Grower Summary

Belowground carbon sequestration potential of apple trees

SF/TF 170

Annual report 2021

Project title: Belowground carbon sequestration potential of apple trees

Project number: CTP_FCR_2019_5

Project leader: Prof Mark Tibbett and Prof Martin Lukac University of Reading and Dr Flora O'Brien and Dr Mark Else NIAB EMR

Report: Annual report October 2021

Previous report: October 2020

Key staff: Catherine Chapman

Location of project: NIAB EMR and the University of Reading

Industry Representative: National Association of Cider Makers and Worldwide Fruits LTD

Date project commenced: October 2019

DISCLAIMER

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

Can apple orchards help to mitigate rising atmospheric Carbon dioxide levels?

I am investigating the attributes that may affect belowground carbon sequestration of apple trees. This includes differences between commercially used rootstock, scion-rootstock interactions, increased temperature on scion-rootstock interaction, tree age and carbon levels in the soil between alleyway and tree stands, and what happens at the end of orchard life to the soil carbon post grubbing up.

Background

Climate Change is affecting global weather patterns, resulting in predicted temperature increases and droughts and flooding episodes, this will put greater pressure on food production. Greenhouse gases (GHGs) in the atmosphere are still rising; in May 2021 the level of carbon dioxide (CO_2) in the atmosphere had risen to 419.05ppm, representing an increase of over 26% since June 1969 when it was 326.76ppm (noaa.gov). The UK signed up to the Kyoto protocol (UNFCCC, 2014) where they agreed to reduce global carbon (C) emissions, this was followed in 2015 by the Paris agreement (*UNFCCC*, 2015) in which 196 countries, committed to keep the global temperature rise below 2^{o}C and to achieve net-zero carbon emissions by the second half of this century. In 2019 the UK became the first major economy to put in a legal frame work to achieve net -zero GHG emissions by 2050 (*UK Gov*). Consequently, the UK government has invested in technologies and projects aiming to mitigate and capture atmospheric CO_2. The Industrial Strategy Challenge Fund representing a major part of the strategy to achieve this.

Perennial crops such as apple trees could help mitigate rising atmospheric CO_2 levels through sequestering C belowground via the roots into the soil. Soil is the second largest active C cycling pool after the oceans (Fry et al., 2018), and it is believed that soil can store more carbon as it is not at full capacity (Stewart et al., 2007). Ledo et al (2020) found that approximately 30% of land is covered with perennial crops such as apple orchards, they suggest that perennial crops over their life time become carbon zero if not C negative as they continually absorb and store carbon as the soil is not being disturbed and releasing CO_2 back into the atmosphere.

Current rootstock breeding has promoted carbon uptake by the fruit, thereby limiting the amounts sent to the roots and out into the soil. Currently, it is not known if any particular apple rootstock has a greater ability to store C below ground, and this is what this study aims to determine. The amount of C that a tree can sequester varies dependent upon tree types (such as fruiting trees, other non-fruiting deciduous and evergreen trees) and the partitioning of carbon in different compartments, such as above ground in stems, branches, and fruit, or belowground in roots or released via exudation into the rhizosphere. This can also be affected by microbial (bacterial and fungal) communities in the rhizosphere, which can promote nutrient uptake from the soil by the roots, in return for root exudates which feed these soil communities (Kell, 2012). Other factors that can affect C sequestration include abiotic stresses such as droughts and flooding, which can all have an impact on the rate of photosynthesis, growth, storage, and production as well as on the soil microbial processes and GHG emissions. In a climate experiment that is currently being carried out at the National Fruit Collection at Brogdale in Kent, UK (*Climate change could alter the face of apple growing in Britain*, 03/10/2018), 20 different dessert apple varieties grafted onto M9 337 rootstock, are being grown under six environmental conditions to see what effect increased temperature and changes in rainfall have on the growth, flowering, fruiting and fruit storage of the apples. Currently, they have no plans to look at belowground carbon sequestration.

Carbon that has been sequestered in the soil can be released back in to the atmosphere as CO_2 via soil respiration which can increase as a result of disturbance e.g. tillage (Schlesinger & Andrews, 2000). Dessert orchards have a commercial life span of 15-20 years, whereas cider orchards are between 50-80 years, after which they are grubbed up, which causes soil disturbance, and the aboveground growth is generally burnt.

This project aims to see what affects the ability of an apple to sequester carbon belowground, such as root system architecture via different rootstocks sizes, scion-rootstock interaction, temperature and watering and other factors.

Summary

In my first year of work, I set up a short-term glasshouse experiment to investigate if there was a difference between three UK commercially used apple rootstocks (M9, M116, and MM106) in the amount of carbon they sequester both in the roots and the soil. The rootstocks were all grafted with Cox's Orange Pippin to avoid the influence of the scion-rootstock interaction and were grown in 1 meter x 30cm x 3cm rhizotron boxes in fumigated soil. Soil samples and images were collected at monthly intervals and 12 trees were harvested every six weeks, with the final 18 trees being harvested 19 weeks after planting.

Root samples were sent away and showed that nitrogen levels were the same across the three rootstocks, but carbon levels were higher in the larger rootstocks. Soil carbon levels significantly increased over the experiment in the two soil regions under investigation (Bulk and Root zone (1cm around the root)).

This year I have set up two experiments one based at NIAB EMR and the other at the National Fruit Collection at Brogdale Farm in Kent.

The first of these aims to determine whether scion-rootstock interactions affect the levels of C stored belowground. This experiment takes place in the poly-tunnels and glasshouses at NIAB EMR for up to 18 months. I am using 90 trees; 60 trees are being grown in pots (which are in the poly-tunnels) and 30 in rhizotrons which are in the glasshouse. It uses 3 commercial dessert apple varieties (Cox's Orange Pippen, Braeburn and Gala) and 2 cider apple varieties (Dabbinett and Michelin) all of which are grafted on to the same rootstock (M9).

The second experiment looks at the effect of increasing temperature on scion rootstock interaction on belowground C sequestration. This experiment will run for 2 years and uses the climate change experiment running at Brogdale for the past 5 years, funded by the National Fruit collections Trust. The trees are planted directly in the ground and covered by poly tunnels. One of the tunnels is open sided to maintain the outside temperature while being slightly protected from the weather conditions. In contrast, the other two are fully closed and vented when temperatures exceed +2°C and+ 4°C. They have about 20 different dessert apples all grafted on to M9 rootstocks, out of these I have chosen to use 8 varieties for my experiment (listed below) with 6 trees per tunnel per variety (153 samples in total including 3 alley ways).

Table 1: Show the varieties of apples that I am collecting soil samples from underneath.

Scion variety	**Scion variety**	**Scion variety**	**Scion variety**
Gala	Braeburn	Cox's Orange Pippen	Winter Pearmain
Discovery	Tropical Beauty	Brambly seedling	George Cave

I am taking soil samples under the trees and alley ways every three months to see how carbon sequestration alters seasonally within the root zone of the tree (30cm from the tree trunk), as this will show root exudate carbon in the root zone. These samples will be taken to the lab for a variety of tests to determine carbon levels, including total nitrogen/carbon/ inorganic and organic carbon levels, microbial biomass carbon.

I have a further two experiments planned to begin this winter and through next year. They are comparing soil C levels associated with different ages of apple trees and determining what happens to the stored C after the orchard has been grubbed up at the end of the orchard’s commercial lifespan. These experiments will just be looking at the total carbon and nitrogen levels in the soil.

Financial Benefits.

There are currently no financial benefits from this project at this stage.

Action Points

There are currently no action points at this stage.