Studentship Project: Annual Progress Report 10/2001 to 11/2022

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Project Title:	Belowground carbon sequestration potential of apple trees		
Lead Partner:	NIAB East Malling and the University of Reading		
Supervisor:	Prof Mark Tibbett and Prof Martin Lukac University of Reading and Dr Flora O'Brien and Dr Mark Else NIAB East Malling		
Start Date:	Sep 2019	**End Date:**	Sep 2023

1. Project aims and objectives

This project aims to investigate possible factors that may increase or inhibit the potential of apple trees to sequester carbon belowground during the lifetime of an orchard (life cycle).

The objectives of this research were to assess five attributes that may influence the belowground carbon sequestration ability of apple trees:

1. Establish if different apple rootstocks effect the carbon levels found in different soil regions around the tree roots (bulk, rootzone and rhizosphere soil). The rootstocks (M9, M116 and MM106) are all commercially used in the UK apple growing industries (cider and dessert growing).
2. Determine whether the grafted scion would influence the rootstocks' ability to sequester carbon into the soil, through the comparison of 5 different scion varieties on the same rootstock. The rootstock used in this investigation was M9, which is a dwarfing variety that is commonly used in the production of dessert apple.
3. Investigate how global temperatures affect the sequestration ability of different scions (all grown on M9 rootstocks).
4. Research if the amount of carbon stored in the soil changes as orchards age (specifically on cider orchards as they have a greater longevity than dessert orchards). This was done by comparing 17 orchards ranging in ages from 2 to 46 years at the end of harvest in November and December 2021.
5. Study what happens to stored orchard soil carbon following the removal of the trees.

2. Key messages emerging from the project

Apple trees are continuously sequestering carbon into the soil over the lifespan of the tree. However, the amount of carbon which is stored will be determined by many factors both during the lifetime of the orchard and at the time the orchard is grubbed.

Results from the orchard age comparison study (Objective 4) showed that carbon is maintained but does not increase as orchards become older. By comparing orchards of different ages at one off sampling points, soil carbon levels under apple orchards at a depth of 30cm have been shown to be maintained throughout their lifetime. Therefore, natural carbon turnover through soil and microbial respiration must be offset by sequestration. Experiments to date have also shown that carbon is being stored in different regions of the soil and these stores are maintained over the lifespan of the orchard (Objectives 1 and 4).

However, the influence of scions on rootstock and the difference in carbon stored by different rootstocks (Objectives 1 and 2) have been inconclusive. These objectives may require longer-term studies. Potentially, the duration of the experiments in this project are too short for any differences to be observed.

3. Summary of results from the reporting year

Data has been collected and analysis is ongoing.

Objective 1: Establish if different apple rootstocks effect the carbon levels found in different soil regions around the tree roots (bulk, rootzone and rhizosphere soil)
Experiments showed soil pH increased within the bulk soil across the three rootstocks (soil not in contact with any roots), but this could be down to the fertigation. From the start, biomass carbon levels significantly increased both above and below ground.

Objective 2: Determine whether the grafted scion would influence the rootstocks' ability to sequester carbon into the soil, through the comparison of 5 different scion varieties on the same rootstock
The scions had little effect on soil nitrate levels by the end of the experiment. Figure 1 shows there was variability between the same variety of scions. Soil nitrate can influence the ability of the soil to store carbon. Root biomass carbon (% Carbon) generally increased from planting to the final harvest 18 months later, some did show a slight decrease but there were some scion differences all the way through the experiment, Gala showed a significant difference from the first harvest to the final harvest but not at the intermediate stages (between harvest 1 and 2 or harvest 2 and 3) (Figure 2) and some showed wider variations within the same scions.

In the two experiments where trees were being regularly fertigated results showed increases in soil nitrate levels, but this was down to the daily nitrogen-based feed.

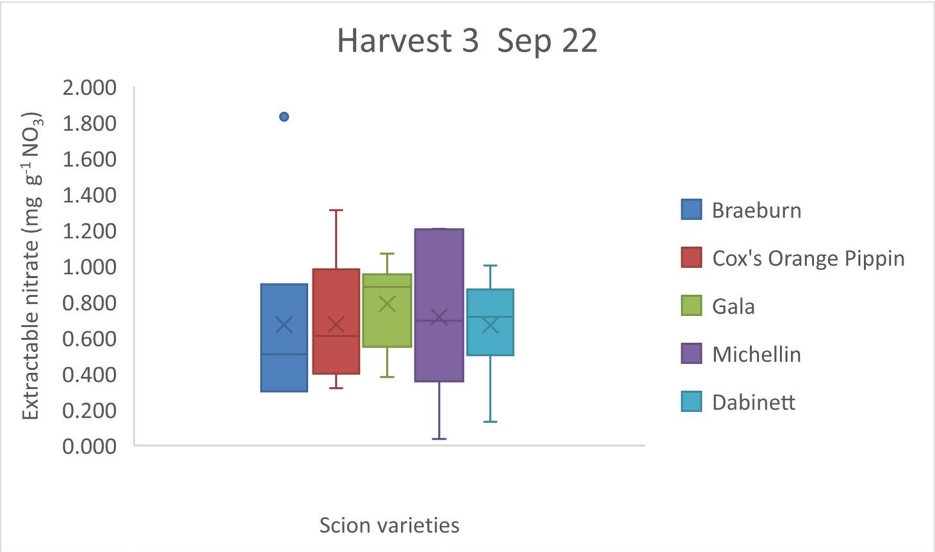

Figure 1: Soil nitrate levels at the final harvest of the rootzone soil for the five different scions under investigation.

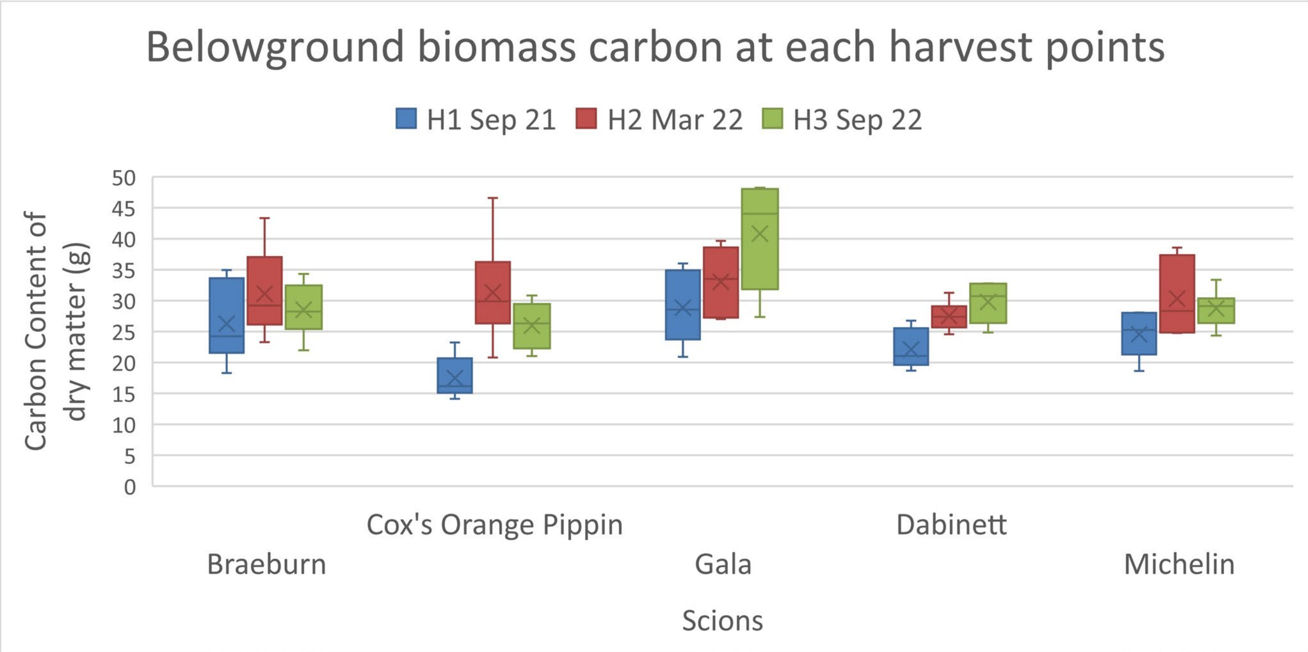

Figure 2: Showing the belowground biomass carbon across the three harvest points that were six months apart.

<u>Objective 4: Research if the amount of carbon stored in the soil changes as orchards age</u>

The comparison of soil carbon under different ages of orchards (within the tree rows and grass alleys) shows very similar results across all the various carbon fractions that were assessed as part of this experiment, an example of the results seen are shown below in Figure 3, (samples were processed by NRM). Grass alleyways mirrored what happens to that of the tree rows, but at a slightly lower level (although were not significantly different). In the younger orchards where the trees have been relatively newly planted (which had had soil enrichment added) carbon levels showed a decline until the age of 5-6. At this point there was an increase in soil carbon, which fluctuated within a narrow range over the remaining forty years.

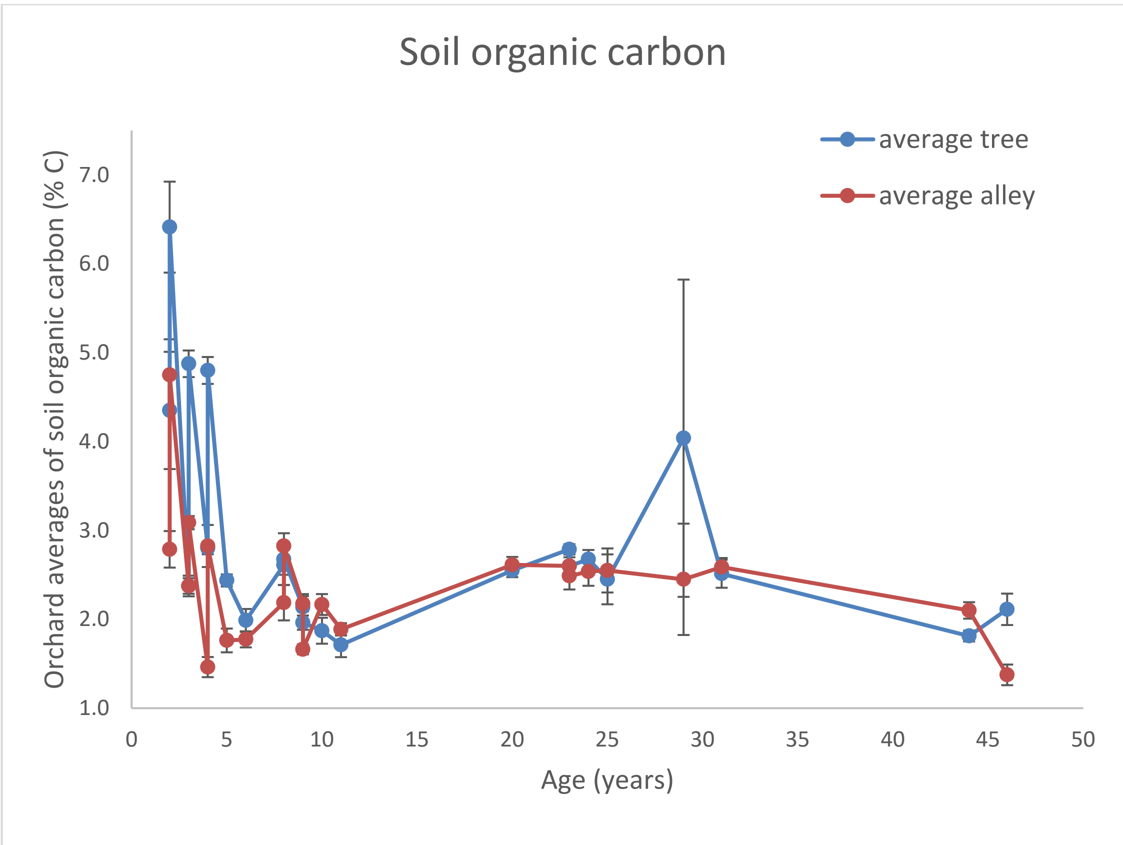

Figure 3: The soil organic carbon % across the age range of orchard sampled as an average of each individual orchard. Orchards of different ages were sampled just once.

4. Key issues to be addressed in the next year

Finishing off laboratory analysis of soil samples, including soil and root total carbon and nitrogen levels, microbial biomass carbon (chloroform fumigation extraction method followed by ninhydrin-reactive n assay for microbial biomass-) and active carbon through a permanganate assay. All the collected data will need to be analysed, including bioinformatic analysis of amplicon sequencing data to identify changes in soil bacterial and fungal communities. Finally, to complete writing up and to submit the thesis by next September.

5. Outputs relating to the project

(events, press articles, conference posters or presentations, scientific papers):

Output	**Detail**
World congress of soil science 2022	Poster and short oral presentation on the experiment looking at the soil carbon under cider orchards of different ages (lifespan of the orchard)
Poster	For visiting DTP students to see the work of PhD student based at NIAB at East Malling
Poster	Update for NACM for cider growers at their machine and crop walk

6. Partners (if applicable)

Scientific partners	AHDB, University of Reading, NIAB Easting Malling AND CTP-FCR
Industry partners	Berry Garden Growers, Worldwide Fruits, NACM, Marks and Spencer's, Worshipful company of Fruiters.
Government sponsor	BBSRC