Impact of biochar and animal manure on soil fertility

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1 Introduction

With the increasing population among the world, food security has become one of the main problems nowadays. To ensure a sustainable agriculture, soil management in maintaining soil fertility and agronomic productivity is inevitable. (Lal et al., 2009) Sicily is one of the most important agricultural regions in Italy and Europe. However, due to several degradation processes, its arable land area is one of the lowest within European regions. (Fantappiè et al., 2019) Thus, soil management regarding the fertility is important for a stable food production in Sicily.

Amazonian dark earth (Terra Preta) is an anthropogenic soil originally found in Amazon Basin. It is a soil with high soil organic carbon content and have a higher ability to sustain the nutrients and water in the soil when it compared to normal soil. (Chia et al., 2010) Due to the advantages of terra preta. Synthetic terra preta(STP) has been widely study. Chia et al.,(2010) state that by adding biochar, animal manure, bonds, or inorganic materials into the soil can mimic the structure of terra preta. In that case the soil might have similar characteristics as terra preta. Biochar is the name given to charcoal made from plant materials and wood in the same way as ordinary charcoal is made with controlled burning or roasting in the absence of oxygen, known as pyrolysis. Studies show that the biochar can increase the soil fertility, nutrients availability, and lock up carbon in the soil, reducing CO_2 in the atmosphere and mitigating the climate change problem. David et al.,(2010) indicates that biochar can efficiently prevent soil nutrients from leaching. Atanu Mukherjee and Rattan Lal (2021) also mentioned in their study that biochar can be used as a tool for soil C sequestration and offset the greenhouse gas emissions.

With studies mentioned above, Giacche Verdi Bronte developed an idea to create its own STP to improve the soil fertility and reduce the greenhouse gas emissions in its own lands. By using the biochar, which was produced from the wooden waste from Giacche Verdi, and the horse manure (HM) which was collected from the farm, we can create our own STP. We carried out several pot experiments to further proof the effects of animal manure and biochar on soil. In this report, the design of experiment and the results are shown. Following the analysis of data, conclusions and reflections are given at the end of the report. Besides, several suggestions are mentioned for further study in the future.

2 Methodology

2.1 Selection of plants and animal manure

The choose of animal manure was depended on the local situation. As Giacche Verdi Bronte organization owns several horses in the farm, so we decided to use HM as our animal manure in this study.

Tomatoes are often used as a indicate plant for different agricultural practices.(Aladjadjiyan and Anna, 2018) Lettuce, has a short growth cycle which is approximately 30 days. For short-term study, lettuce could be an ideal choice. Both tomatoes and lettuces require adequate levels of nitrogen (N), phosphorous (P), and potassium (K). These characters allow us to test the biochar efficiency for retaining nutrients. Besides, Shaji et al., (2021) also point out that HM is an ideal fertilizer for crops like lettuce, tomato, and mint because it increases the crop yield with a lasting presence in the soil. Thus, in this study, we selected lettuce and tomato as our target plants to indicate the soil fertility by comparing the plant height.

2.2 The design of pot experiments

There are three treatments in total: (A) Soil, (B) Soil mixed with HM, (C) STP. Each treatment was replicated 4 times in two different plants. (Table 1) The biochar was made from olive branches collected from the field of Giacche Verdi Bronte. After pyrolysis under 500 degrees, the branches were collected and grinded into small pieces by hand. The fresh horse manure was collected from the Giacche Verdi farm and was used right after mixing with water. Biochar and HM was mixed in the ratio of 1:5 to get the biochar&HM mixture.(Figure 1) All the addiments were completely mixed with the soil and filled in the pots with same sizes. The plants were bought from the market and were hand transplanted into the pots.

For lettuces, the HM to soil ratio applied for group B is 1:4, the biochar&HM mixture to soil ratio applied for group C is 1:4. For tomatoes, the HM to soil ratio applied for group B is 1:2, the biochar&HM mixture to soil ratio applied for group C is 1:2.

The study lasted for 25 days (27/6/2022-21/7/2022) and the entire study area contained 24 pots (4 replicates × 3 treatments × 2 plants). (Figure 2)

Group	Composition
A	Soil
C	Soil + HM
C	STP (Soil + Biochar & HM mixture)

Table 1. Soil sets

Figure 1. Plant measurement & HM and biochar

Figure 2. Lay out of pot experiments

2.2 Data collection and analysis

The growth height data was measured manually as it is shown in Figure 1. Data were statistically analyzed by using GraphPad Prism 9.0. One-way ANOVA test was applied to test the significance of the data between three groups. T-test was applied to compare if group B and C has a significant difference.

3 Results and discussions

In our hypothesis, group B and C should have a higher growth rate compared to group A. However, according to the box and whisker plots shown in figure 4, we can see that the growth situation of group A is the best. By comparing the end status of the plant in figure 3, we can also observe that the growth of group A is the best. We have several assumptions that could lead to these results.

Firstly, the incomplete pre-treatment of the horse manure might be one of the reasons. Several studies show that before using HM as a fertilizer, the fermentation of HM is necessary. During the fermentation process, the bacteria inside the HM can be killed to ensure the further application in the soil is safe. However, due to the time limit in this experiment, we didn't leave enough time for HM to ferment, and it probably can lead to an inhibition effect on the plants.

Figure 3. Growth situation at the end of the experiment

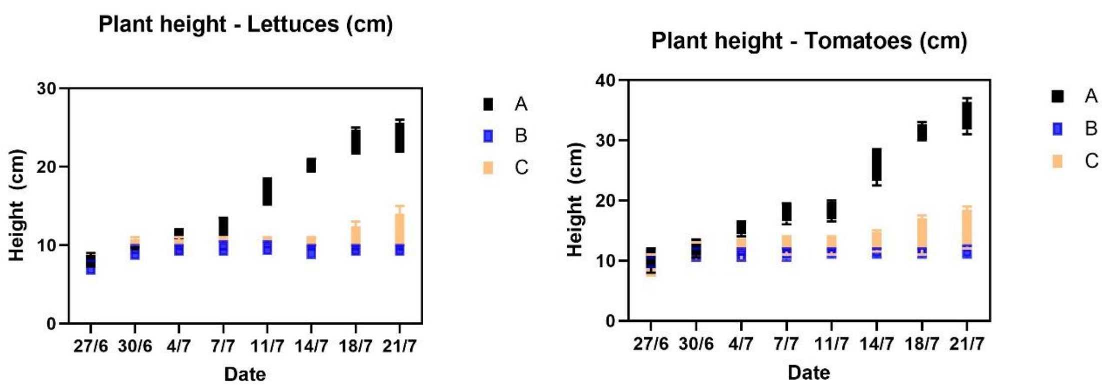

Figure 4. Plant height of lettuces and tomatoes (cm)

Study from Aladjadjiyan and Anna (2018) showed that soil with the treatment of biochar & HM mixture can have a better yield of tomatoes when comparing to the soil just treat with HM. Since the treatments applied on the soil in our study are similar to the study of Aladjadjiyan and Anna (2018), we expected to get similar results on both lettuces and tomatoes groups.

However, according to Figure 4. No significant difference in height between group B and C is shown in the graph. For further exam, t-test is used to exam if the data between group B and C has significant difference. In null hypothesis, we assume there is no significant difference between group B and C. After running the t-test, we have the confidence to say that there is no significant difference between group B and C on both plants ($P>0.05$).(Figure 5&6) Additionally, the QQ plots in figures 5 and 6 show a strong correlation between actual residuals and predicted residuals. Thus, we can consider the model is statistically applicable on data.

The reason for lacking the significance is probably due to the biochar fragments are not fine enough. Besides, in gardening practices, farmer need to leave the mixture for approximately one year to let the biochar react with soil. We ideally assume that without reaction time, biochar and HM can still have the same effect in the soil, thus reaction time for the biochar is missing in this experiment. This could also be the main reason that the group C doesn't show its advantage over the group B.

Nested t test Tabular results	
Table Analyzed	Lettuce
Column C	C
vs.	vs.
Column B	B
Nested t test	
P value	0.1799
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=1.518, df=6
F, DFn, Dfd	2.303, 1, 6

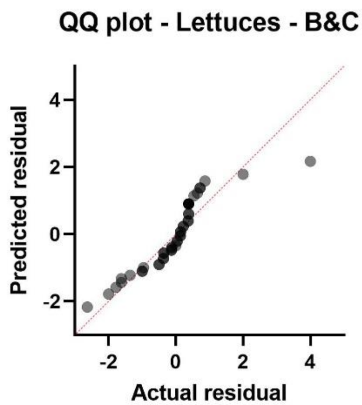

Figure 5. T-test result between group B and C of lettuces

Nested t test Tabular results	
Table Analyzed	Tomato
Column C	C
vs.	vs.
Column B	B
Nested t test	
P value	0.0976
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=1.961, df=6
F, DFn, Dfd	3.844, 1, 6

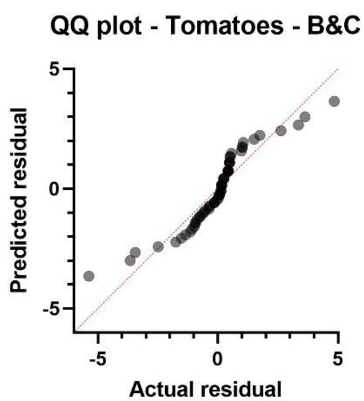

Figure 6. T-test result between group B and C of tomatoes

One-way ANOVA test was applied on all data sets to exam if there is a significant difference among different treatments of the soil. According to the data in figure 7 and 8, the difference of soil can significantly impact the growth of lettuces and tomatoes ($P<0.05$). Because the previous t-test applied on group B and C shows that there is no significant difference in between. We can conclude that the significant difference exists between group A and B or group B and C. Conforming to figure 4, we can easily see group A has the best growth situation.
The QQ plots show that the data closely align with the dot lines which can indicate a normal distribution of the residuals. And a strong correlation exists between actual residual and predicted residual which means the ANOVA test can accurately describe the data.

Nested 1way ANOVA Tabular results	
Table Analyzed	Lettuce
Data sets analyzed	A-C
Nested one-way ANOVA	
P value	<0.0001
P value summary	****
Significantly different (P < 0.05)?	Yes
F, DFn, Dfd	30.58, 2, 93

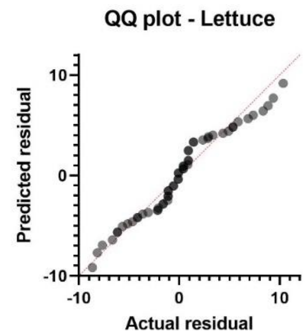

Figure 7. One-way ANOVA test result of lettuces

Nested 1way ANOVA Tabular results	
Table Analyzed	Tomato
Data sets analyzed	A-C
Nested one-way ANOVA	
P value	<0.0001
P value summary	****
Significantly different (P < 0.05)?	Yes
F, DFn, Dfd	33.13, 2, 93

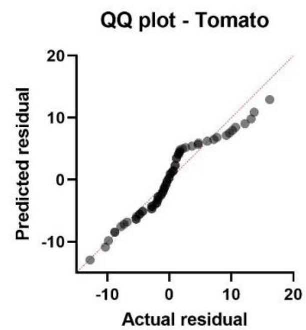

Figure 8. One-way ANOVA test result of tomatoes

4 Conclusion, reflections, and suggestions

Both lettuces and tomatoes growth situation can be influenced by different treatments applied on soil. Results show that soil with HM and STP didn't show an improvement on plan growth. On contrary, the additional addiments inhibit the plant growth.

It probably caused by the incomplete pretreatment of HM and biochar. The HM need to be completely fermented before use, and the biochar should be fined enough to increase the reaction surface in the soil. Besides, the after mixing the addiments into the soil, a certain amount of time should be given to the soil as well. For operative error, we didn't give the same amount of water to each pot. Thus, the difference of water content could also be a factor in influencing the plant growth.

For future study, researcher can very the ratio of the biochar & HM mixture, and the addiment proportion in the soil. Light and water amount should also be controlled in the pot experiments. Additional water holding capacity can also be tested at the end of the experiments.

5 Reference

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Annex

Table 1. original data from field - lettuces

Date	27/6	30/6	4/7	7/7	11/7	14/7	18/7	21/7
A1	9	9.5	10.5	11	16.5	20	23	22.5
A2	7.5	10	12	11.5	14.5	19	21	21.5
A3	8	9.5	11.5	13.5	18.5	21	25	24.5
A4	7	9.5	11.5	13.5	18	21	24	26
B1	8	9.5	10	10	10	10	10	10
B2	8	10	10	10.5	10.5	10	10	10
B3	7	8	8.5	8.5	8.5	8	8.5	9
B4	6	8.5	9	9	9.5	9	9	8.5
C1	9	10	10	10.5	10.5	11	13	15
C2	9	11	11	11	11	11	10.5	11
C3	8.5	8.5	8.5	9	9	9	8.5	8.5
C4	9	10	10	10	10	10	10	10.5

*1-4: parallel groups for lettuces; unit: cm

Table 2. original data from field – tomatoes

Date	27/06/2022	30/06/2022	04/07/2022	07/07/2022	11/07/2022	14/07/2022	18/07/2022	21/07/2022
A5	12	13	16.5	18	20	22.5	30	31
A6	11	12	14	16	16.5	25.5	31.5	34
A7	8	10.5	15.5	19.5	18	28.5	30.5	34.5
A8	12	13.5	16	19	19	28	33	37
B5	10	11	11.5	12	12	12	12	12.5
B6	9	10	10.5	10	10.5	10.5	10.5	10.5
B7	10.5	12	12	12	12	12	12	11
B8	9	10	10	11	11	11	11	12.5
C5	10.5	13	13.5	14	14	14	17.5	19
C6	7.5	12	13	13	13	12.5	15.5	16.5
C7	7.5	10	10	11	11	11.5	11	12
C8	11	12.5	13.5	14	14	15	14.5	14.5

*5-8: parallel groups for tomatoes; unit: cm