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January 2019

Annual Project Report
January 2018 to December 2018
No. 91140002-APR2018

Soil Biology and Soil Health Partnership

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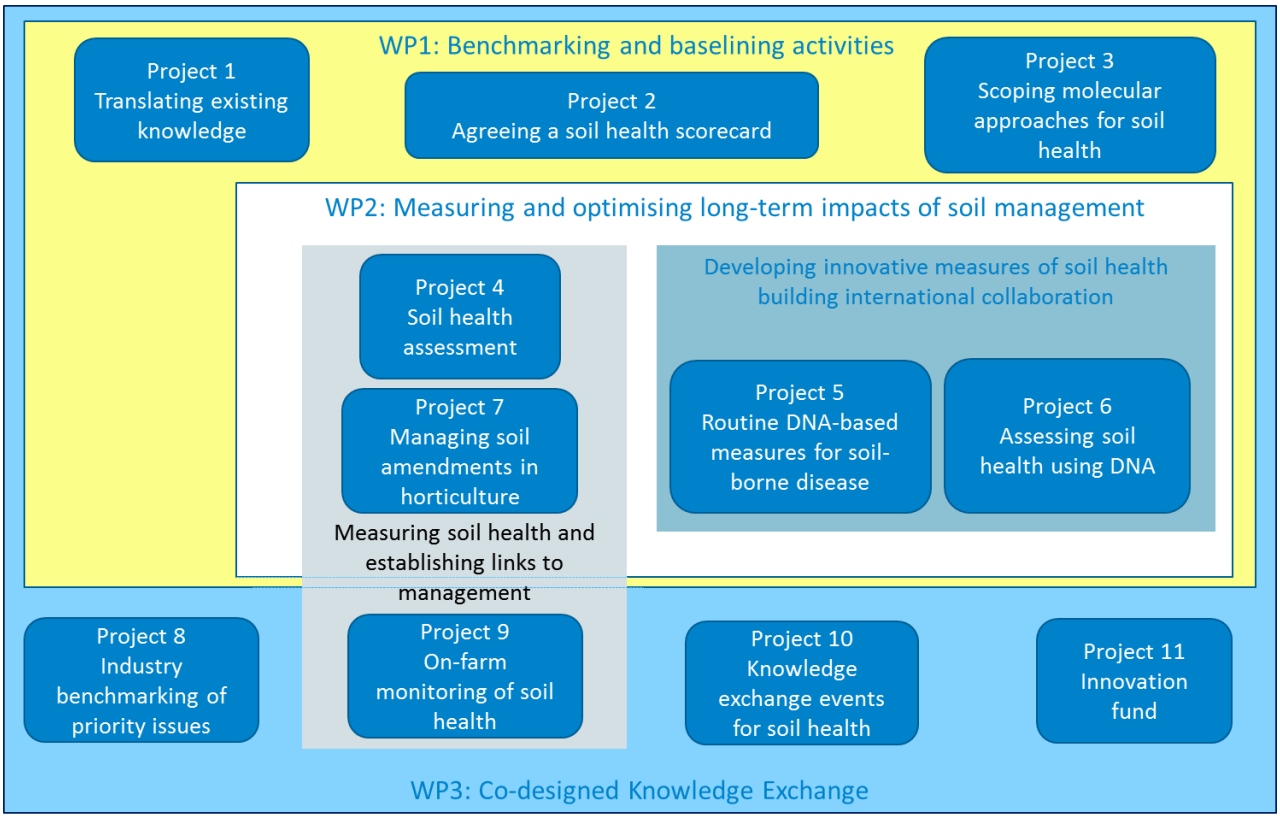
PARTNERSHIP OVERVIEW

Funded by AHDB and BBRO, the Soil Biology and Soil Health Partnership is a five-year (2017–2021) cross-sector programme of research and knowledge exchange designed to help farmers and growers maintain and improve the productivity of UK agricultural and horticultural systems through better understanding of soil biology and soil health. The overarching aims are to:

- Improve on-farm understanding of soil health by sharing current academic and industry knowledge in usable formats
- Develop and validate indicators of soil biology and soil health in research trials and on-farm

The programme comprises a series of interlinked projects.



Further information and reports can be accessed via www.ahdb.org.uk/greatsoils

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COMPLETED PROJECTS

Project title	**Translating existing knowledge of management effects on soil biology and soil health for practitioners**		
Project number	91140002-01		
Start date	January 2017	**End date**	December 2017
Final report and supplementary information	https://cereals.ahdb.org.uk/media/1360270/91140002-final-report-01.pdf https://cereals.ahdb.org.uk/media/1392558/91140002-final-report-01b.pdf		

Project title	**Selecting methods to measure soil health and soil biology and the development of a soil health scorecard**		
Project number	91140002-02		
Start date	January 2017	**End date**	December 2017
Final report	https://cereals.ahdb.org.uk/media/1360273/91140002-final-report-02pdf.pdf		

Project title	**Molecular approaches for routine soil-borne disease and soil health assessment – establishing the scope**		
Project number	91140002-03		
Start date	January 2017	**End date**	December 2017
Final report	https://cereals.ahdb.org.uk/media/1362039/91140002-final-report-03pdf.pdf		

Project title	**Identifying current understanding, knowledge gaps and confirming the key priority issues in understanding and management of soil biology and health**		
Project number	91140002-08		
Start date	January 2017	**End date**	December 2017
Final report	https://cereals.ahdb.org.uk/media/1414623/91140002-final-report-08-final.pdf		

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ONGOING PROJECTS

Project title	**Soil health assessment**		
Project number	91140002-04		
Start date	01/08/2017	**End date**	31/08/2021

Project aim and objectives

The overall aim of this project (Project 04) is to quantify the effects of contrasting management practices on soil biology and health in relation to crop yield and quality, and to evaluate the use of simple tools for assessing soil health. The specific objectives are:

1. To quantify the effects of contrasting management practices and resultant soil conditions (organic matter, drainage status, structure and pH) on crop establishment, yields and quality across rotations including cereals, sugar beet, potatoes, horticultural crops and grass leys.
2. To evaluate the effect of contrasting management practices on weed and disease pressures for each crop in the rotation.
3. To evaluate the effects of contrasting management practices on key measures of soil biological, physical and chemical health.
4. To explore links between soil biology, soil structure and crop productivity
5. To provide a test bed for the development of DNA-based soil health tests (Projects 05 and 06)
6. As part of the whole Soil Health Research Partnership programme, to translate the findings into simple measures of soil health, linked to measurable outcomes and practical management solutions (the integrated soil health scorecard).

Key messages emerging from the project

The prototype soil health scorecard has been successfully evaluated using data from one experimental site with a history of repeated organic material additions. Scores were more favourable ('green traffic light – no risk to production') for soil chemical properties (pH, extractable nutrients, organic matter) where organic materials had been applied ('amber' where only manufactured fertiliser had been applied – 'risk to production, investigate further'), although across the site inherently high extractable P indicated a potential risk to the environment (but not production). More work is required to refine the scoring system particularly for biological properties.

Summary of results from the reporting year

A network of seven existing experimental sites with a history of different management practices and known differences in soil organic matter content, pH and drainage status/structure (key drivers of soil biological functioning) has been established covering a range of soil and agro-climatic conditions in Britain and rotations that include grass leys, cereals, sugar beet & potatoes. These sites provide the test bed for the methods confirmed from Project 2, and facilities to test and develop the molecular-based techniques (Projects 05 & 06).

The following soil quality parameters are being evaluated at each of the sites (with sampling staggered across the lifetime of the project): pH, extractable P, K & Mg, organic matter (loss on ignition and dumas methodologies), total N, bulk density, penetrometer resistance, visual soil assessment of soil structure

(VESS), earthworm numbers, respiration (Solvita CO_2-burst), microbial biomass carbon (MBC), potentially mineralisable N (PMN), nematodes, microarthropods and DNA measures of pathogens (Project 05) and beneficial biology (Project 05 & 06). The assessments will be evaluated in relation to any differences in crop health and productivity.

Training for the project team on the methodologies and assessments was undertaken in September 2017 at the Loddington experimental site (arable rotation on a heavy clay soil), prior to introduction of two contrasting tillage regimes (three replicate strips of a continuous direct drilled field were ploughed). This was followed by sampling at Harper Adams, a sandy loam soil at the end of a 2 year grass/clover ley, in October 2017. This site has a history of repeated organic material additions (cattle FYM and slurry applied for 23 years, green compost for 13 years, green/food compost for 7 years and food-based digestate for 9 years, with a control receiving manufactured fertiliser only), with cumulative organic matter inputs from these materials ranging from 6 to 130 t/ha. The organic material additions increased soil organic matter content, nutrient status and pH (particularly the FYM and green compost treatments; $P<0.05$), with FYM also increasing the PMN content ($P<0.05$). There were no statistically significant differences in the other soil parameters or in the yield of the winter wheat crop (yields ranged from 5.5 t/ha on the food-based digestate treatment to 7.2 t/ha on the FYM treatment, $P>0.05$ due to high variability across the site). In relation to the soil health scorecard, organic material application scored more favourably than the manufactured fertiliser control, particularly for soil chemical properties (pH, extractable K, Mg, organic matter), although extractable P was high across the whole site. More work is required to develop robust benchmarks/thresholds for the biological properties.

The second year of sampling has just (October 2018) been completed at the Loddington experimental site (1 year after introduction of the contrasting tillage techniques; 6 plots) and at the crop rotation x pH experiment at Craibstone near Aberdeen where 48 'plots' were sampled comprising 4 pH levels (pH 4.5, 6.0, 6.5 & 7.5) and following 4 crops (potato, wheat, 3 year grass ley, oats – after grass). Samples are currently being analysed.

Key issues to be addressed in the next year

- Complete analysis of the Craibstone and Loddington experimental sites
- Undertake sampling in autumn 2019 at Craibstone crop rotation x fertiliser (4 crop types, with or without fertiliser N, P & K) and the Gleadthorpe organic material experiment (repeated additions of broiler litter, cattle FYM and slurry, green compost, manufactured fertiliser control).
- Ongoing analysis of the growing database in relation to the soil health scorecard.

Lead partner	ADAS (Anne Bhogal)
Scientific partners	NIAB, SRUC, Fera, GWCT
Industry partners	NRM

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Project title	Monitoring soil-borne disease (DNA measures)		
Project number	91140002-05		
Start date	01/04/2017	End date	31/08/2021

Project aim and objectives

Project 5 (Fera led) aims to demonstrate the value of robust molecular methods (reviewed in Project 3) to quantify the effects of management on soil health across a range of existing (long-term) trial sites and to better understand the link between soil management approaches and minimisation of soil-borne disease risk. Activities across Projects 4, 5, 6 and 7 aim to explore causal links between management and soil-borne disease control by providing some insight into the relationship between pathogen populations and the diversity and function of the overall soil microbiome.

Specific objectives of this project are to:

1. Validate a toolkit of qPCR assays for quantitative detection of the key intractable soil-borne pathogens in arable and horticultural rotations.
2. Establish relationships between pathogen distribution and concentration in soils and potential for disease development.
3. Evaluate the effects of soil management practices (rotations, amendments and cover crops) on the soil microbiome and survival of specific soil-borne pathogens in relation to overall soil health.
4. Design and demonstrate the benefits of an appropriate soil health testing service for growers and agronomists.
5. Integrate results of molecular testing for soil-borne disease risk with associated chemical and physical data to provide a robust soil health scorecard to enable effective on-farm decision support systems for farmers and agronomists.

Key messages emerging from the project

- Standardisation of procedures for soil sampling, DNA extraction from soils and target sequences for DNA amplification is key to understanding soil-borne pathogen distribution, spread and survival across a range of soil types, cropping systems management and disease control practices,.
- Newly validated metabarcoding procedures can now be used to investigate the effect of soil management on the overall bacterial and fungal soil microbiomes.
- A number of qPCR assays have been validated for detection and quantification of a wide range of plant pathogenic soil-borne fungi.
- There is a need to better understand the relationships between detection of pathogens in soil and the risk of disease development so that the benefits of soil health monitoring can be clearly demonstrated.
- Further validation is needed of qPCR assays designed for detection/quantification of beneficial micro-organisms, including biocontrol agents, either individually or in their functional groups.

Summary of results from the reporting year

Toolkit of qPCR assays: Validation data has been compiled for detection of a range of soil-borne plant pathogens using a series of available qPCR assays. Analytical sensitivity and assay efficiency

were determined in the laboratory for 17 different soilborne fungi pathogenic to cereals, potato, brassicas, sugar beet, onion, *Narcissus* or raspberry. Diagnostic specificity of these qPCR assays was determined after spiking 21 different soils, collected from all key trial sites under investigation by the Partnership, with high, medium and low concentrations of each target pathogen. In addition, qPCR assays targeting generic bacterial 16S rRNA and fungal 18S rRNA were similarly validated for use as controls. Detection of total bacterial and fungal populations was possible from all 21 soils, although the accuracy of quantification varied between soil types. Differences in pathogen quantification between soil types appeared to be related to differences in the efficiency of DNA extraction from each soil, rather than to co-extraction of different concentrations of soil materials inhibitory to the PCR reactions.

Pathogen distribution and concentration in soils: Validated qPCR assays have subsequently been used to benchmark populations of relevant soilborne pathogens across the sites under investigation within the Partnership. Populations of *V. dahlia* and *V. longisporum* but not of *Verticillium albo-atrum* or *Phytophthora rubi* were detected in soil samples prior to planting the raspberry trial in Project 07. *Fusarium oxysporum* but not *Sclerotium cepivorum* were detected prior to planting the onion trial (Project 07). Neither pathogen was detected in soil samples prior to planting the *Narcissus* trial (Project 07) although *F. oxysporum* was detected and isolated from the *Narcissus* bulbs to be planted.
Soil-borne fungal pathogens *Rhizoctonia solani* AG2-1 and *Fusarium culmorum* were detected in soils sampled under a grass ley from the Project 04 trial site at Harper Adams but their populations did not differ significantly between long-term organic amendment treatments. Other cereal pathogens, *Rhizoctonia solani* AG-8, *R. cerealis* or *Fusarium graminearum,* were not detected in the same samples from this site. Results from the rRNA control qPCR assays suggested that overall bacterial and fungal populations were highest where farmyard manure (FYM) had been regularly applied. These results aligned with Project 04 findings where microbial biomass (MBC), potentially mineralisable N (PMN) and organic matter (% loss on ignition - SOM) were highest for the continuous FYM treatment ($P<0.05$ for PMN & SOM).

An additional 48 soil samples, collected in April 2018 from the NIAB STAR sustainability trial for arable rotations, were also analysed for soil-borne cereal pathogens. Results of qPCR testing indicated presence of *Fusarium culmorum, Fusarium graminearum*, *Gaeumannomyces graminis* var. *tritici* and *Rhizoctonia solani* AG2-1. Initial data analysis suggested that lower populations of the take-all fungus, *G. graminis* var. *tritici*, were detected in plots where spring or winter beans had been grown as break crops compared with continuous wheat or alternative fallow rotations.

A further 120 samples were collected in October-December 2018 from the Loddington, Craibstone, STAR, Narcissus and onion trials. DNA has been extracted from these samples for additional molecular analyses in early 2019 as part of two PhD studies that started in September 2018.

Effects of soil management practices on the soil microbiome: A metabarcoding procedure for evaluating fungal and bacterial microbiome diversity was standardised. Two DNA extraction methods were compared: A commercial kit (QIAGEN DNeasy PowerMax Soil Kit) extracting DNA from 10g subsamples of soil was compared with a method developed at Fera Science Ltd., which extracts DNA from larger 250g soil subsamples. Metabarcoding was performed on extracted DNA following PCR amplification with16S rRNA bacterial primers and ITS rRNA fungal primers. High throughput sequencing of the amplicons used the Illumina MiSeq platform. A total of 1,160,437 16S and 764,783 ITS sequence

reads were processed using the QIIME2 software pipeline and taxonomic annotation of the resulting operational taxonomic units (OTUs) was performed against the reference sequence databases SILVA (for 16S) and UNITE (for ITS).

Estimates of both fungal and bacterial diversity in soil samples from the STAR site were more affected by the method of DNA extraction than by any of the combinations of 4 crop rotations and 4 cultivation soil management treatments applied in the trial. The 10 most abundant bacterial phyla and the three most abundant fungal phyla, that accounted for most of the diversity, were identified for each sample. Presence/absence of bacterial and fungal families representing both beneficial and detrimental microorganisms could be recognised.

Further metabarcoding analysis of the DNA extracted from soil samples obtained from the various trial sites in Project 04 and Project 07 will be undertaken as part of the 2 PhD studies that started in September 2018.

Key issues to be addressed in the next year

- Procedures will be selected that ensure reproducible and representative extraction of total DNA, from a range of soil types, that is of suitable quality for high-throughput sequencing.
- Metabarcoding of bacterial and fungal microbiomes will be conducted on soils sampled from long-term trials investigating the effects of pH, crop rotations, organic amendments, cultivation practices and drainage.
- Bacterial and fungal benchmark communities that are common to UK agricultural soils will be created and used to standardize interpretation of soil microbiome data obtained across different DNA extraction methods, sequencing platforms and reference databases.
- Initial data relating pathogen populations in soil to disease development for different crops and pathogens will be investigated under glasshouse conditions.
- Soils sampled multiple times across a grid pattern will be analysed to investigate the distribution of individual soil borne pathogens and the diversity of bacterial and fungal microbiomes within a field.
- Soils sampled from Project 7 field trials to evaluate the effects of soil management treatments on soilborne diseases of onion, Narcissus and raspberry crops will be analysed by qPCR to quantify the effects of treatments on pathogen populations.

Lead partner	John Elphinstone, Fera
Scientific partners	ADAS, NIAB, SRUC, SARDI
Industry partners	None

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Project title	Assessing soil health using DNA		
Project number	91140002-06		
Start date	01/04/2017	End date	30/08/2021

Project aim and objectives

Project 6 will evaluate the use of DNA-based analyses to replace individual tests in an appraisal of overall soil health, with the following specific objectives:

1. To short-list targets for analysis for DNA-based approaches (from: molecular biomass; total bacteria and fungi; microbial community structure; functional genes; nematodes; microarthropods; earthworms).
2. To compare results from soil extracted DNA with current methods for assessing soil health used on the experimental sites in Project 04 and further evaluate the effects of soil management practices (rotations, amendments and cover crops) on the soil biological community and its function
3. To optimise the extraction of environmental DNA (eDNA) from soil.
4. To compare of results from soil extracted DNA and eDNA
5. To evaluate whether molecular testing for soil health should be integrated with the soil health scorecard and with pest and pathogen diagnosis to provide information on the soil biological community. Ultimately to enable the further development of effective on-farm decision support systems for farmers and agronomists.

Key messages emerging from the project

The key message to date is that useable environmental-DNA (eDNA) can be routinely extracted from a range of soil types and it gives the same level of sensitivity for the detection of specific plant pathogens as conventional methods of DNA extraction.

Summary of results from the reporting year

The technique for extracting eDNA from soil was improved by the inclusion of a brief bead-beating step, which gave increased recovery of DNA from clay-rich soils. We can now extract eDNA from the range of soil types covered by the SBSH programme (and typically used in UK agriculture) as envisaged in Objective 3. For the e-DNA extraction we are using 250g of soil mixed in phosphate buffer followed by DNA extraction using a NucleoSpin kit and purified using a DNA Clean & Concentrator kit from Zymo Research following manufacturer's instructions. However, the protocol is time consuming, as the first step (the ball mill and incubation in phosphate buffer) can only be done 4 samples at a time so it takes a very long time to process the samples. After that the DNA extraction itself using the NucleoSpin kit, takes about 2-3 hours for 24 samples and the clean-up is roughly in the same range.

This eDNA was shown to be amplifiable with PCR primers regularly used for specific quantification of bacterial and fungal plant pathogens (qPCR) and for the detection of microbial community structure using high-throughput sequencing for bacteria, fungi and fauna (metabarcoding) identified in Objective 1.

The soil samples from the Harper Adams experimental site, (Project 04), are currently being used to compare results from soil extracted DNA and eDNA (Objective 4), in a fully factorial manner:

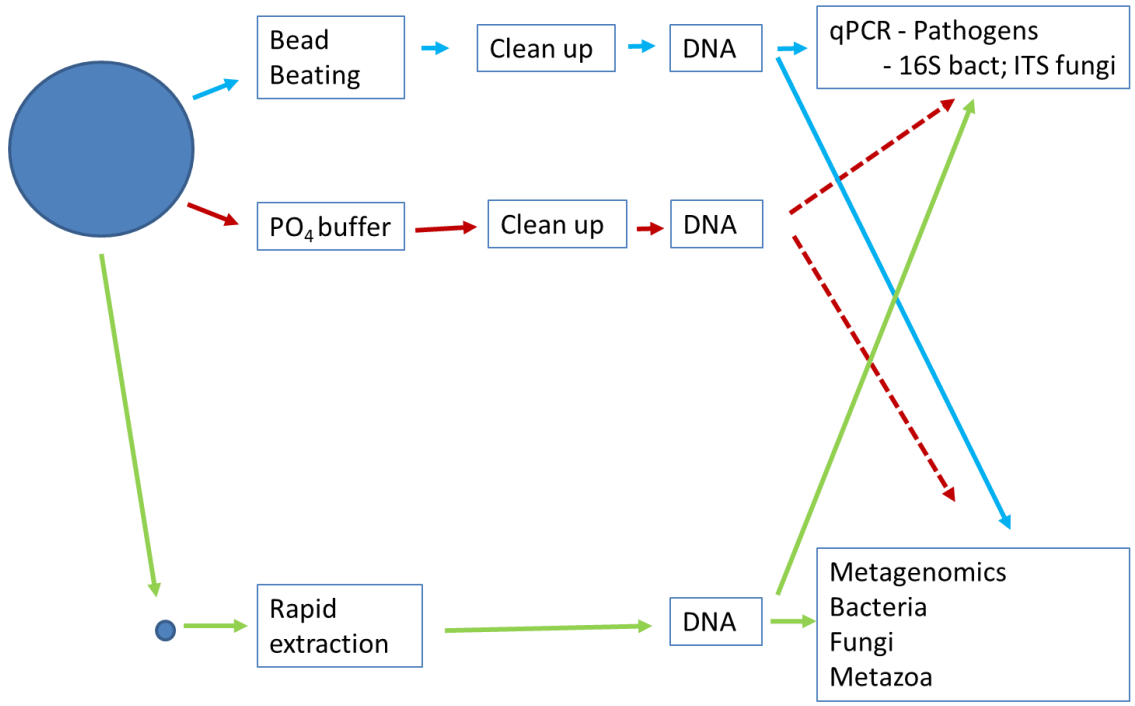

Fig 1. Diagram explaining how the eDNA extraction (PO_4 buffer) will be compared with 2 conventional methods of DNA extraction. The blue circles reflect the fact that typically tiny (<1g) amounts of soil are used in many cases.

Metagenomic analysis is currently under way.

Key issues to be addressed in the next year
• Complete the methods comparison as in Fig. 1 • DNA from soil samples from the Loddington and Craibstone experimental sites (sampled under Project 4) will be analysed for pathogens (qPCR) and biological community structure (metagenomics) once the methods comparison (Fig 1) results are available.

Lead partner	Bryan Griffiths, SRUC
Scientific partners	NIAB, ADAS, Fera, University of Lincoln, GWCT, Natural England
Industry partners	None

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Project title	**Managing soil amendments in horticulture**		
Project number	91140002-07		
Start date	01/08/2017	**End date**	31/08/2021

Project aim and objectives

This project aims to quantify the effects of soil amendments and management on soil health in horticultural production systems, studying sites with a history of intractable soil diseases. Specifically, the following inter-related objectives seek to gain a better understanding of the soil biology and key soil health metrics that should be recorded by growers in order to be able to manage soils to be good for plant health and development:

1. To identify three fields with a history of fungal and/or oomycete soil-borne diseases in preceding horticultural crops and quantify by qPCR the presence of up to six intractable soil pathogens to include at least one able to cause disease in the following horticultural crop;
2. To benchmark the composition of the soil microbiome to be able to analyse changes in the microbial community over the life of the subsequent crop, including the presence and quantity of any pathogens;
3. To carry out physical, chemical and visual assessments of the field soils in tandem with sampling for molecular assays and seek to determine any relationship between these;
4. To record changes in the soil microbiome over one to three years following the use of soil amendments;
5. To determine any relationship between the microbial population composition and levels of disease in onion, narcissus and raspberry as example horticultural crops;
6. To carry out knowledge exchange with growers on the usefulness of the various soil analytical techniques used in the Project for the assessment of soil health / soil disease suppression / pathogen levels of concern.

Key messages emerging from the project

There has been exceptional support for this work by the host growers. Whilst crop rotations can be effective at controlling some pathogens, *Fusarium, Verticillium* and *Phytophthora* are known to remain viable in the soil for years. Some growers have used chemical soil sterilisation before planting, but legislation has started to remove this option. Project work so far has sought to use molecular techniques to quantify pathogen content in the soil. The project will seek to relate these measurements to incidence and severity of crop diseases and to identify the effect of control strategies.

Summary of results from the reporting year

Two crops were planted in 2018 (Raspberry and Narcissus), and Onions will follow early in 2019. Soil sampling for physical (Visual Evaluation of Soil Structure-VESS), chemical (organic matter, pH, extractable P, K and Mg) and biological (Solvita respiration burst, earthworms and crop pathogens) properties was conducted in November 2017 as part of the field selection process (including molecular testing/qPCR). Additional molecular testing and qPCR analysis was undertaken as part of Project 05. Subsequent sampling has been scheduled prior to establishment of the onion crop and will be repeated after the final harvests (all crops) to examine any treatment effects.

Raspberry cv. Maravilla, Tunstead, Norfolk:

In November 2017, a high concentration of *Verticillium dahliae* microsclerotia (41.6/g soil) was found by Harris testing. PCR analysis of soil samples reported a concentration of 0.29 pg/g *Verticillium dahliae*, but no *Verticillium albo-atrum* or *Phytophthora rubi*.

In spring 2018, the 0.8 m wide beds were formed in an area kept from dazomet sterilisation. Plots 8m long were marked out for three treatments (T2-T4) and one untreated control (T1), with six replicate blocks. On 10 May 2018, anaerobic digestate solids (PAS 110 maize/vegetable waste) were hand-applied at 50 t/ha (fresh weight) to T2 and T4 and incorporated by rotavater. Raspberry modules were planted (14/plot), on 16 May 2018. On 21 May, 4 June and 22 October the biofungicide Prestop (*Gliocladium catenulatum*) was applied to the soil around each plant in T3 and T4 at a standard 10% concentration. No phytotoxicity occurred. By 22 October 2018, the 10 central plants/plot assessed showed no signs of Verticillium wilt in 17 of the 24 plots and in affected plots there was usually only one plant with symptoms. Wilt is expected to develop more fully in the second and third year of this experiment to allow treatment comparisons. Soil was sampled by Fera for PCR testing for pathogens on the 22 October.

Narcissus cv. Carlton, Terrington St Clements, Norfolk:

In November 2017, *Verticillium dahliae* microsclerotia at a concentration of 14.2/g soil were found by Harris testing, although PCR found neither species of *Verticillium*, or *Fusarium oxysporum*. On 22 August 2018, plot areas 10m long were marked out in wheat stubble for three treatments (T2-T4) and one untreated control (T1), with six replicate blocks; initial soil samples were taken. On 29 August, green compost (PAS 100 garden waste 0-30 mm) was hand-applied at 50 t/ha to T2. Well-rotted farmyard manure (pig) was hand-applied at 35 t/ha to T3. The soil was then chisel and mouldboard ploughed, power harrowed and put through a bed former to produce 1.6 m wide beds. On 30 August, the bulbs were mechanically planted in two rows at 1700 bulbs per 10 m of bed. For T4, 1.4 kg/plot of a granular mycorrhizal product were scattered over the bulbs as they arrived onto the planter platform before descending the coulters. A sample of bulbs was taken for incubation for disease and 11 out of 29 produced pinkish fungal growth which was confirmed by PCR to be *Fusarium oxysporum*. The planted bulbs will start to produce foliage in spring 2019 and disease assessments will be carried out over two years, including the bulb harvest in autumn 2020.

Onion (cv. to be determined) at Shefford, Bedfordshire:

In November 2017, a high concentration of *Verticillium dahliae* microsclerotia (28.2/g) soil was found by Harris testing (this is not an onion pathogen). PCR found neither species of *Verticillium*, but 439 pg/g *Fusarium oxysporum*. In 2019 three treatments (T2-T4) and one untreated control (T1), will be established, with six replicate blocks. On 31 August 2018, three 11 m wide strips of cover crop (rye (80%), vetch (15%) and Phacelia (5%)) were direct drilled at 35 kg/ha into wheat stubble (T2 & T4), leaving 11 m wide strips undrilled in between. On 4 December 2018, the soil was sampled separately in the cover crop and stubble for physical and chemical properties; cover crop establishment was poor. At the same time, Fera used a grid pattern to collect soil for assessment of pathogen distribution (by PCR) as part of Project 5. In spring 2019, prior to cover crop incorporation T4 will receive an application

of green compost (PAS 100 garden waste 0-30 mm) and T3 will receive only the green compost. The onions will be assessed for yellowing foliage during 2019 and the roots examined at autumn harvest.

Key issues to be addressed in the next year
• Any further development of Verticillium wilt in raspberries will be recorded • Any development of *Fusarium* in the narcissus will be assessed, although there is a likelihood that this could arise from infestation on the bulbs, rather than from the soil • Compost will be applied prior to incorporation of the cover crop and then onions planted • A sample of onion sets will be retained at planting to check for any infestation pre-planting and any development of *Fusarium* in the onions in the field will be assessed The expression of both Verticillium and *Fusarium oxysporum* wilts in plants is heightened by hot dry conditions and so the appearance and severity of wilts will have some dependence on the weather.

Lead partner	ADAS
Scientific partners	Fera
Industry partners	NRM

Project title	**On-farm monitoring of soil health**		
Project number	91140002-09		
Start date	01/08/2017	**End date**	31/12/2021

Project aim and objectives

In this project we will establish farmer-research innovation groups (8-15 growers per group) that link up a wide range of farms and farming systems across the country (encompassing a diverse range of climate, soil, rotations). We will ensure that the innovation groups include farmers with sugar beet, potatoes and/or horticulture in their rotations, as well as reduced / zero-till, cereal/oilseed rotations and grass-based systems. The overall aim of Project 09 is to measure the impacts of the broad range of innovations in management of soil health already present on commercial farms by working with farmer/grower groups to collate data on impacts of crop yield/ quality and measurements of soil health using paired field comparisons/ split field treatments.

The specific objectives project are to:

1. Establish 6-8 farmer-research innovation groups (8-15 growers per group) that link up a wide range of farms and farming systems across the country (encompassing a diverse range of climate, soil, rotations)
2. Support the use of a soil health scorecard approach (developed in WP1, Project 02) to ensure that it provides farmer-friendly soil assessment together with management data to collect a soil health dataset that can be linked to crop yield constraints and their extent over 3 cropping years within on-farm rotations
3. Work with at least one farmer in each group to establish on-farm trials that compare / contrast different management approaches alongside their normal practices (e.g. split field experiment) that dovetail and/or extend the range of treatments studied in the trials in WP2 (Project 4 and 7) and collate data on impacts of changed management on soil biology and health
4. Collate the data from all the farmer-research innovation groups and test and develop the descriptive model developed in WP1 (Project 1). Case studies of the innovative practices (both written and in video form) will be developed together with the farmer groups. Outputs from the model, these on-farm studies and the outputs of the research projects in WP2 will be used to develop a range of appropriate KE materials as part of Project 10.

Key messages emerging from the project

- Farmers and growers are already implementing a range of innovative approaches to soil/water management within rotations, often combining a number of the strategies that are being examined in detail through projects on the experimental sites in WP2.
- Farmers and growers are willing to be actively engaged in sampling and consideration of soil health issues on farm; 73 farmers plus advisors and observers are now actively engaged with the 8 farmer innovation research groups and a further 18 farmers expressed an interest but are geographically too far from the resulting groups to be directly involved at this stage.

- Interest in the sector in monitoring soil health on farm remains strong and there are a number of proposed solutions being rolled out by laboratories and agronomists.

Summary of results from the reporting year

- The industry workshops (Project 8) were used to stimulate expressions of interest in participation in, or co-ordination of, farmer-research innovation groups from advisors and farmer discussion/ benchmarking groups. Over 50 expressions of interest were received from around the UK.
- Project initiation workshops took place with 10 groups in late spring 2018. These discussed possible sampling sites and also reviewed the draft on-farm sampling protocol, which was updated following the feedback received.
- The distribution of group and farming systems covered was reviewed by the Partnership. An additional dairy/arable focussed group was consequently added in collaboration with the AHDB Dairy KE team.
- Discussions with protected cropping, field vegetable and tree fruit sectors have taken place and these sectors are likely to add groups/sites in the future. It has been agreed that they will wait until the initial development of the protocol is complete and opt in at a later stage especially when molecular-based tests are included.
- Further discussions are on-going with other possible funders about further farmer groups, which would be aligned with the Partnership work but which will be funded separately.
- 73 farmers plus advisors and observers are now actively engaged with the 8 farmer innovation research groups around the UK (Table below). In autumn 2018, the groups met on farm to try out the protocol ahead of sampling on farm and identify sampling sites for the future. Over 50 samples were then collected. Farmers have provided rotation and previous crop management data.
- The results from the autumn sampling and the overall on-farm programme will be integrated over the winter ahead of the group meetings, where findings will be discussed and benchmarked, and this data summary and discussion will inform programme KE outputs in spring 2019.

Approx. location	No of farmers currently engaged	Farming systems	Date of sampling workshop
East Anglia	6	Arable – sugar beet – veg – pigs?	17th October 2018
Berks/ Wilts	10	Dairy	18th October 2018
Aberdeen	8	Arable -mixed with potatoes	19th October 2018
Shropshire	6	Lowland livestock, arable, field veg.	23rd October 2018
Appleby	6	Grazing systems	24th October 2018
North East	8	Arable - mixed	25th October 2018
York	15	Arable – mixed with root crops	26th October 2018
Leicestershire	14	Arable – mixed	12th November 2018

Key issues to be addressed in the next year
• On-going work with the farmer groups will expand sampling to new farms/fields and explore different paired-field comparisons though sampling in autumn 2019. • Farmer data will be used to test the underlying conceptual descriptive model of soil functions and their link to management practices. • Soil health monitoring is a developing area with rapid industry roll-out of proposed solutions. There is a need for co-ordination and discussion amongst the providers and users of the data so that improved understanding rather than confusion results for farmers and growers. • Careful negotiation and discussion is needed to develop the opportunities that arise for further farmer groups, which would be aligned with the Partnership work but which will be funded separately and to ensure effective alignment of the work.

Lead partner	NIAB
Scientific partners	ADAS, SRUC, GWCT, ORC
Industry partners	NRM, Frontier, LEAF, Innovation for Agriculture, BASF, The Wye & Usk Foundation

GREATSOILS

British Beet BBRO Research Organisation

AHDB

Project title	Knowledge exchange		
Project number	91140002-10		
Start date	01/01/2017	End date	31/12/2021

Project aim and objectives

Within the Soil Biology and Soil Health Research Partnership, this project aims to develop and disseminate co-designed KE outputs resulting from the knowledge gained mainly through the projects of the Soil Biology and Soil Health Research Partnership. We are also working to link and create a coherent set of inter-locking messages with the AHDB Research Partnership for the "Management of Rotations, Soil Structure and Water". The project will arrange a series of on-farm events to share knowledge of emerging findings throughout the Partnership and allow agri-business to provide inputs as critical friends to the Partnership. All the outputs will be designed to be easily accessed, understood and implemented by farmers to aid them in the improved management of soil health.

The specific objectives for this KE project are to

1. Provide base-line understanding of soil biology and monitoring and management of soil health on farm at KE events in Year 1 of the project using workshops and demonstrations.
2. Use farmer-researcher interaction to co-design farmer-friendly KE material that supports the development of improved understanding of soil biology and practical advice relating to the monitoring and management of soil health.
3. Produce KE materials in formats influenced by co-design with famers to be made available through KE events within this project and as legacy KE through AHDB and BBRO media outlets and by other agreed means.
4. Present research outcomes demonstrating increasing understanding of soil biology, the use of the soil health scorecard and how management on farm affects soil health through workshops and demonstrations in Years 3 and 5 of the project.

Partnership projects featured in the following in the past year

Events

- Presentations at AHDB Cereals and Oilseeds regional KE events (Wales, West, North), February 2018
- Presentations at winter agronomist / technical conferences (AICC, Velcourt, Crop Partners – Hampshire) – January -March 2018
- Presentation at the Leafy Salads Technical Day – March 2018
- Presentation at the Sustainable Landscapes programme conference organised by Future Food Solutions Ltd and Yorkshire Water – March 2018
- SPOT Farm East – Elveden – summer event – May 2018
- Bridgnorth Monitor Farm (Cereals, livestock, potatoes) – summer meeting – June 2018
- Cereals – Soils Pit – farming event – June 2018
- Groundswell – Soil pit with AHDB Monitor farm programme – June 2018
- National Sheep Association event, Malvern – July 2018

- AHDB Dairy workshop series (x 7) on soil management and grassland re-seeds – July -August 2018
- AHDB Narcissus growers events – 6th September Lincolnshire, 18th September Cornwall
- 'Tillage Live 2018' event, posters and soil focus on the SRUC/ NIAB stand September 2018
- Farm Advisory Service, Scotland event, October 2018
- AgriTEch East – Soil health conference, November 2018
- AHDB Agronomists conference – soil health workshop, December 2018

Press articles

Digging into soil dynamics. Crop Production Magazine May 2018.
Elphinstone J. Sorting the health wealth from the soil spoil. Crop Production Magazine May 2018.
http://www.cpm-magazine.co.uk/wp-content/uploads/2018/05/CPM-May-2018.pdf

Elphinstone J. The Good, the bad and the unknown. Soil Matters CPM Supplement. August 2018
http://www.cpm-magazine.co.uk/wp-content/uploads/2018/07/CPM-Soil-Matters-2018.pdf

Why does soil health matter? Grower Dec-Jan 2019
https://horticulture.ahdb.org.uk/publication/grower-decjan-19

Conference presentations, papers or posters

STOCKDALE, E.A., BHOGAL, A., CROTTY, F.V., ELPHINSTONE, J.G. and GRIFFITHS, B.S. 2018. Soil health – moving from general principles to site-specific on-farm management at rotational scale. In: Soil improvement: Impact of management practices on soil function and quality. Association of Applied Biologists, Aspects of Applied Biology 140, pp 1-4.

GRIFFITHS, B.S., HARGREAVES, P., BHOGAL, A., ELPHINSTONE, J. and STOCKDALE, E.A. 2018. Soil Health- visualising the consequences of management change and developing a scorecard for monitoring. In: Soil improvement: Impact of management practices on soil function and quality. Association of Applied Biologists, Aspects of Applied Biology 140, pp 1-4.

CHAPELHOW, C., COOPER, J., BUDGE, G. and ELPHINSTONE, J. 2018. Predicting crop disease from molecular detection and quantification of soil-borne plant pathogens. AHDB Studentship Conference and also at Fera/IAFRI Annual Science Symposium.

FERNANDEZ-HUARTE, M.., ELPHINSTONE, J., ADAMS, I. and GODDARD, M. 2018. High throughput sequencing to measure changes in soil biology in response to long-term management practices. AHDB Studentship Conference and also at Fera/IAFRI Annual Science Symposium.

STOCKDALE, E.A., GRIFFITHS, B.S., HARGREAVES, P., ELPHINSTONE, J. and BHOGAL, A., 2018. *Developing a practical and relevant soil health measurement toolkit for UK agriculture*. International Fertiliser Society Proceedings 824. Paper presented to the International Fertiliser Society at a Conference in Cambridge, UK, on 7th December 2018.

STOCKDALE, E.A. *Using soil indicators as Big Data: challenges and opportunities.* Keynote presentation. CUPGRA 29th Annual Potato conference

Scientific papers
STOCKDALE, E.A., GRIFFITHS, B.S., HARGREAVES, P.R., BHOGAL, A., CROTTY, F.V. and WATSON.C.A. (2018). Conceptual framework underpinning management of soil health – supporting site-specific delivery of sustainable agroecosystems. Food and Energy Security; e00158. https://doi.org/10.1002/fes3.158
Other
MSc Dissertation. Luke Briggs 2018. Application of molecular analyses to measure the effects of long-term crop rotation and cultivation treatments upon soil microbiology. Harper Adams University. 48 pp. As part of collaborative working with Project 5. Podcast: Soil health special (16 November 2018) https://cereals.ahdb.org.uk/podcast Factsheet – Measuring and managing soil organic matter (published) https://www.ahdb.org.uk/knowledge-library/measuring-and-managing-soil-organic-matter Factsheet – The soil food web (in preparation) Guide – Principles for managing healthy soils (in preparation)

Lead partner	NIAB
Scientific partners	SRUC, ADAS, Fera, GWCT, Natural England
Industry partners	NRM, Frontier, LEAF, Innovation for Agriculture, BASF, The Wye & Usk Foundation