley (Direct drilled)	Woodland
Top Strip	7.4	Field Beans (Direct drilled)	Grass/Stone wall
Bottom Strip	6.3	Winter Oats (Cultivated)	Grass/bank
Castle Heggie	12.0	Spring Oats (Direct drilled)	Treeline
Tank Wilsons March	16.0	Winter Wheat (Direct drilled)	Grass
East Bank Treaton	20.0	Spring Barley (Cultivated)	Treeline/Walkway

In each field, transects were established in the field margin and in the field centre (i.e. at a distance of at least 50 m into the field) (Figure 3.2). Additionally, to coincide with surveying in the Strategic Farm West and East a second transect was established in winter wheat fields 10 m into the field to assess dispersal of natural enemies and pests into the crop.

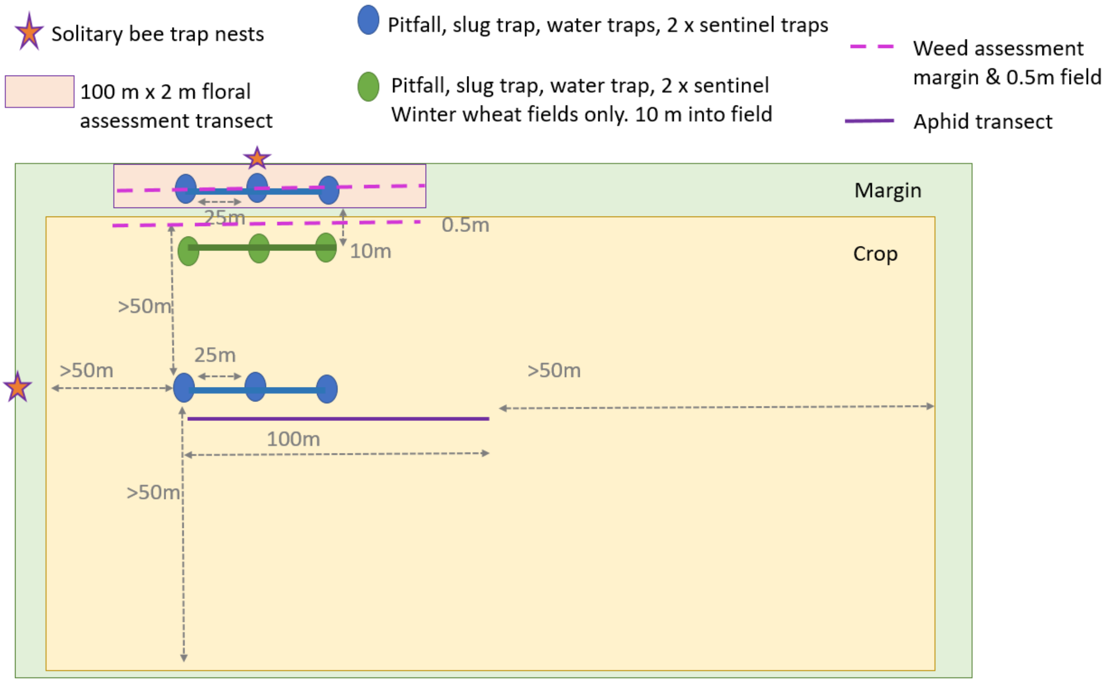


Figure 3.2: Sampling protocol for each field.

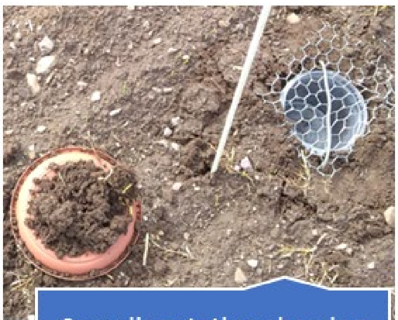
Assessments

Survey techniques were specifically selected that could readily be undertaken by farmers with minimum training. As such all techniques were easy to use and equipment was easily sourced.

Objective one: Baseline monitoring of ground active invertebrates and pests in spring

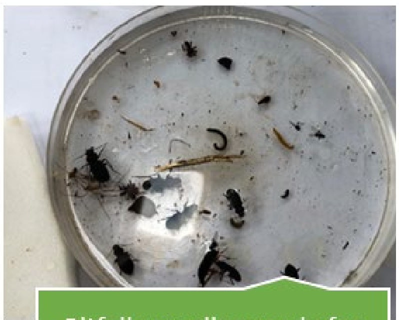
Slugs were monitored in spring during crop establishment using baited traps. Traps consisted of inverted plant saucers baited with a couple of tablespoons of poultry mash and traps were left in place for five days (Figure 3.3).

Ground active invertebrates were surveyed using pitfall traps (Figure 3.3). 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 (although saline solution works equally well). Traps were covered with chicken wire to prevent small mammals entering the trap and were left in place for five days.



Sampling station showing slug board and pitfall

Slugs on lid of the baited trap



Pitfall sampling ready for processing

Figure 3.3: Spring assessments highlighting slug and ground active invertebrate survey techniques

Objective two: Baseline monitoring canopy active invertebrates, predation rates and summer aphids

Aphid populations in the field centre were assessed in mid-July using visual counts of aphids on the ears and leaves of the crop (figure 3.4). A transect of 100 m in length was established in the field centre, and at 5 distinct survey points 20 tillers were randomly selected and visually inspected for aphids and natural enemies (e.g. hoverfly larvae, aphids etc.). A second transect was established 10 m into the crop in the two winter wheat fields. In addition to surveying live aphids, diseased and mummified aphids, and natural enemies (e.g. hoverfly larvae, spiders etc.) were also counted. The aphid assessment is in line with the current recommended threshold assessment for cereal aphids.

Clear water traps were established in mid-July to monitor canopy active predators, insect pollinators and pest populations (Figure 3.4). Water traps consisted of 3 L clear plastic buckets (diameter = 200 mm). Traps were half filled with saline solution and a drop of unscented detergent added to break the surface tension of the water. Traps were established in the field and adjacent field margin and left in place for six days.

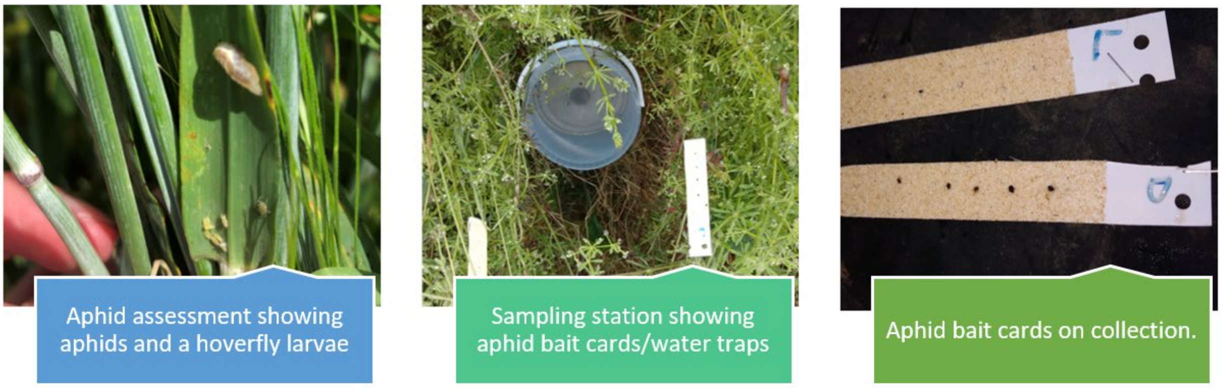


Figure 3.4: Summer assessments highlighting aphid, canopy active invertebrate surveys and aphid bait cards to measure natural enemy predation rates

Aphid bait cards baited with five aphids were established in mid-summer to directly determine predation rates of natural enemies (Figure 3.4). The cards were left in place for 48 hours and on collection the number of aphids consumed was counted. Aphid bait cards were established adjacent to water traps to provide direct comparison between predation rate and density of predators/prey.

Objective three: Baseline monitoring of solitary bees, weed assessment and field margin floral resources

Two solitary-bee trap nests (length 170 mm, diameter 68 mm) containing 31 cardboard tubes were established in each field margin (i.e. 16 nests in total) (Figure 3.5). Traps were secured at a height of 1.2 m, avoiding shaded locations, and oriented to south/south-east for maximum sun and angled downwards for drainage. Traps were established in March and retrieved in mid-July. Any tubes with solitary bee occupancy were removed (determined by mud caps) and the tubes opened, and bee pupae counted.

Field weed assessments were carried out in mid-May and mid-July. Two transects were established, one in the field margin, and a second parallel to this 0.5 m into the established crop. Transects were 100 m in length and a 0.1m^2 quadrat was used to assess the presence of weed species at 10m intervals along this transect (Figure 3.5). All weeds present were identified to species level.

A floral resource assessment was undertaken in the middle of each field margin, parallel to the field edge, over a continuous transect length of 100m in early and late summer (mid-May and mid-July) (Figure 3.5). Transects coincided with pitfall and water traps, and margin weed assessments. Actively flowering plants within 1 m either side of the transect line were identified to species level and abundance estimated using the Domin scale.

Figure 3.5: Solitary bee trap nests, weed assessment and floral resources assessment field margin

What results has the project delivered?

Objective one: Baseline monitoring of ground active invertebrates and pests in spring

Key findings slugs

- Slug densities were extremely low, and this was most likely a consequence of the uncharacteristically dry weather experienced in spring 2021 and no slugs were recorded in three of the fields surveyed (Castle Heggie, Castle Park and East Bank Treaton) (Figure 3.6). As these were all spring sown, this could be due to in field operations alongside the dry conditions. However, the highest slug populations recorded were also in spring sown field - Top Strip (average= 1.67).

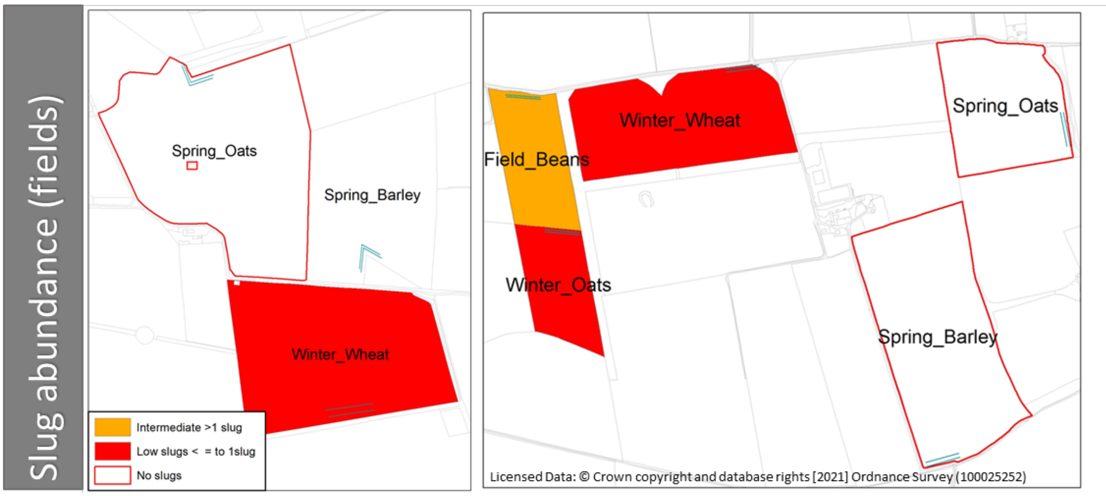


Figure 3.6: Farm scale results showing variability of slug populations across seven of the survey fields. Birds interfered with traps at Horse Park and thus no data is available for this field.

- Slug populations tended to be higher in field margins than field centres (Figure 3.7). This most likely reflects the denser vegetation of the field margins providing harbourage for slugs during the dry weather. There was no evidence that high margin populations resulted in high field populations.

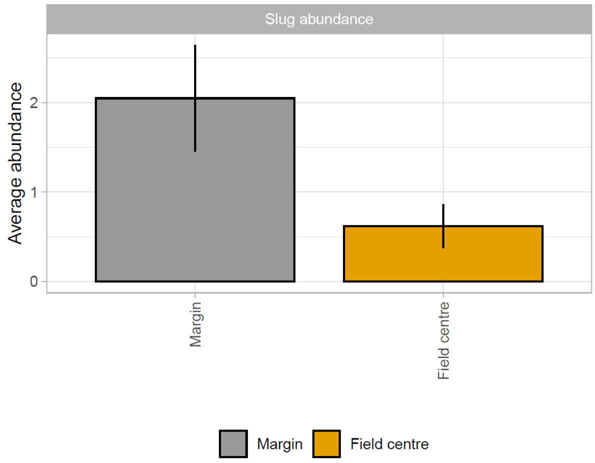


Figure 3.7: Average abundance of slugs caught in field margins and field centres

Key findings ground active natural enemies

- A total of 240 ground beetles were recorded from pitfall traps at the SFS and these were identified to 27 different species. There was considerable variation between the three traps established in a specific field (or margin) highlighting that ground beetles are influenced by variations in microhabitat.
- The abundance of carabids varied across the farm (Figure 3.8). This variation was not clearly related to location on the farm, current crop or sowing date and it is most likely driven by a combination of factors (e.g. crop, tillage practices, soil properties, margin quality and adjacent habitat).

Figure 3.8: Farm scale results highlighting average ground beetle abundance for the eight fields surveyed. The top map reflects abundances in the field with the bottom map reflecting abundances in the field margins.

- The abundance and species richness (i.e. number of species) of ground beetle assemblages was similar in the field, and the field margin (Figure 3.9). Ground beetle richness appeared highest 10 metres into the field, potentially indicating an edge effect where communities of both the field and margin habitats mix. However, surveying was only conducted at 10 meters in two winter wheat fields, and this only therefore provides observational evidence.

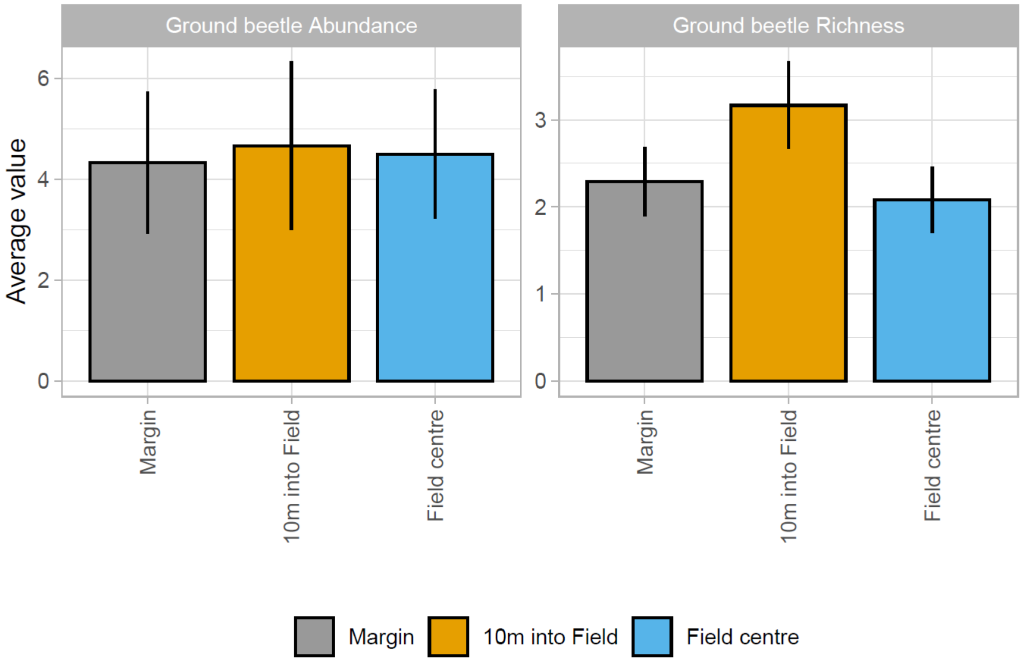


Figure 3.9: Average abundance and species richness of ground beetles. Error bars reflect the standard error.

- Exploring the community structure highlighted clear differences between the ground beetle species found in the field centres and margins (Figure 3.10). In spring, certain species (e.g. *Carabus nemoralis* and *Pterostichus niger*) were associated with the margins, while *Bembidion* spp. were associated with the field centres. *Nebria brevicollis* was ubiquitous occurring at high densities in both the fields and the margins.

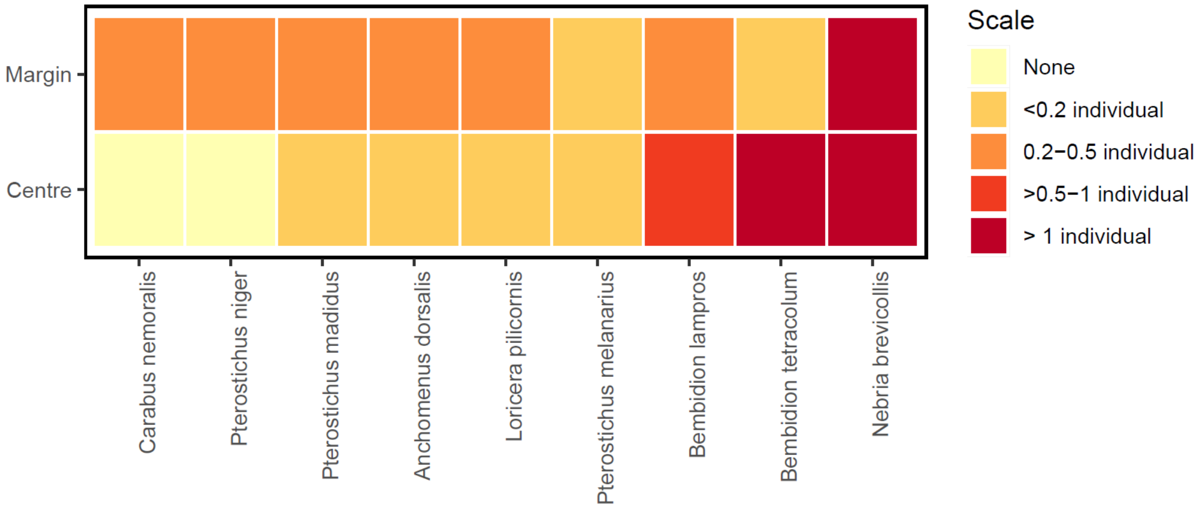


Figure 3.10: Heat maps based on the average abundance of carabids

- Differences between field centres and margins could be the result of either differences in habitat requirements or differences in dispersal ability with smaller species dispersing more quickly than larger species. To help determine this, we explored historic data from arable fields across Scotland for four key species.

- In May, the relative abundance of four key species at Balbirnie was comparable to arable fields across Scotland (Figure 3.11). *Carabus nemoralis* did not occur in fields indicating that this large flightless species is restricted to field margins. As the season progresses, Scottish data indicates that *Pterostichus niger* populations increase in the fields indicating that they may be slower to disperse than *Bembidion* spp. or *Nebria brevicollis*. This highlights that different species are active in the fields at different points in the season, thus promoting species diversity is likely to help stabilise biocontrol.

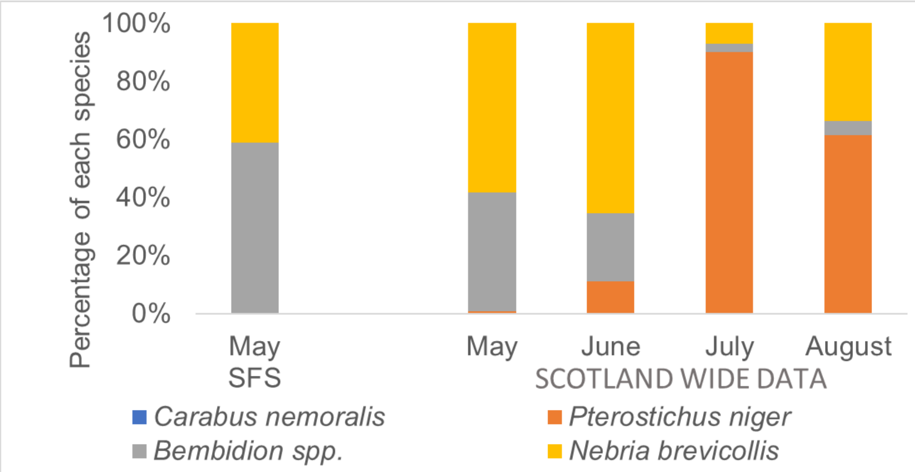


Figure 3.11: Relative abundance of four key species caught in May pitfall traps at the SFS, alongside Scottish data for arable fields surveyed on a monthly basis from May until August

Objective two: Baseline monitoring canopy active invertebrates, predation rates and summer aphids

Canopy active invertebrates

- A total of 6,944 invertebrates were identified from the water traps. The traps were effective in surveying flies, parasitic wasps, aphids, money spiders and rove beetles, but less effective at surveying bumblebees (attracted to brightly coloured traps), ground beetles and wolf spiders (primarily ground active and thus more effectively sampled by pitfall trapping). This highlights the importance of targeting your survey method to the taxa of interest.
- Exploring the abundance of key taxa in the field margin and centre indicated differences in responses (Figure 3.12). Aphids were more abundant in the field centres as were predatory hoverfly larvae. Adult hoverflies are highly mobile and seek high aphid densities to lay their eggs. Predatory harvestmen, rove beetles (mixed diet) and parasitic wasps, on the other hand, were more abundant in the field margins than the fields. Money spiders were ubiquitous with similar abundances in the field margins, 10 m into the field and the field centres.

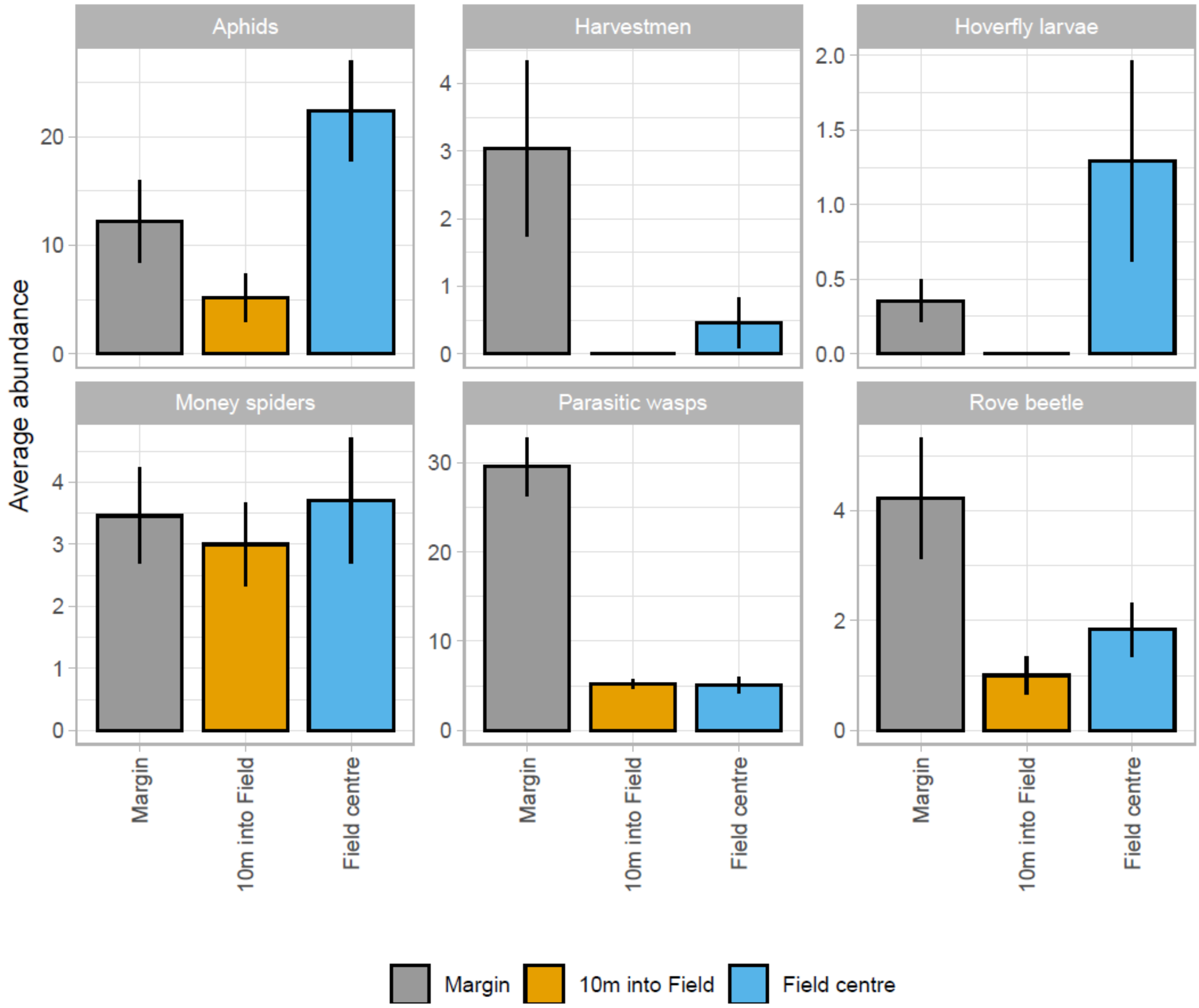


Figure 3.12: Average abundance of aphids and natural enemies. Error bars reflect the standard error.

- Focussing on field populations of money spiders, parasitic wasps and hoverfly larvae considerable variation was found across the eight fields surveyed (Figure 3.13). For some fields there was consistency in the abundance of these three key taxa (e.g. intermediate populations of all taxa in Castle Park the large spring oats field). This was, however, by no means consistent indicating that different factors drive infield populations of these natural enemies. With different factors driving populations, there is the potential for the different taxa to complement each other. For example, low hoverfly abundance in the winter oats field could be compensated for by high abundances of money spiders and parasitic wasps.

Figure 3.13: Farm scale results highlighting the average abundance of parasitic wasps and money spiders recorded in water traps in the eight study fields.

Aphid predation rate

- Aphid bait cards were baited with a total of 540 aphids. Of these aphids, 137 were consumed by predators giving a predation rate of approximately 25% across the farm. Predation rates varied across the farm, and this was not clearly driven by crop or location on the farm (Figure 3.14). Interestingly, the winter oat field with the highest rate of predation supported the highest number of money spiders, while the three fields where no aphids were predated on supported the lowest populations of money spiders. This may highlight that money spiders were the key predators consuming aphids on the bait cards.

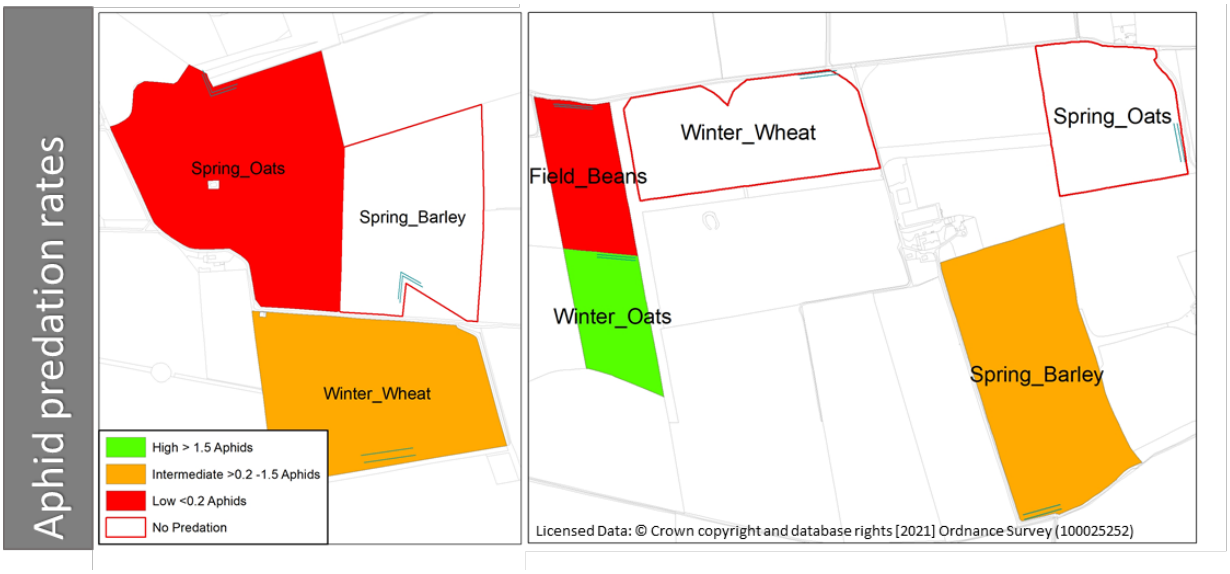


Figure 3.14: Farm scale results highlighting the average number of aphids consumed in the eight study fields. Data averaged over the six aphid bait cards established in a field.

- Predation rates in the field centres were clearly lower than those in the margins (Figure 3.15). This could reflect a higher rate of predation by natural enemies in the margins and several key predators were more abundant in field margins including rove beetles and harvestmen. Alternatively, margins could have fewer prey items making the aphids on the bait card more desirable. Data derived from the pan traps, however, indicates that aphids were more abundant in field centres. The highest predation rates were detected 10 m into the field; however, care should be taken in interpreting this result as it is only based on two fields.

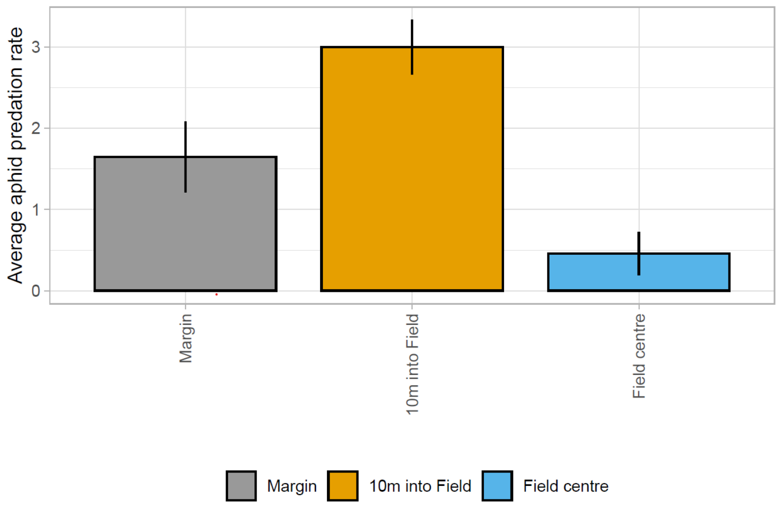


Figure 3.15: Average number of aphids consumed in the three sampling locations. Error bars reflect the standard error.

Summer aphids

- The dominant species found were *Metopolophium dirhodum* the rose-grain aphid and *Sitobion avenae* the grain aphid (recorded at an abundance of 462 and 212, respectively). These species differed in the location on the plant they were observed on with *Metopolophium dirhodum* tending to occur on the leaves while *Sitobion avenae* mainly occurred on the ears.
- The population of both aphid species varied across the farm and populations were influenced by crop (Figure 3.16). Populations of the rose-grain aphid were highest in spring barley fields, while those of the grain aphid tended to be higher in oat fields.

Figure 3.16: Farm scale indicating the average number of rose-grain, and grain aphids, found in field assessments in the eight study fields. Please note that green indicates high aphid densities while red indicates low densities.

Objective three: Baseline monitoring of solitary bees, weed assessment and field margin floral resources

Solitary bee trap nests

- Of the 16 trap nests established at the SFS, solitary bees were only detected in one location (Castle Park). Three tubes were occupied a total of 24 larvae extracted The low occupancy rate is comparable with other surveys using solitary bee trap nests conducted in Scotland. Solitary bees typically have low dispersal capabilities and their presence this field margin might be related to the proximity of early season forage (e.g. willow or bird cherry trees).

Figure 3.17: Solitary bee trap nests showing mud caps, pupae in and out of the tubes.

Weed assessment

- May weed burdens varied across the farm (Figure 3.18). Spring cultivated fields, as we would expect, had the lowest weed burdens with weeds having little time to establish before the May assessment. Direct drilled and winter cultivated fields had higher burdens.
- Weed burdens tended to be lower in July than in May (Table 3.2). In May the most common weed species observed (based on the number of fields a particular species was recorded in) were newly emerged cotyledons (too small to accurately identify), chickweed, creeping thistle and cleavers. In July the most prevalent weeds were knotgrass, creeping thistle and sow thistle.

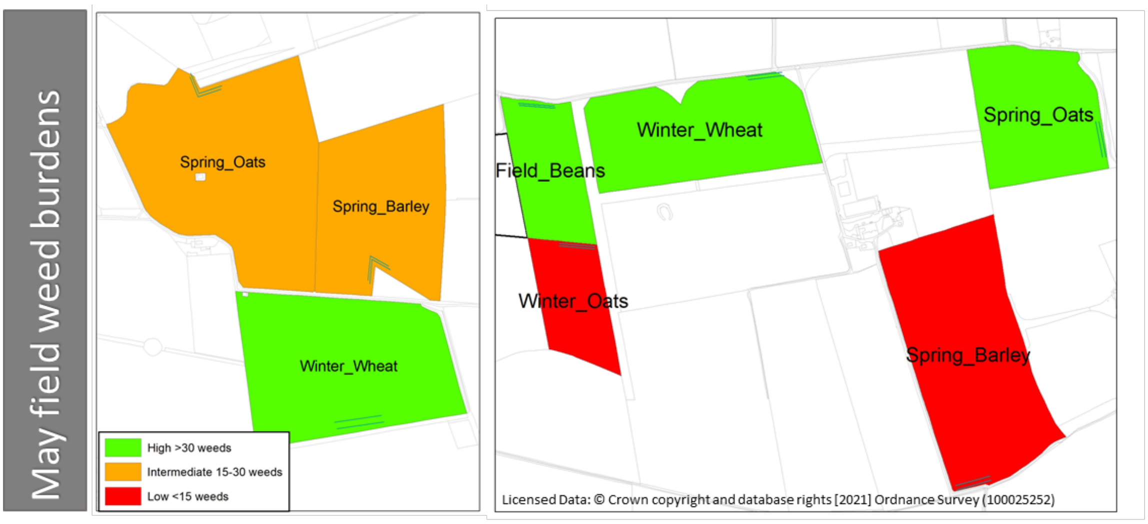


Figure 3.18: Farm scale results of May weed counts 0.5m into the field. Please note that green indicates high weed burdens while red indicates low burdens.

Table 3.2. Frequency of key weed species 0.5 m into the field based on the % of quadrats that each species was recorded. Weeds are listed in order of prevalence, with the most common species listed first. Weed burdens of over 50% are in bold.

Common name	Bottom Strip	Castle Heggie	Castle Park	Horse Park	Tank Wilsons	Tile Park	Top Strip	Treaton
May survey								
Cotyledons spp.	0.0	0.0	**100.0**	**90.9**	**81.8**	0.0	**100**	9.1
Chickweed	0.0	9.1	**90.9**	0.0	27.3	**72.7**	45.5	0.0
Creeping thistle	0.0	0.0	27.3	36.4	27.3	**54.5**	36.4	0.0
Cleaver	36.4	27.3	0.0	0.0	**54.5**	**54.5**	0.0	0.0
Common hogweed	0.0	**54.5**	9.1	0.0	18.2	0.0	0.0	18.2
Knotgrass	0.0	9.1	0.0	0.0	9.1	36.4	18.2	0.0
Yorkshire fog	0.0	**90.9**	0.0	0.0	9.1	0.0	**54.5**	0.0
Agrostis spp.	0.0	**72.7**	0.0	9.1	0.0	0.0	**63.6**	0.0
Groundsel	**81.8**	0.0	0.0	0.0	0.0	36.4	0.0	0.0
Cocksfoot	0.0	27.3	0.0	0.0	0.0	0.0	0.0	**72.7**
Scentless mayweed	0.0	0.0	0.0	18.2	0.0	36.4	0.0	0.0
Stinging nettle	0.0	45.5	0.0	9.1	0.0	0.0	0.0	0.0
Redshank	0.0	0.0	0.0	0.0	72.7	0.0	0.0	0.0
July Survey								
Knotgrass	0.0	**90.9**	0.0	18.2	0.0	0.0	**72.7**	**54.5**
Sow thistle	0.0	0.0	9.1	0.0	18.2	36.4	**63.6**	0.0
Creeping thistle	0.0	18.2	0.0	0.0	9.1	18.2	0.0	36.4
Annual meadow grass	0.0	45.5	27.3	45.5	0.0	0.0	0.0	0.0
Pineapple weed	0.0	0.0	0.0	36.4	0.0	9.1	**54.5**	0.0
Forget-me-not	0.0	0.0	45.5	0.0	0.0	0.0	9.1	27.3
Chickweed	0.0	0.0	27.3	0.0	0.0	0.0	**72.7**	0.0

Floral resource assessment

- A total of 37 plants were recorded flowering in field margins at the SFS and fields showed considerable variation in floral resource availability, both with respect to the diversity of resources on offer (i.e. the number of plant species) and the abundance of resources (figure 3.19).
- Floral resources were scarce in May and no plants were observed flowering in transects in three fields (i.e. East Bank Treaton, Castle Park and Bottom Strip). Coltsfoot and dandelion were the most abundant floral resources observed in spring (i.e. both with respect to the number of field margins they were present in and percentage area). Transect walks focussed on floral resources at ground level. Consequently, resources provided by spring flowering trees (e.g. willow and bird cherry) and shrubs (e.g. hawthorn and blackthorn) which are known to provide important sources of early season forage, are not accounted for.

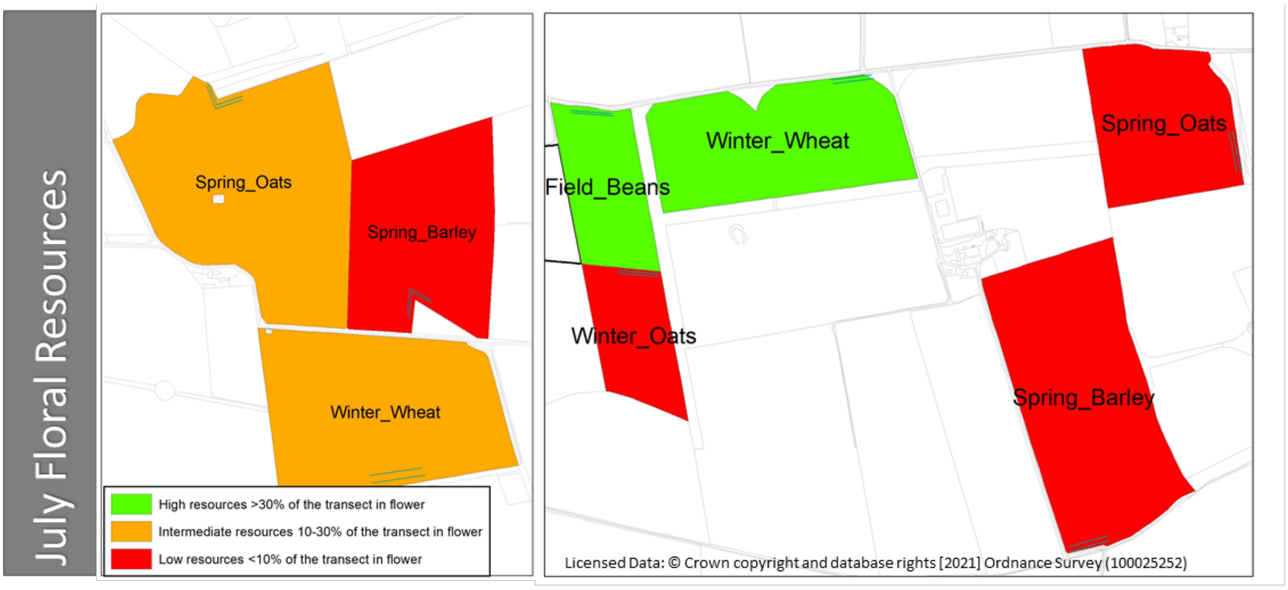


Figure 3.19: Farm scale results of floral resources in the field margins recorded in July based on the percentage abundance of the transect in flower.

- In July, stinging nettle and common hogweed were the most abundant floral resources in field margins. While nettle typically provides low quality forage, the open flowers of common hogweed are frequently visited by hoverflies and parasitic wasps. Other key floral species included creeping thistle and tufted vetch, both known to attract pollinators with thistle attracting both bumblebees and hoverflies and vetch being more accessible to bumblebees than hoverflies due to its deeper flower structure.

What farmers should do

Our results agree with previous research that highlights the importance of field margins as overwintering sites for natural enemies (Woodcock et al. 2010). In addition to field margins providing harbourage from field operations (e.g. cultivation, sowing), their tall tussocky vegetation buffers temperature fluctuations providing a more a stable microclimate. Encouraging tussocky grass species (e.g. *Dactylis glomerata*) in some field margins, and ensuring these remain undisturbed from autumn to spring (e.g. avoiding grazing or mowing during this period), will help provide suitable overwintering habitat for natural enemies.

Our results show that ground beetles disperse into the fields at different rates. Natural enemies provide an important first line of defence against pests, preventing populations from becoming established. Creating infield overwintering sites that contain tussocky grass species (e.g. beetle banks) will help to increase infield populations of less mobile species early in the season. Ground beetle species that disperse into the field later in the season, help to control pests during summer, thus having a diversity of species that are active in the fields at different points in the season can provide more stable biocontrol.

With flower-rich margins typically not flowering until summer in Scotland, consideration should be given to the provisioning of early season forage. Woody shrubs (e.g. hawthorn and blackthorn) and flowering trees (e.g. willow and bird cherry) provide key forage in March and April, and the importance of mass flowering crops (e.g. oilseed rape and field beans) to provide forage in May and June should not be undervalued.

Many natural enemies require a variety of habitats to meet their resource requirements throughout the season. Parasitic wasps, for example, require tussocky grass to overwinter, yet require open flowers to forage on as adults. Supporting a diversity of habitats across the farm will help to ensure that natural enemies are catered for throughout their life cycle. Furthermore, with different habitats providing floral resources at different points in the season (Cole et al. 2017), promoting habitat diversity will help to safeguard insect pollinators.

Links to further information/references

Cole, L.J., Brocklehurst, S., Robertson, D., Harrison, W. and McCracken, D.I., 2017. Exploring the interactions between resource availability and the utilisation of semi-natural habitats by insect pollinators in an intensive agricultural landscape. Agriculture, ecosystems & environment, 246, pp.157-167.

Woodcock, B.A., Redhead, J., Vanbergen, A.J., Hulmes, L., Hulmes, S., Peyton, J., Nowakowski, M., Pywell, R.F. and Heard, M.S., 2010. Impact of habitat type and landscape structure on biomass, species richness and functional diversity of ground beetles. Agriculture, Ecosystems & Environment, 139(1-2), pp.181-186.

4. Adjusted nutrition trial

Trial leader: Steve Hoad

Start date: October 2020

End date: September 2021

Headline

Crop demand for nutrients varies throughout the season and is greatest when a crop is growing quickly. 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. Results from laboratory nutrient analysis or tissue testing can be time-consuming and may become outdated as soon as they arrive. Therefore, we need develop procedures for on-farm, user-friendly, crop measures for nutrient status and health. Our approach in year 1 of this project was to evaluate approaches towards ‘adjusted nutrition’ based on crop assessment, including leaf tissue testing, and in-field testing, to support crop nutrient management, as well as crop protection.

What was the challenge/demand for the work?

To determine whether amending crop nutrition in response to frequent crop monitoring including growth and development and tissue testing will have an economic benefit on crop health, yield and grain quality. This challenge includes how change in crop management impacts on overall resource use efficiency of the crop.

How did the project address this?

We know that the timing nutrient applications correctly is as important as applying the right amount. We also know that 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. Therefore, this ‘adjusted nutrient’ trial compared three tramlines, each with three replicated zones, to examine how a standard farm nutrient programme (tramline 2, T2) compared with an untreated control (tramline 1, T1) and an adjusted nutrient programme (tramline 3, T3).

The work was carried out on winter wheat (cultivar LG Skyscraper) in Tank Wilsons March (field 11). The design of the tramline trial is presented in **Figure 4.1**. Each 36 mm width tramline was zoned in approx. 33 m lengths. A fourth tramline was retained as a spare experimental area if needed.

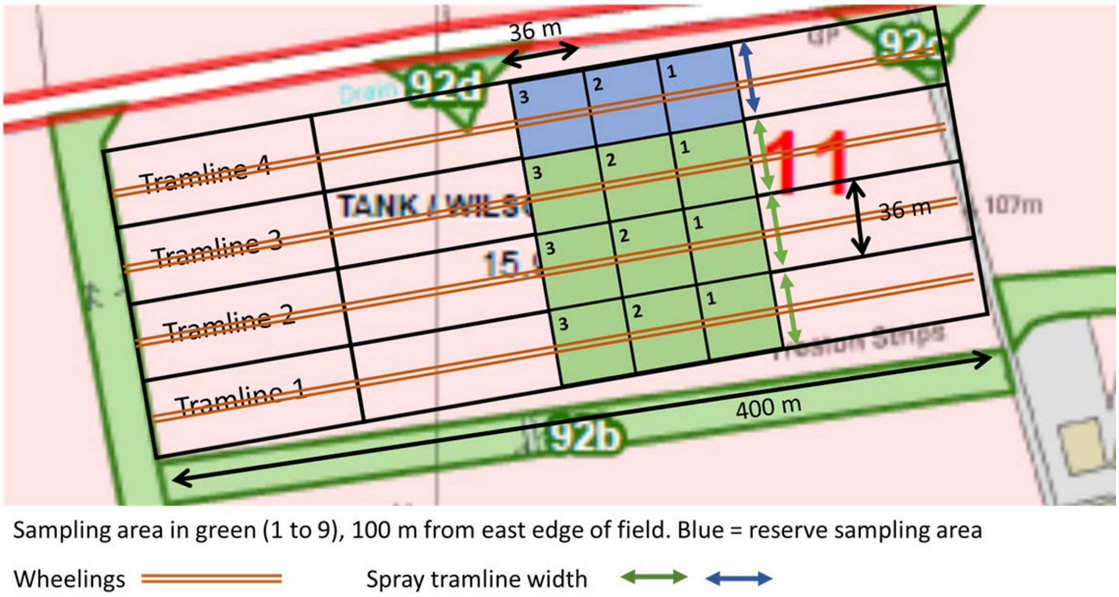
T1. Tramline1 - untreated or unfertilised (control 1).

T2. Tramline 2 - standard farm fertiliser (nutrient) management (control level 2).

T3. Tramline 3 - nutrient adjusted fertiliser and crop protection (tailored approach).

The difference between T1 and T2 was expected to inform the project about the efficiency of the farm's current management system, whilst the difference between T3 and T2 will enable quantification of cost and efficiency benefits of an adjusted nutrient and crop protection programme. The trial design with replicated in each tramline was expected to allow precise monitoring of field variation in crop growth and development. This would also allow sufficient crop area in which to measure spatial and temporal change in crop condition and provide representative sampling areas.

Figure 4.1. Layout of experimental area for adjusted crop nutrition trial.



Assessments

A series of crop growth and development, and physiological, assessments, along with disease assessment, was made at key growth stages, with harvest yield and grain quality. Key measures included the following:

Growth stage, from leaf 3 (GS13) to harvest. Including plant, shoot and final ear counts.

Crop ground cover through visual assessment of percentage green leaf to ground area (at three earliest growth stages).

Green leaf area (GAI) at GS22/23, GS30 and GS31 using photos of crop in conjunction with online service e.g. BASF CAT https://www.agricentre.basf.co.uk/en/Services/Online-Tools/The-CAT-Online/ Option to assess GAI post GS31 using photos as in 4, or with a Sunscan leaf canopy analyer (Delta-T Devices).

Leaf nutrient status I – Lab analysis. Sample of leaf tissue for nutrient analysis at SRUC's Analytical Services Department as soon as possible after GS13, then at the following growth stages: GS23 and GS30.

Leaf nutrient status II – Lab sap test. Sample of leaf tissue for nutrient analysis (leaf sap test) through a commercial lab. In year 1, the project used the Omex Sap Analysis Service, with six timings for leaf sampling and dispatch, from GS23 to GS39.

Leaf nutrient status III – Leaf Brix values. Measurement of dissolved solids (sugars) in Brix units (equivalent to 1 g sucrose in 100 g 'solution') were made using a refractometer as soon as possible after GS13, then at the following growth stages: GS22-23, GS30, GS39. See **Figure 4.2**. A refractometer is a simple instrument used for measuring concentrations of aqueous solutions. It requires only a few drops of liquid and is used as lab equipment throughout the food, agricultural, chemical, and manufacturing industries. In crop plants, Brix is mostly a measure of sugars and minerals dissolved in water. It has been proposed that Brix is a good indicator of leaf and plant health and physiological status. The objective was to test if Brix measures could inform about plant nutrient and physiological status. For example an increase in Brix value is proposed to indicate an improved balance of solutes, with benefits for disease and pest resistance.

Leaf nutrient status IV – Leaf SPAD units. Measure of leaf greenness with a Minolta SPAD meter at 5 growth stages: GS22-23, GS30, GS39, GS65, GS75-77

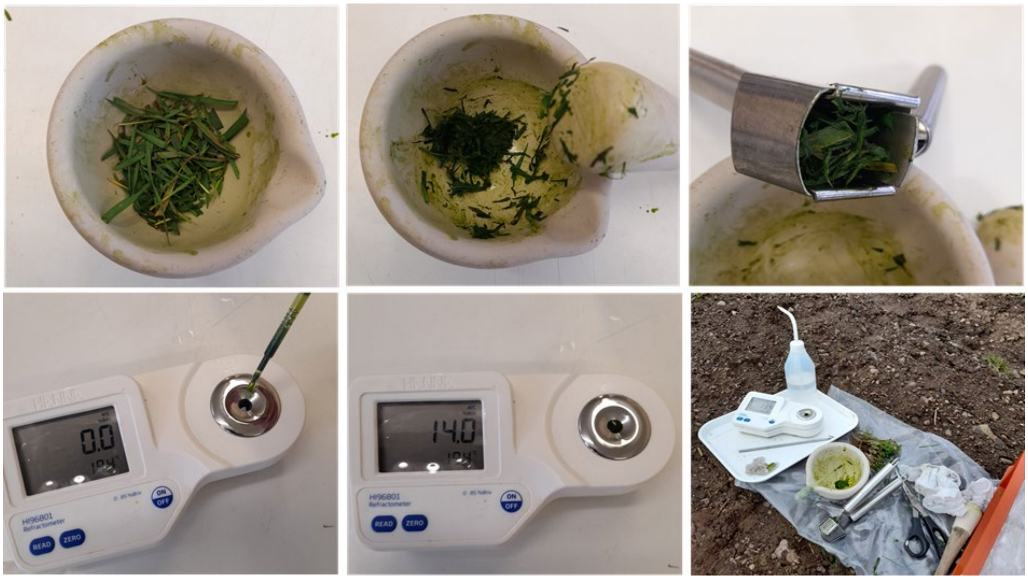


Figure 4.2. Measuring leaf nutritional health using a BRIX meter. From top left to right: Cut lengths from several leaves into a mortar (bowl) and grind with a pestle; place sample into a garlic crusher to extract a few drops of sap. From bottom leaft to right: Pipette 2 drops of sap into refractometer cell. The zero reading is calibrated with water. In this example the BRIX reading is 14.0.

What results has the project delivered?

Testing physiological measures

During early stages of crop development, several test were compared to optimise sampling procedure and value of each output. **Figure 4.3** show assessing of leaf greenness (chlorophyll estimate) using a SPAD meter and Brix units using a refractometer (Hanna Instruments) in leaves at GS 13-21 and GS14-23 for each tramline. As expected, there was no significant differences between the untreated (no fungicide), standard agronomy (full inputs) and adjusted nutrient and crop protection (managed or tailored approach) tramlines at this early stage. This comparison provided a useful baseline for subsequent crop assessment.

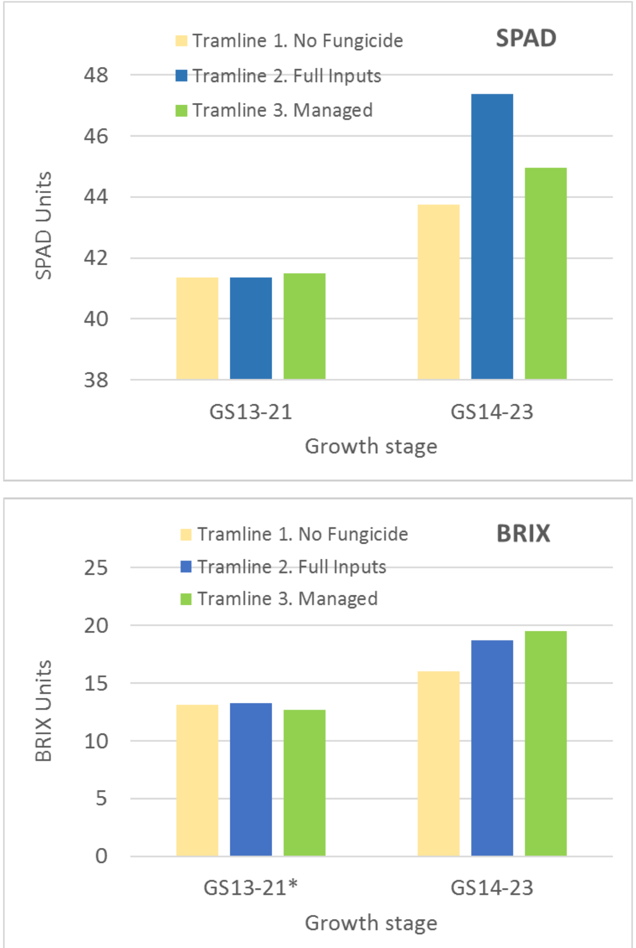


Figure 4.3. Assessing (a) leaf greenness (chlorophyll estimate) using a SPAD meter and (b) Brix units in leaves at GS 13-21 and GS14-23 for each tramline.

Leaf area and sampling for sap and nutrient analysis

Figures 4.4 illustrates how leaf sampling as estimate of crop ground cover and GAI was undertaken at GS30. Replicate measures i.e. zonal measures and samples were made in each tramline. **Table 4.1** shows derived data for GAI and N offtake at GS30 and shoot number (from quadrat counts).

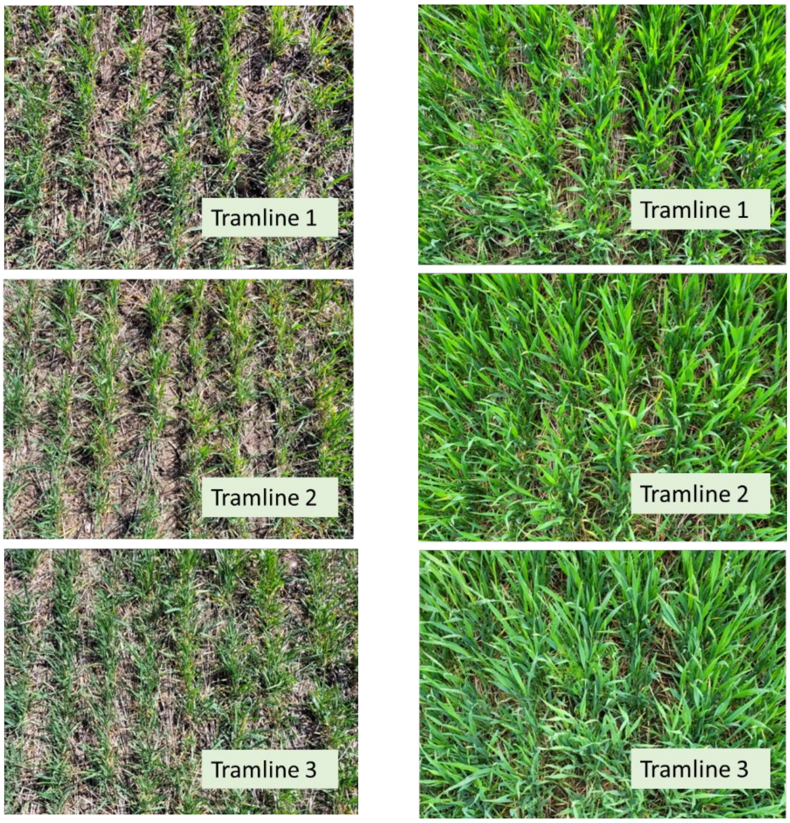


Figure 4.4. Measuring shoot number, assessing green leaf area and leaf sampling at GS30 (April 21st) and GS33 (19th May).

Table 4. 1. Green leaf area, leaf N estimate and shoots per m^2 at GS30

	GAI	N offtake estimate (kg ha^{-1})	Shoots m^{-2}
Tramline 1	0.49	14.6	517
Tramline 2	0.54	16.3	548
Tramline 3	0.49	14.8	521

Laboratory Sap analysis

Figures 4.5 and **4.6** show output from commercial sap testing, including pH and sixteen nutrients. At GS23 (Figure 4.5) there was low (red) manganese, and good (green) and excess (blue) other nutrients across each tramline. By contrast, at GS33 there was low (red) calcium in each crop tramline, and low magesium in tramline 2. Overall, tramline 3 was closest to an optimal nutrient balance.

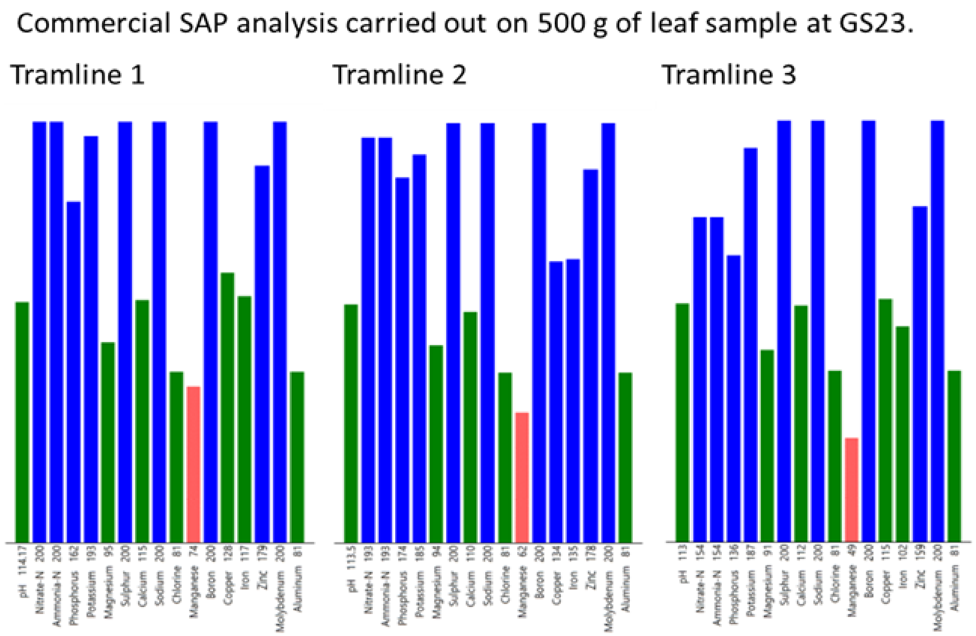


Figure 4.5. Sap analysis at GS23 indicating low (red) manganese, and good (green) and excess (blue) other nutrients. At this stage, each tramline was similar in leaf nutrient status.

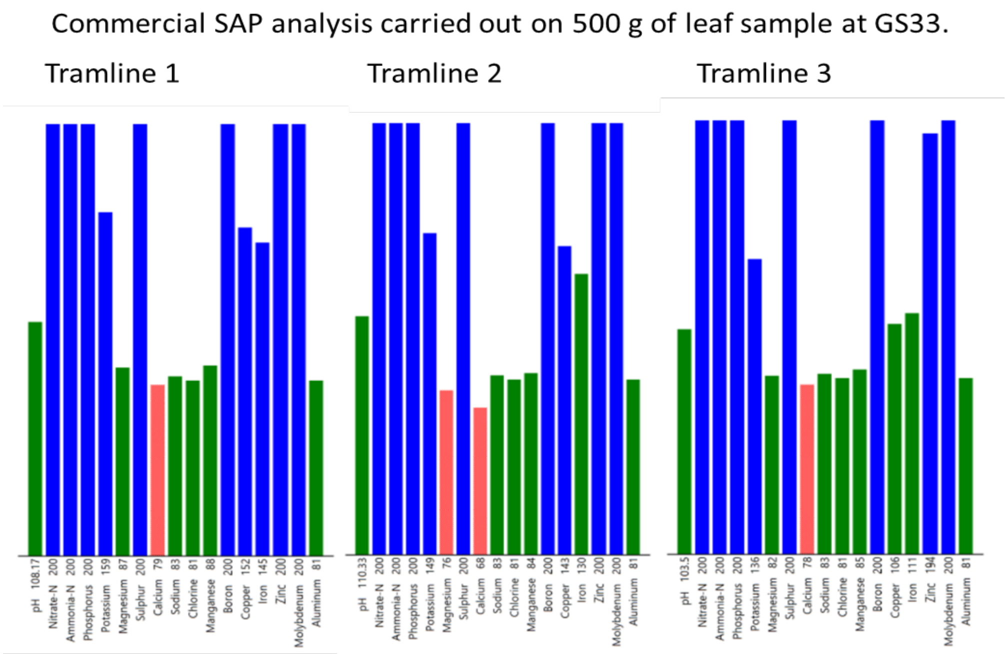


Figure 4.6. Sap analysis at GS33 indicating low (red) calcium in each crop tramline, and low magesium in tramline 2. Overall, tramline 3 was closest to an optimal nutrient balance.

Brix analysis

Figure 4.7 shows Brix measures for replicated zones in each tramline (1 untreated, 2 standard and 3 tailored) from GS21 in mid-March towards ear emergence in mid-June. **Figure 4.8** presents the mean values for each tramline. Overall there was no significant seasonal difference in Brix values between tramlines (P = 0.893) (Figure 4.7). However, between tillering (mid-April) to stem extension (early-May), Brix values were just significantly greater (P = 0.05) in tailored agronomy (21.3) compared to untreated (17.9) and standard agronomy (19.4) (Figure 4.8).

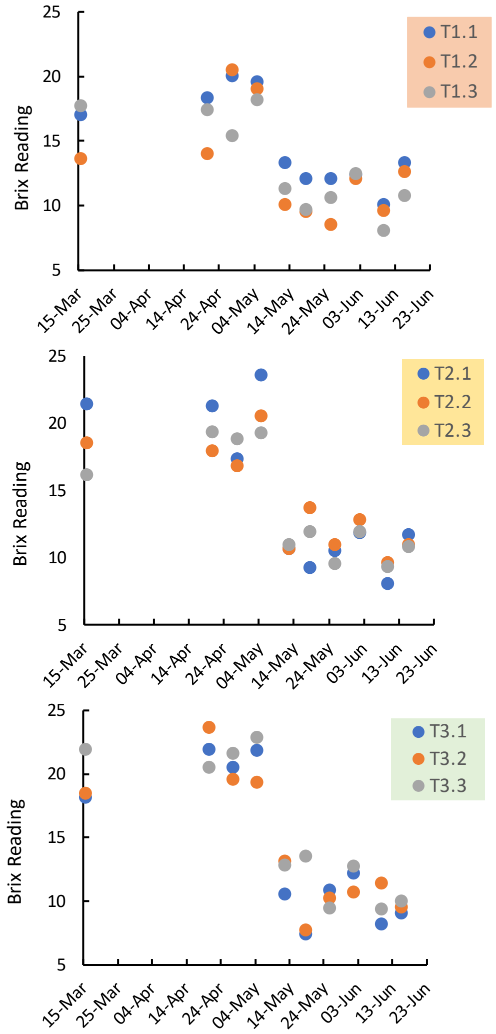


Figure 4.7. Brix measures for replicated zones in each tramline (1 untreated, 2 standard and 3 tailored) from GS21 in mid March towards ear emergence in mid June.

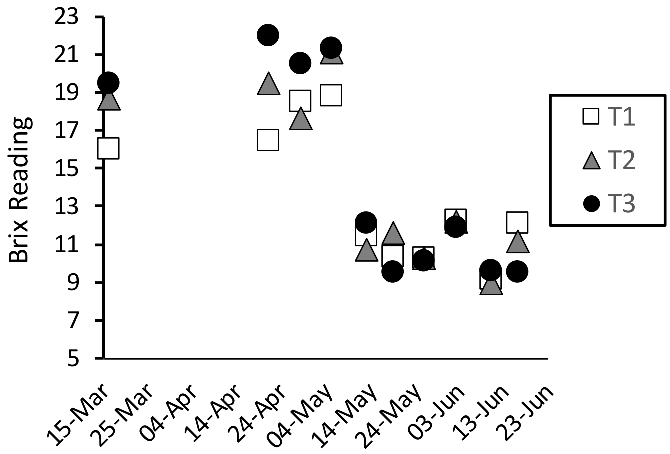


Figure 4.8. Brix measures each tramline (T1 untreated, T2 standard and T3 tailored) from GS21 in mid March towards ear emergence in mid June.

Towards efficiency measures

Using FarmBench data for Tank Wilsons March, it was possible to estimate several efficiencies for each tramline. Final productivity and efficiency value will be based on more details yield and crop data from each zone, but an initial analysis is presented in Table 4.

These preliminary results suggest that overall wheat grain yield was low in this field, and that the standard agronomy tramline resulted in substantially higher yield compared to the untreated and tailored (adjusted) agronomy tramlines.

In terms of efficiency measures: (1) as yield per cost of nutrient input, or N offtake or estimated grain N use efficiency (NUE), the standard agronomy tramline was substantially higher than the untreated and tailored (adjusted) agronomy tramlines, (2) when using crop protection costs only, the tailored agronomy had most yield-to-cost benefit, and (3) for overall input costs, yield-to-cost benefit was comparable among each tramline.

Table 4.2. Yield, input costs and efficiency measures for each tramline; untreated (no fungicide), standard (farm full agronomy) and tailored (adjusted nutrient and crop protection).

	Untreated	Standard	Tailored
Yield (t/ha)	5.0	7.7	5.5
Seed costs (£/ha)	55	55	55
Nutrient costs (£/ha)	112	136	136
Crop protection costs (£/ha)	27	117	27
Total costs (£/ha)	194	308	218
N applied (kg/ha)	160	160	160
N offtake grain (kg/ha)	79.5	109.3	91.3
NUE' (grain yield / fert N)	31.3	48.1	34.4
Yield (kg) per £ (nutrients)	44.6	56.6	40.4
Yield (kg) per £ (protection)	185.2	65.8	203.7
Yield (kg) per £ (total)	25.8	25	25.2

Action points for farmers and agronomists

Main action points are to:

- As this project refines protocols and quantifies cost-benefits towards a tailored agronomy approach, all farms will be invited to check and compare crop assessment methods that are most appropriate and timely for their fields and cropping system.

- At this stage, several lab and field tests for monitoring crop health are being evaluated for productivity and efficiency value.

- Measurement of Brix units and established approaches such as SPAD (leaf cholorophyll) readings has potential to report on crop health, which in the longer term could become part of remote sensing for crop nutrient and health status.

- Year 1 of our project has helped us to develop protocols for use of lab and in-field measures. This information can now be used to complete a more quantitative analysis of in-field measures such as Brix units in year 2.

- Lab assessment, such as leaf nutrient or sap testing, still take several days to sample, process plant material and deliver results. This project will continue to evaluate the practicality and time-frame of in-field measurements towards tailored agronomy, with the aim to link this activity to advanced technologies such as remote sensing for crop health.

- The project will engage with AHDB’s extensive nutrient management research programme for arable crops, comprising work to improve and optimise nutrient applications that are both environmentally and economically sustainable.

- This project will also link with other recent work at SRUC and the University of Edinburgh, which has focused on ways in which ground measures of crop growth and development can help to predict yield and crop resource use. This work has also been coupling crop and soil measures on the ground with remotely sensed crop imaging in order to develop rapid and scaled-up crop monitoring.