The Effect of Novel Materials on Crop Yield and Soil Biodiversity when used on Commercial Crops

Mortimer Natasha[1*], Fletcher Louise[1], Velis Costas[1]
[1] Pathogen Control Engineering Institute, School of Civil Engineering, University of Leeds, Leeds, LS2 9JT, UK.
*Corresponding author: bio5ns@leeds.ac.uk

Abstract
This research is funded by the European Union LIFE programme as part of a project called CONDENSE and is concerned with the use of novel fertilisers such as biochar, locally available organic wastes and a material produced from olive mill wastewater (OMW) on arable crops. The methods of assessment for this research are related to the comparative yield when compared with traditionally fertilised crops, and the effects of the novel treatments on soil quality and biodiversity. The trials have been set up at the University of Leeds (UoL) farm and will run for two seasons, 2013 and 2014. The trials consist of 5 different treatments applied to the standard arable crops of winter wheat (WW) and oilseed rape (OSR). As the research is in its early stages there are no results as yet, however based on what is known in the literature regarding the impact of organic material on soil biota it is anticipated that there will be a difference in the soil quality between the different treatments.

Introduction
The aim of the research is to assess the effects of novel wastes, composts and biochar on commercial arable and horticultural crops and the impact on soil quality and biodiversity. The research will focus on determining the benefits of replacing inorganic fertilisers with novel wastes and compost (such as chicken manure and OMW) along with the carbon sequestering properties of biochar. Alongside the sustainability of using composted waste as a fertiliser it is important to understand any implications the use of these novel products have on soil health. The health of the soil is key to producing high yield crops year on year. Soil health is measured using abiotic and biotic factors.

The project will involve the measurement of a number of chemical and biological parameters to assess the effects of different treatments on crop quality and yield and the impact on soil biota. The project will enhance the research being carried out by two EU funded projects CONDENSE and FERTIPLUS. The CONDENSE waste management system has been designed to produce a novel fertiliser from manure and OMW. The FERTPLUS project is looking at the reduction in the use of mineral fertilisers and chemicals through the use of biochar made from urban and agricultural wastes. This project will use novel materials generated through CONDENSE together with biochar and manures to carry out a range of agricultural field trials and smaller scale greenhouse and pot trials to determine the impact of these novel materials on crop quality and yield as well as effects on biodiversity within the soil.

Olive Mill Waste
The process of olive extraction is a worldwide industry, predominantly based in Mediterranean countries, but recently intensively cultivated in Argentina, Australia and South Africa. The olive tree (*Olea europea*) is one of the main Mediterranean crops with a cultivated area of approximately 8.2Mha [1]. This crop produces an annual volume of 10 million m^3 of olive mill wastewater and 6 million m^3 of solid olive mill by products; consisting of olive stones, leaves, and pomace [2]. This waste should be utilized in the best way possible for both economic and environmental reasons.

Biochar
The first use of the term biochar was around 1998 for the solid residual of biomass pyrolysis (Bapat and Manahan 1998 in [3]). There was a shift in the 1980s for the purpose of biochar production as a way of sequestering carbon from its previous purpose as an energy and chemical resource [3]. The first people to use biochar as a soil amendment were the Amazonians using 'slash and char' agricultural practices to create the Terra Preta soils or Amazonian Dark Earths which have higher soil fertility relative to standard tropical soils [3-6]. Pyrolysis is the process of thermochemical

decomposition of organic materials in the absence of oxygen at elevated temperatures [3, 7]. There are three product streams from the creation of biochar. These products are: noncondensable gases, combustible bio-oil, and the solid remaining which is biochar [3].

Soil fertility is influenced by a balance of abiotic and biotic reactions that are influenced themselves by the season and their location in relation to other resources. Previous studies have shown that adding biochar to soils may produce immediate effects on properties such as soil nutrition, water retention, or microbial activity [4, 7]. Because of the mineral elements within biochars the incorporation of them into the soil influences soil structure, texture, porosity, particle size distribution and density [4]. The structure can provide a refuge for beneficial soil microorganisms such as mycorrhizae and bacteria and it also influences the binding of nutritive cations and anions [4, 5]. Spokas et al 2012 noted that of the biochar studies they compiled approximately 50% of the studies observed short-term positive yield or growth impacts, 30% reported no differences and 20% noted negative yield or growth impacts [3].

Nematodes

Nematodes have been studied as a measure of soil quality for many years. The monitoring of soil nematodes as a parameter for estimating biodiversity is useful because nematodes are a good indicator of the condition of soils as a result of the impact of pollutants and other stresses [8]. This is because they; occur in high diversity and density in every soil and sediment type, live in the soil capillary water, react rapidly to disturbances, are easily isolated and identified, can be easily allocated to trophic groups; and are in direct contact with dissolved compounds in soil due to their permeable cuticle. [8]

The generation time for nematodes (days to years) is longer than metabolically active microbes (hours to days). This makes them more stable temporally and not simply fluctuating with transient nutrient flushes [9]. Bongers (1999) discussed how the nematode community assemblages are assessed with reference to the Maturity Index (MI). This is based on the allocation of taxa according to life strategy from colonisers (*r*- strategists) and persisters (*K*- strategists). MI has received attention in relation to; soil health and sustainability, biodiversity studies, ecosystem management and the effects of agricultural regimes and ecotoxicology

The MI is the weighed mean of the individual coloniser-persister (cp) scores for the individuals in a sample and in practice varies from 1 under extremely enriched conditions to a value of between 3 and 4 under undisturbed conditions. Manuring and tillage result in increased microbial activity in the soil and the populations of bacterial feeders with high reproduction rates respond more rapidly resulting in a decreased MI. Persisters are more sensitive to pollutants therefore the MI also serves to measure the impact of mixtures of pollutants. There are two groups of opportunistic nematodes, enrichment opportunists (cp-1) which only develop under food rich conditions and form dauerlarvae as soon as the microbial activity decreases and general opportunists (cp-2) which can live under food-poor conditions and are unable to form dauerlarvae [8]. Dauerlarvae are formed in some genera and species as a response to certain adverse environmental conditions such as high population density, lack of food and high temperature [10].

Materials and Methods

The area selected for the plot trials is part of a large research farm in which the primary soil type is the Wothersome series. The area was selected to allow the planting of two different crop types onto the same soil type to ensure that there was no variability due to different soils types. The Wothersome soil is a brown forest soil with a high base status. The crop varieties chosen for this study within the Wothersome series were winter wheat (WW) and oil seed rape (OSR) as these were typical commercial crops grown on the land in this area.

The plots were located so that they fell between the tractor tramlines in the fields with a 6m buffer to neutralise any effect that may occur due to wind effects and spray from the standard treatments applied by the tractors. Both test fields have hedge boundaries enclosing them and the plots were located 18m from the nearest boundary hedge. Hedges within agricultural systems are stores of biodiversity and provide important physical and biological services for the crops. [11], distance from the hedge can impact on the soil faunal species diversity and abundance [12]. A stratified random plot design was chosen to allow for randomisation within the plots whilst making it possible to account for difference between plots depending on their distance from the hedge.

The initial trials described here were carried out using a locally available replacement enhanced organic N source in the form of dried chicken manure alone and in combination with commercially available biochar and were compared to the use of a traditional inorganic fertiliser. The five treatments on each of the crops were as follows:

- Treatment A: Standard ammonium nitrate fertiliser treatment at 30kgN/ha
- Treatment B: Replacement organic fertiliser in the form of pelletised organic chicken manure treatment at 30kgN/ha
- Treatment C: Double dose of replacement organic fertiliser 60kgN/ha
- Treatment D: Treatment B with the addition of biochar at 10tonnes/ha
- Treatment E: Treatment C with the addition if biochar at 10tonnes/ha

According to standard practice when carrying out stratified randomised plots, six replicates of each of the treatments were used for each crop and within each stratified row there were two of each of the treatments. Each sub-plot measured 6 x 4m, this size was chosen to enable the plot harvester with a 2m cutting width to harvest through the centre of each plot. The layouts can be seen in Figure 1 below.

C_5	A_5	B_5	E_5	D_5	E_6	D_6	B_6	C_6	A_6
C_3	B_3	E_3	A_3	D_3	D_4	E_4	C_4	B_4	A_4
B_1	C_1	A_1	D_1	E_1	D_2	B_2	A_2	E_2	C_2

Figure 1: Layout of the sub-plots within the fields (letters refer to the treatment and the numbers to the replicate)

In addition to the plot trials described above it is anticipated that small scale pot trials using the same arable crops will be carried out with the OMW and biochar as a scaled down version of the field trials. Although the small scale pot trials will allow the effect of these materials on the crops to be determined it will not be possible to carry out any biodiversity measurements and therefore determine the impact on soil quality and biodiversity. The OMW will also be trialled within horticultural crop growing within a polytunnel using strawberries as the chosen crop since these are readily grown locally and over an extended season when grown undercover. They are a high value traditional English grown crop and will be subject to treatment with the OMW and biochar. Similar to the arable pot trials, no biodiversity measurements will be made on these trials.

Laboratory Analyses

A number of parameters will be measured in order to determine the impact of the wastes, composts and biochar on crop growth including: plant height, plant (roots, stem/leaves and fruit) dry weight, productivity (fresh and dry weight), and leaf chlorophyll and fluoresces level on site, leaf photosynthesis (Pn), leaf stomata conductance (gs). The physiochemical monitoring will include the following: pH and EC of the soil, nutrients and other elements build up in the soil, analysis of the hydroponic dilution for nutrients reduction rate, presence in the soil of polyphenols, proteins concentration in the leaves, sugars concentration in the products, vitamins and other characteristic for each cultivation molecules, and pathogens analysis in the soil.

Nematodes

The nematodes will be sampled for three months in the growing season and for three months in the harvest season. For OSR this is from March-August and for WW this will be from March-May and July-September. Sampling in this pattern will give an idea of the size and composition of the nematode community through the season [13]. Five samples using a 2.5cm diameter and 30cm long corer will be taken from each plot and pooled to make a composite sample. The samples will be taken in a systematic ‘W’ within each plot, systematic sampling is preferred as it is easier to implement and be consistent between plots [14] and it can give more reliable results [15]. The methodologies for extracting nematodes are varied (Baermann funnel technique, Tyler screen method [16], Whitehead and Hemming tray method [17]). For this research the Whitehead and Hemming tray method has been chosen due to its simple repeatable nature, and no requirement for specialist equipment.

Results

At the time of writing this paper no results were available due to the seasonal constraints of the project; however it is anticipated that there will be some results available at the time of the conference.

Conclusions and Perspectives

Given the information available in the current literature it is not entirely clear what impact the application of these materials will have on the growth and productivity of the crops and soil biodiversity. However given the known properties of biochar it is possible that the addition of biochar will reduce the leaching of nutrients from the soil and could have a positive impact on crop growth.

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