Tutor/s

Dr. Anna Rigol Parera
Departament d'Enginyeria Química i Química Analítica
Facultat de Química

Dr. Teresa Sauras Yera
Departament de Biologia Evolutiva Ecologia i Ciències Ambientals
Facultat de Biologia

Grau de Química

Treball Final de Grau

Improving urban soil quality for city re-greening through learning-service actions

Millora de la qualitat del sòl urbà per el reverdiment de la ciutat a través d'accions d'aprenentatge servei

Bet Noguer Pich

June 2018

UNIVERSITAT DE BARCELONA

BKC Barcelona Knowledge Campus
Campus d'Excel·lència Internacional

Aquesta obra esta subjecta a la llicència de:
Reconeixement–NoComercial-SenseObraDerivada

http://creativecommons.org/licenses/by-nc-nd/3.0/es/

A l'Anna Rigol per tota la seva dedicació en el projecte i per donar valor a la química que va més enllà dels laboratoris.

A la Teresa Sauras per fer ajudar-me en els temes de biologia que se m'escapaven de les mans.

A la Jacqueline Estévez pel seu suport i la seva gran ajuda al laboratori i al camp experimental.

A l'Olga i la Sara per donar suport sempre que el projecte ho requeria.

Al CCCB, en especial a l'Amanda Masha i el Josep Perelló, per brindar-nos l'oportunitat de participar en aquest projecte.

A la Lai i la Laia, les mediadores, per la seva gran tasca dinamitzant els tallers.

Als infants que van participar als tallers per la seva actitud participativa i motivada.

A la meva familia pel seu suport incondicional en tots i cadascun dels àmbits de la meva vida.

A tots aquells que han posat un granet de sorra en aquest treball, heu estat una peça clau.

REPORT

CONTENTS

1. SUMMARY 3
2. RESUM 5
3. INTRODUCTION 7
3.1. Contextualization 7
3.2. Urban soils 7
3.3. Compost 8
3.4. Biochar 8
3.4.1. Origin 8
3.4.2. Production 8
3.4.3. Benefits 9
4. OBJECTIVES 10
5. RHIZOTRON EXPERIMENT 11
5.1. Materials 11
5.2. Preparation of the rhizotron experiment 11
5.2.1. Mixtures 11
5.2.2. Planting 12
5.3. Characterization of materials and mixtures 13
5.3.1. Density and mass percentage 13
5.3.2. Acid neutralization capacity 14
5.3.3. Water holding capacity 15
5.3.4. Humidity 16
5.4. Plant measurements 17
6. FIELD EXPERIMENT 20
6.1. Description of the experiment 20
6.2. Plant measurements 20
6.2.1. Green area 20
6.2.2. Plant biomass 22
6.2.3. Correlation between green area and plant biomass 23
7. LEARNING-SERVICE 24
7.1. Event “Moviment Biochar” 24

7.2. Water holding capacity recipe 26
7.2.1. Workshop 26
7.2.2. Results and analysis 27
7.3. Rhizotron recipe 27
8. CONCLUSIONS 29
9. REFERENCES AND NOTES 30
10. ACRONYMS 31
APPENDICES 33
Appendix 1: Doctor X recipe 35
Appendix 2: Evolution of the sunflower growth 37
Appendix 3: Green Area of Melissa and Ruda 39
Appendix 4: Ruda and Melissa biomass 41

1. SUMMARY

A space for citizien action towards the improvement of environmental health, the so-called City Station, was set up as one of the elements of the exhibition “After the end of the world”, held by Centre de Cultura Contemporania de Barcelona, CCCB. Many activities were organized in order to bring environmental problems and their possible solutions closer to citizenship. One of the environmental issues treated was the low quality of urban soils that hampers vegetation growth. The use of compost and biochar as amendments can improve plant growth by diminishing soil compaction, and increasing soil water and nutrient retention. In this context, two different approaches were followed to assess these improvements: field and rhizotron experiments. Besides, learning-service actions were conducted.

In both field and rhizotron experiments, we treated the soil with three doses of biochar, compost and compost mixed with biochar. Plant parameters as shoot hight, number of leaves, green area and plant biomass; and soil parameters as acid neutralization capacity, water holding capacity and humidity, were assessed. In general, the addition of amendments improved soil properties that leads, for example, on water savings. Increasing benefits are found at higher doses of amendment. Furthermore, the best option was the combination of biochar and compost since biochar allows keeping nutrients and water for longer while sequestrering carbon and reducing CO_2 releases into the atmosphere.

Regarding learning-service actions, we designed and performed different activities with citizens e.g. “Moviment Biochar” and workshops with students. “Moviment Biochar” was a set of workshops and informative talks about the benefits of adding biochar to urban soils, organized and made along with IDÀRIA SCCL and MontBio project. In the workshops students could confirm by themselves the increase of water holding capacity of a soil when biochar is added. Citizens appreciated the activities and were very interested and closer to the environmental issue and the proposed action based on biochar.

Keywords: learning-service, soil quality, city re-greening, sustanibility, biochar, compost.

2. RESUM

Dins de l'exposició "Després de la fi del món" a càrrec del Centre de Cultura Contemporània de Barcelona, CCCB, es va destinar un espai per a l'acció ciutadana cap a la millora de la salut ambiental, l'anomenada Estació Ciutat. Es van organitzar moltes activitats per apropar els problemes ambientals i les seves possibles solucions a la ciutadania. Un dels aspectes mediambientals tractats va ser la baixa qualitat dels sòls urbans, la qual dificulta el creixement de la vegetació. L'ús de compost i biochar com a esmenes pot millorar el creixement de les plantes disminuint la compactació del sòl i augmentant la retenció d'aigua i nutrients. En aquest context es van seguir dos enfocaments diferents per avaluar aquestes millores: l'experiment de camp i l'experiment amb rizotrons. A més, es van realitzar accions d'aprenentatge i servei.

En ambdós experiments es va tractar el sòl amb tres dosis de biochar, compost i compost amb biochar. Es van avaluar els paràmetres de planta com la mida de tija, el nombre de fulles, l'àrea verda i la biomassa de la planta; i els paràmetres del sòl com la capacitat de neutralització àcida, la capacitat de retenció d'aigua i la humitat. En general, l'addició d'esmenes millorava les propietats del sòl la qual cosa va comportar, per exemple, un estalvi d'aigua. Els majors beneficis es troben en els tractaments amb major proporció d'esmena. A més, la millor opció era la combinació de biochar i compost, ja que el biochar va permetre mantenir els nutrients i l'aigua durant més temps i, alhora, va segrestar i reduir el CO_2 alliberat a l'atmosfera.

Pel que fa a les accions d'aprenentatge i servei, vam dissenyar i realitzar diferents activitats amb la ciutadania, com ara la jornada "Moviment Biochar" i tallers amb estudiants. La jornada "Moviment Biochar", que va ser organitzada i realitzada juntament amb el projecte IDÀRIA SCCL i el projecte MontBio, va incloure un conjunt de tallers i xerrades sobre els beneficis d'afegir biochar als sòls urbans. En els tallers els estudiants van confirmar per si mateixos l'augment de la capacitat de retenció d'aigua d'un sòl quan s'afegeix biochar. Els ciutadans van apreciar les activitats i es van mostrar molt interessats i propers al problema mediambiental i a l'acció proposada basada en el biochar.

Paraules clau: aprenentatge servei, qualitat del sòl, reverdiment de la ciutats, sostenibilitat, biochar, compost.

3. INTRODUCTION

3.1. CONTEXTUALIZATION

The exhibition “After the end of the world”, held by Centre de Cultura Contemporània de Barcelona, consists, among others, of City Station, a space for citizen action towards the improvement of environmental health (CCCB, 2017).

In City Station, located in the district of Sant Martí (passatge Trullàs s/n, Barcelona) took place two types of activities to empower the citizenship to take action to remediate the low quality of the surrounding environment. On one hand, workshops for schools were performed following recipes prepared by experts without disciplinary boundaries called Doctors X. We prepared two recipes: *Aplicació de biochar als sols urbans: millora de la qualitat del sòl* (Cabrero, 2018) and *Aplicació de biochar als sòls urbans: millora del creixement de la vegetació* (Appendix 1). On the other hand, different set of workshops and informative talks around a topic of environmental health took place on Saturdays, for example, the one in which we participated, “Moviment Biochar”. One of the environmental issues treated in City Station was the low quality of urban soils that hampers vegetation growth in re-greening cities.

3.2. URBAN SOILS

Soils are fundamental to life on earth, but human pressures on this resource are close to critical limits. On one hand, a greater loss of productive soils will increase the price of food, which means million people living in poverty (EMRS, 2015). On the other hand, green areas will be diminished, affecting animal and vegetal species that live in these areas, and affecting the public health, as they allow air renovation and have therapeutic function for people (López, 2013). In order to give answers to the problem, it is necessary to know the principal factors that affect soil functions. The main threaten factors are erosion, loss of organic carbon, nutrient imbalance, acidification, contamination, waterlogging, compaction, sealing, salinization and the loss of soil biodiversity (EMRS, 2015).

In order to improve soil quality, one possibility is to use organic amendments as compost and biochar, which can improve properties as water holding capacity, compaction and humidity, among others.

3.3. COMPOST

Compost is organic matter that has been decomposted in a process called composting. Composting is an aerobic degradation by the action of microorganisms in conditions of controlled humidity, temperature and aeration. These microorganisms convert the long-chain organic substances into short-chain organic substances, a stable and hygienized product (Yu et al., 2008). Ideal feedstocks for composting have from 60 – 70% moisture and high nutrient levels (International Biochar Initiative, 2017).

Its application has environmental and agronomic benefits. Its application in soil results in short-term improvement of soil properties as nutrient content and cation exchange capacity (CEC). Furthermore, as to environmental benefits, its use can remediate contaminated soils by capturing heavy metals (Venegas et al., 2016).

3.4. BIOCHAR

Biochar is a stable solid obtained from the pyrolysis of biomass, rich in carbon, which can endure in soil for thousands of years enhancing their agricultural and environmental value. (International Biochar Iniciative, 2017).

3.4.1. Origin

The use of this material had origin in Amazon Basin in a process that begun thousands of years ago, where indigenous people created islands of rich, fertile soils called Terra Preta, in the framework of tropics where the soils are usually infertile. The enhanced fertility is coming from cooking fires, what results on a high content of black charcoal that means higher levels of soil organic matter, nutrient content, water holding capacity and pH (Glaser et al., 2001; International Biochar Iniciative, 2017). Due to its polycyclic aromatic structure, black carbon is chemically and microbially stable and persists in the environment over centuries, holding carbon and nutrients (Glaser et al., 2001).

3.4.2. Production

The process of production of biochar consists in pyrolise biomass, at high temperatures with limited supply of oxygen. To provide the required energy and reach the needed temperature, in modern pyrolyzers, volatiles from biomass descomposition are reconducted to the pyrolysis chamber (Laird et al., 2009). The process has an important influence on the properties of biochar, specially temperature and duration of the process; also, the biomass source is an influent factor too (Sohi et al., 2010).

As the goal of the production is to create a sustainable approach that potentiates the environmental and agronomic benefits, the source and the process should be sustainable too. On one hand, the process should reduce the emisions of greenhouse gases. The application of biochar reduces the quantity of CO_2 released, because in the pyrolysis a 50% of C forms biochar and will stay stable in the soil, instead of the 99% of C released as CO_2 in the carbon cycle (McLaughlin, 2014). On the other hand, the source of the biomass should be agricultural or forestry waste (Laird, 2008), to avoid scenarios where the production is not based on waste management, but in risky technological alternatives promoted for commercial interests that could foster deforestation and threat biodiversity and natural ecosystems (Salva la selva, 2009). Anyway, if the goal is the valuation of plant waste, it is not a sufficient reason to stop using it.

3.4.3. Benefits

Biochar has a lot of environmental and agronomic benefits when added to the soil. On one hand, it has agronomic benefits due to its porous structure; it can increase the retention of water and nutrients, decreases the soil density and increases the drainage, aireation and root penetration. Otherwise, it also has environmental benefits as the potential to immobilise heavy metals, pesticides, herbicides and hormones; prevent nitrate leaching and faecal bacteria into waterways; and reduce N_2O and CH_4 emissions from soils. (International Biochar Iniciative, 2017).

However, Schmidt et al. (2014) observed that in some cases the use of biochar might lead to reduce plant growth, due to nutrient immobilisation caused especially by the adsorption of mineral nitrogen (N_{min}) and dissolved organic carbon (DOC). In order to solve this drawback, it was suggested to enhance the biochar with organic or mineral nutrient, as compost.

4. OBJECTIVES

The present project has two main objectives. The first one is the assessment of the effect of compost and biochar as amendments in an urban soil. This objective will be addressed by two approaches:

- Analising the capacity of biochar and compost to enhance plant growth in field conditions.
- Implementing rhizotrons at lysimetric scale and measuring different plant parameters (e.g. roots's size, number of leaves, shoot hight) of the sunflowers planted in soils with different doses of biochar, compost and compost with biochar.

The second objective is to take part of a learning-service project to approach the science to the citizens. Specially:

- Performing the Doctor X recipes that determine the water holding capacity of different mixtures of soil and biochar, and evaluate the shoot and root growth.
- Taking part of the workshop "Moviment Biochar" along with MontBio project and IDÀRIA SCCL.

5. RHIZOTRON EXPERIMENT

5.1. MATERIALS

The materials used are soil, compost, biochar, rhizotrons and sunflower seeds.

Soil, compost and biochar are used to make the different treatments. Soil was provided by Buresinnova S.A. (Mercabarna Flor, Sant Boi de Llobregat). Soil contains weathered granodiorite parent materials, including mica, feldspar and quartz, sieved at 10 mm. It is a sandy soil with pH 8.0, low in organic matter and nutrient conten (Cabrero, 2018). Compost was also provided by Buresinnova S.A. Biochar was provided by IDÀRIA, Empresa d'Inserció, SCCL (Llagostera), where the raw materials used, as woof of heather, arbutus and holm oar; are resulted of fire prevention works in Gavarres and Ardenya Cadiretes.

Rhizotron is a laboratory flowerpot that consists in a dark pot with a clear face through which one can observe roots as they grow. We constructed the rhizotrons and we bent each one into a bigger dark pot in order to avoid light on the clear face.

The target plant was the sunflower. It was used in this experiment due to the following reasons. Firstly, sunflower is a model plant in agronomic studies having low power of penetration into the soil that makes it very sensitive to the compactation of the soil, so the differences between the compactation of the differents treatments will be more evident. Secondly, the morphology of the plant is useful because of its simplicity, especially the reduced number of leaves and the single shoot, which makes easy to follow the growth. Also, it is used due to economical reasons and the short duration of its cycle (Gómez-Arnau, 1989).

5.2. PREPARATION OF THE RHIZOTRON EXPERIMENT

5.2.1. Mixtures

Three types of mixtures were made: soil with biochar, soil with compost and soil with biochar and compost. Each mixture is made in three different doses of amendment: low, medium and high, by duplicate. The acronyms used and the ratio of volumes (V) mixed of each materials, for each mixture, are described in table 1.

Table 1. Acronyms and composition of each mixture

Acronym	Description	$V_{Amendment}$:V_{Soil}
BL	Soil with low content of biochar	3:10
CL	Soil with low content of compost	3:10
CBL	Soil with low content of compost and biochar	(1.5+1.5):10
BM	Soil with medium content of biochar	6:10
CM	Soil with medium content of compost	6:10
CBM	Soil with medium content of compost and biochar	(3+3):10
BH	Soil with high content of biochar	9:10
CH	Soil with high content of compost	9:10
CBH	Soil with high content of compost and biochar	(4.5+4.5):10

Five liters of each mixture were prepared in the space City Station by taking volumes of each material sieved at 5mm. The quantity of each mixture that we didn't use on rhizotrons was taken to analyse in the laboratory.

5.2.2. Planting

Planting was done by children who participated in the workshop "Moviment Biochar" being guided by me (Figure 13).

Two liters of a mixture, approximately, were put in a rhizotron. Then, three sunflower seeds were planted vertically and together, in a depth of, approximatelly, one centimeter. Finally, it was watered.

Automatic irrigation was installed by the gardening company Buresinnova S.A (Mercabarna Flor, Sant Boi de Llobregat) in order to water each plant in the same way, two minutes a day.

5.3. CHARACTERIZATION OF MATERIALS AND MIXTURES

5.3.1. Density and mass percentage

Density of mixtures was determined in the lab. We measured a known volume of mixture and then, we weight it. It was determined twice for each mixture. The results are showed in Table 2.

Table 2. Density of mixtures

Mixtures	Density (g/mL) Mean (SD)
BL	1.00 (0.03)
BM	0.87 (0.01)
BH	0.79 (0.01)
CL	0.99 (0.01)
CM	0.94 (0.01)
CH	0.90 (0.05)
CBL	0.98 (0.01)
CBM	0.91 (0.06)
CBH	0.88 (0.03)

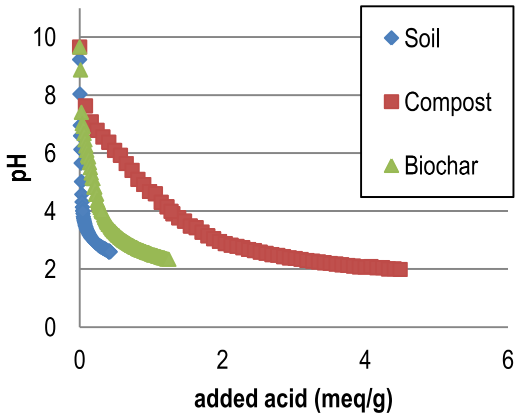
Density was clearly lowered when applying amendment in higher doses. That means that the addition of amendments could facilitate the plant to penetrate the soil due to the decrease in soil compactation. Knowing the density of mixtures, it was possible to calculate the mass percentage of it (Table 3)

Table 3. Mass percentage of mixtures

Mixtures	Composition		
	% w/w Soil	% w/w Biochar	% w/w Compost
BL	94	6	-
BM	88	11	-
BH	84	16	-
CL	91	-	9
CM	83	-	17
CH	76	-	24
CBL	91	3	6
CBM	85	6	9
CBH	78	8	14

5.3.2. Acid neutralization capacity

Acid neutralization capacity (ANC) is a measure for the overall buffering capacity against acidification. ANC of materials is the quantity of acid added (meq/g) to reach a pH=4. It was determined by using Banc pH-103, which works by adding acid from time to time and measuring the pH, while stirring. The conditions of the determination were the following: to add 0.1 mL every 20 minutes until pH=2. In figure 1 is represented the titration curve by addition of acid and the ANC mean values by duplicate for each material.

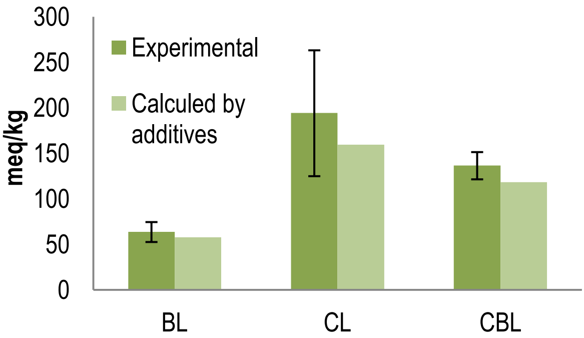


Material	ANC(meq/kg) Mean (SD)
C	1281(1)
B	272(50)
S	45(1)

Figure 1. Curve of materials titrated with acid (left) and ANC values (right)

Compost and biochar have more capacity to neutralizate acid additions than soil. It can be explained by studying the functionality of each material. Compost has a lot of functional groups that can be protonated, due to the presence of materials with high levels of polimerization, as humic and fulvic acids. Biochar also has a lot of funcional groups as carbonyl, carboxyl, phenyl, amine, ester groups, etc. (Venegas, 2015). On the contrary, the low clay content leds to low ANC in soil.

As ANC of mixtures are expected to be additives, we calcule how is modified this parameter by the application of amendments. ANC of low dose mixtures were experimentally determined to verify that ANC of the mixtures are additives.



Mixture	$ANC_{calculated}$ (meq/kg)
BL	58
BM	71
BH	82
CL	160
CM	261
CH	344
CBL	118
CBM	169
CBH	234

Figure 2. Comparison between experimental and calculed values (left) and ANC of mixtures (right)

ANC was increased by applying amendments in higher doses. Compost is the best option to increase the buffer capacity of the soil towards acid stress.

5.3.3. Water holding capacity

Water holding capacity (WHC) was determined, following the Doctor X Recipe (Cabrero, 2018) as was done in the workshops (Section 7.2), for materials and mixtures by duplicate. Firstly, a bottle of 33 cL was halved and the upper part was put upside down. Some cotton was placed in the neck of the bottle and the weight of the upper part with cotton was written down. Then, the upper part was filled with the sample, weighted, filled with water until 1 cm above the mixture and left for 24 hours. After this time, the bottle top was removed and the water was left to drain for 48 hours. Then, the cotton was carefully removed, the bottle top was put again and the upper part was weighted. WHC was calculated with the equation 1.

$$\text{WHC}(\%)=\frac{\text{wet weight(g)-dry weight(g)}}{\text{dry weight (g)}}\cdot 100 \qquad [1]$$

In the following figure are tabulated the values of WHC of materials, and there are represented the values of WHC for each type of mixture.

	WHC(%) Mean (SD)
S	19(1)
B	99(8)
C	12(8)

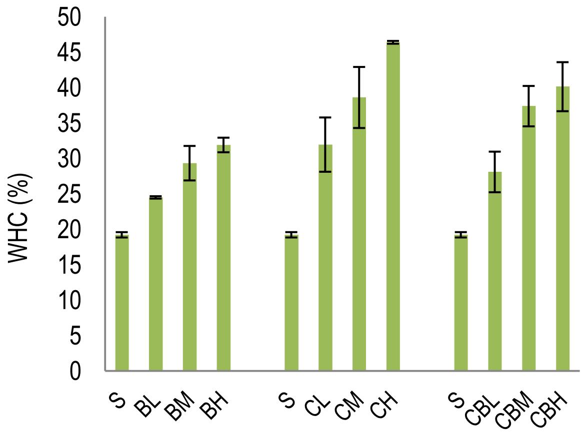


Figure 3. WHC of materials (left) and comparision of WHC between treatments with diferent doses of amendment (right)

WHC significantly increases with the addition of amendements, being compost and compost with biochar the best option. It means that the use of these amendments increases the amount of water available.

5.3.4. Humidity

The humidity of the mixtures where rhizotrons were planted was determined by different methods. Twice, the humidity was determined *in situ* by using ML3 – Sensor ThetaProbe. This device has a sensor which is put into the mixture and determines the humidity, expressed as a volume percentage. Another time, the humidity was determined gravimetrically by taking samples of rhizotrons with a cylindrical graduated tube that was introduced into the mixture and a sample of known volume was taken and hermetically closed. Then, in the lab, all the samples were weighted to determine the fresh weight and put in the oven at 105ºC until constant weight to determine the dry weight, used to calcule the humidity with the equation [2].

$$\text{Humidity}(\%)=\frac{\text{fresh weight(g)-dry weight(g)}}{\text{dry weight (g)}}\cdot 100 \qquad [2]$$

To assess the vality of ThetaProbe we made a correlation between data took in the same day, 8th May.

$$Humidity_{ThetaProbe} = 1.1\ (0.1)\ x\ Humidity_{gravimetric} \qquad [3]$$

$$R^2 = 0.93 \quad p = 7 \cdot 10^{-12}$$

The correlation was significant, consequently we can use ThetaProbe to compare humidity between different treatments.

On the other hand, we compare humidity between treatments in Figure 4.

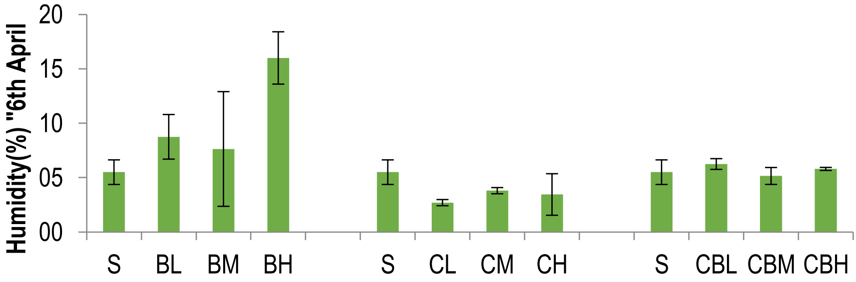


Figure 4. Humidity of each mixture determined with ThetaProbe on April 26th

Comparing humidity between treatments, we could observe that the addition of biochar could improve the humidity of the soil, being more useful at high doses of amendement. In contrast, compost and the combination of compost and biochar did not show a great improvement of the humidity of soil, neither comparing different doses of the same type of amendment. Comparing compost with the combination of compost and biochar, we can observe that humidity is bigger in the combinated treatments, due to the presence of biochar.

Comparing the results of WHC and humidity, we can see that biochar drains faster than compost. But, the drying by evaporation in biochar seems slower than in compost. This can be explained by the porous estructure of biochar that can collect water.

5.4. Plant Measurements

Plant growth was evaluated measuring the shoot hight and the number of leaves at different sampling times and the plant biomass (shoot and root dry weight) at the end of the experiment.

To determine the dry weight of the shoots (aerial part) and the roots, the two parts were separated by cutting with pruning shears. Roots were cleaned with water to remove all the soil and both parts were placed into different paper envelopes. Once in the lab, the fresh weight was determined, and the samples were put in the oven at 80ºC until constant weight. Once in constant weight, dry weight was determined, subtracting the weight of the paper envelope. The evolution of the plant growth is represented in Appendix 2.

The last measurements of the three parametres used to evaluate plant growth are represented in Figure 5.

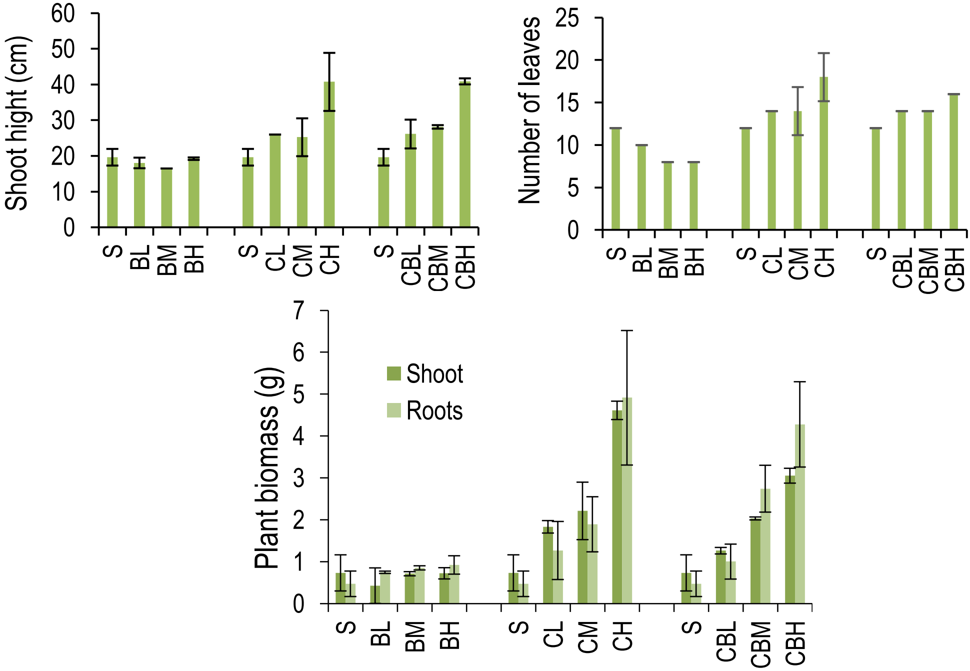


Figure 5. Shoot hight, number of leaves and plant biomass of sunflowers

As we can see in Figure 5, three parameters showed the same trend. Biochar did not enhance the plant growth, unlike compost and compost with biochar that showed an improvement of plant growth, that was increased in high doses of amendment. One important thing to pay attention of this results is the fact that the combination of compost and biochar, which has the half of compost than the mixtures of compost, and consequently less nutrients, grew as much as the mixtures of compost. It means that biochar in combination with compost is capable of retaining nutrients.

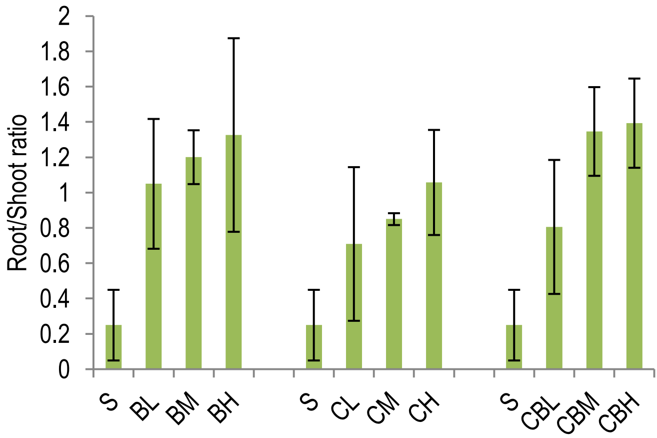


Figure 6. Ratio Root/Shoot for each treatment

Observing the results of Root/Shoot ratio in Figure 6, we can see that in high doses sunflowers made more roots. This is because plant was in an edaphic environment with more porosity, so plants could grow roots easily. Plants dedicate part of their assimilated carbon in roots growth, which act as a surface that absorbs resource.

6. FIELD EXPERIMENT

6.1. DESCRIPTION OF THE EXPERIMENT

A plot of approximately 100 m^2 distributed in areas of 1 m^2 was placed in City Station. The areas were disposed as a rectangle of 12 areas x 3 areas, following the distribution schematized in Figure 7.

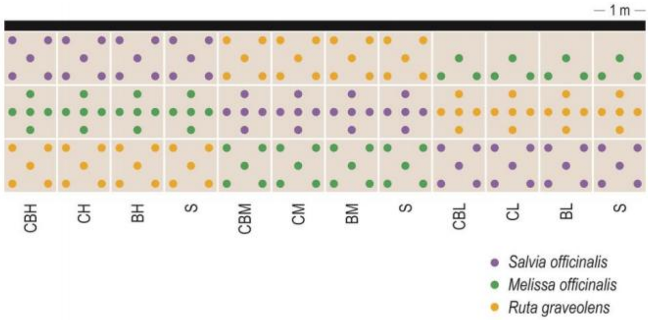


Figure 7. Distribution of the plants and treatments in the plot.

As it is shown, each column had a different treatment, and in each row a different variety of plant is planted. The different treatments are the same used in rhizotrons (Table 1), and the different showy species chosen were *Salvia officinalis*, *Melissa officinalis* and *Ruda graveolens* (Cabrero, 2018).

6.2. PLANT MEASUREMENTS

6.2.1. Green area

Green area (GA) is the percentage of an area covered by leaves. This parameter is determined by taking photos of each group of plants and treatments, considering the same area for each type of plant, in order to compare the percentatge between differents treatments. Photos were processed with the program *Fiji* (ImageJ, 2017), which removes the colour of all the pixels except the green ones (Figure 8), and determine the percentage of green pixels. The obtained value is divided by the number of plants contained in each photo.

Figure 8. Original images (above) and images processed with *Fiji* (below). *Salvia officinalis* (left), *Ruda graveolens* (middle) and Melissa officinalys (right)

The area taken was 126 cm^2 for *Salvia officinalis* and 118 cm^2 for *Ruda graveolens* and Melissa officinalys, respectively. GA was determined twice, on 23th March and on 26th April.

Results of GA of *Salvia officinalis*, as an example, are represented following the spatial distribution in the experimental camp in Figure 9.

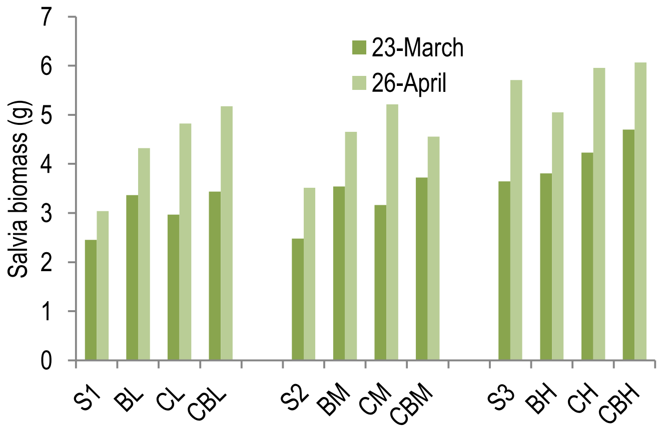


Figure 9. GA of *Salvia officinalis* determined twice with a month of difference

The results obtained showed that during the month the plant growth was very similar between different treatments. Also, we observed that biochar and compost enhace more the plant growth by applying high doses of amendment. In contrast, the combination of biochar and compost present results abnormally high for CBL and low for CBM. This can be attributed to different irrigation between treatments or the low sensibility of the determination of GA.

Results in Melissa are similar than in Salvia, but this plant present results abnormally low at medium doses, that can also be attributed to different irrigation. In smaller plants as *Ruda graveolens*, there are not significant differences between treatments due to the slow plant growth. It made that some result make no sense e.g. a decrease of plant growth. GA of Ruda and Melissa are showed in Appendix 3.

6.2.2. Plant biomass

When the study of plant growth was finished, shoots were cut from roots with pruning shears and were placed into different paper envelopes. Once in the lab, the fresh weight was determined and the shoots were put in the oven at 80ºC until constant weight. Once in constant weight, dry weight was determined, substracting the weight of the paper envelope.

Plant biomass, aerial part, of *Salvia officinalis*, as an example, is represented in Figure 10.

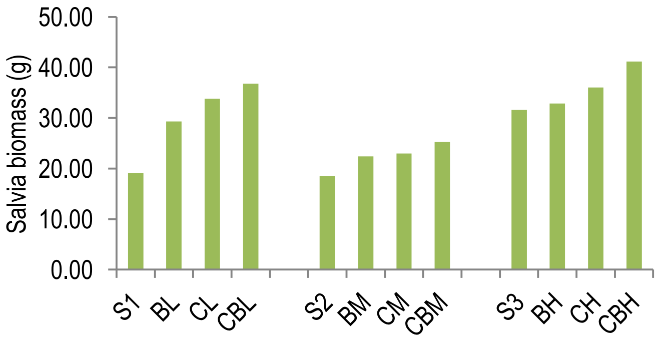


Figure 10. Plant biomass of *Salvia officinalis*

The results obtained showed that all treatments enhace the plant growth, except in treatments with medium dose. It also seems that low dose treatments enhace too much the plant growth. These two unusual results can be attributed to different irrigation between treatments.

In smaller plants as *Ruda graveolens*, the plant biomass was very similar between different doses (Appendix 4). This could be solved by determining the plant biomass by quintupled, we could not do it due to neighbours asked as to leave some plants there, and lengthening the time the plants were studied.

6.2.3. Correlation between green area and plant biomass

To assess the vality of green area measured with Fiji (Fiji, 2017) we made a correlation between green area and plant biomass, determined at the same time.

For *Salvia officinalis* the equation was [4].

$$Green\ Area(\%)/plant\ = 0.15\ (0.08)\ x\ Plant\ biomass/m^2 + 1.9\ (1.5) \qquad [4]$$

$$R^2 = 0.65 \quad p = \ 0.002$$

For *Melissa officinalis* the equation was [5].

$$Green\ Area(\%)/plant\ = 0.3\ (0.2)\ x\ Plant\ biomass/m^2 + 1.6\ (1.5) \qquad [5]$$

$$R^2 = 0.63 \quad p = \ 0.002$$

The correlation for Salvia and Melissa were significant, consequently we can use Fiji and determine green area to have an approximation of the plant growth. The main advantages of using green area to compare plant growth in different treatments is that it is an easy method and does not kill the plant, so it can be used to determine plant growth periodically.

The correlation for Ruda was not significant, due to green area is not sufficiently sensitive to detect small changes of Ruda growth in the short period studied.

7. LEARNING-SERVICE

7.1. EVENT "MOVIMENT BIOCHAR"

"Moviment Biochar" was a set of workshops and informative talks that we designed to show the benefits of adding biochar to poor soils and about the production and use that IDÀRIA SCCL (Empresa d'Inserció, Llagostera) and MontBio project make of biochar.

During the morning I was responsible, with the help of other students of the research group, for the workshops with kids. First of all, we introduced the soil quality issue and made an explanation of biochar's environmental benefits, using some pictures that shows the carbon cycle and illustrates the benefit of biochar as an amendment.

Then, the recipe of *Aplicació de biochar als sòls urbans: millora de la qualitat del sòl* (Cabrero, 2018) was carried out with the children. In that workshop, they saw that the mixture of soil + biochar is less dense than soil, since for the same volume as soil it weights less. As the time was short, the samples were only a quarter of an hour in contact with the water, and then only a quarter of an hour draining. Despite the short time we left the experiment, we could see some significant results: the samples that had more biochar were the ones who gained more weight.

Figure 11. Workshop on the measurement of WHC of mixtures with different percentage of biochar

The second workshop we did was about easily knowing the characteristics of a soil, as the presence of clay, carbonates and organic matter. The presence of carbonates was qualitatively determined using vinegar, because the reaction between carbonates and acetic acid to give carbon dioxide, so gas emission is observed. The presence of organic matter was qualitatively determined using hydrogen peroxide, because in organic matter there is a enzime called catalase that mediates the breakdown of hydrogen peroxide into oxygen and water, so gas emission is observed. The presence of clay was identified by the ring test, where the sample is watered and molded as an elongated cylinder and then, the ends of the cylinder are joined to form a ring.

Figure 12. Ring test for clay soils

Finally, the children helped me in the planting of the sunflowers in rhizotrons (Section 5.2). The children were happy to be active part of the project.

Figure 13. Planting of sunflowers

While children were doing these workshops, their families were participating in a debate with IDÀRIA SCCL, MontBio project and Anna Rigol.

The participants found the activity very useful and profitable for all ages. When “Moviment Biochar” was finished some children shared the things that they saw in the workshops with their families and they linked it with the concepts discussed in the debate.

7.2. WATER HOLDING CAPACITY RECIPE

7.2.1. Workshop

The workshop was made with four schools; three schools were lead by mediators, trained by me, and the other one by me. The workshop that I lead was with approximately 22 students from the school El Til·ler. They were doing a common project between second and fifth grade.

First of all, we spoke about environmental issues, specifically about poor soils and biochar as a potential solution for it. Then, the recipe of *Aplicació de biochar als sòls urbans: millora de la qualitat del sòl* (Cabrero, 2018) was carried out with the children organized in pairs, formed by one student of second grade and one of fifth grade.

Three different samples were used: soil, soil + 10% B and soil + 50% B. Despite putting the same volume of material, the weight was different between the samples. So, the students saw how the mixture of biochar+soil has lower density than soil.

As the time we had was short, we did the same procedure as the explained in section 7.1.

During breaks, children were interested on the field experiment and I could explain it and clarify any doubt that they had. Teachers also were very interested in biochar and they took some biochar to use in their school in order to do an experiment following the indications that they recive during the workshop.

Figure 14. Workshop on the measurement of WHC of mixtures with different percentage of biochar

7.2.2. Results and analysis

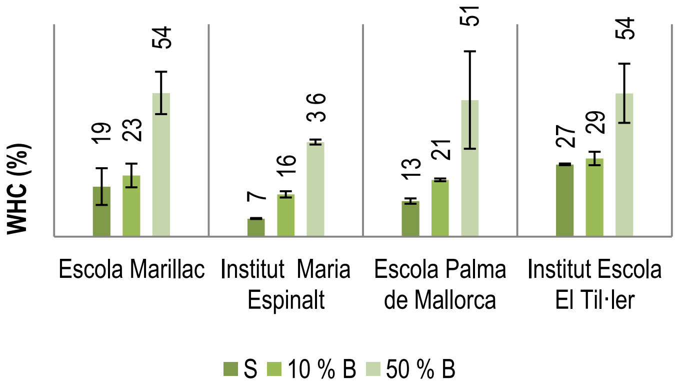


Figure 15. Results obtained by different schools

Results show that when the dose of biochar is increased, water holding capacity increases too. This results have a great variability between the different schools and it can be explained with some differences in the procedures followed during the determination, but the tendence of increasing the water holding capacity when biochar is added is the same that was obtained in the lab.

7.3. RHIZOTRON RECIPE

One recipe was written in the context of this project: *Aplicació de biochar als sòls urbans: millora del creixement de la vegetació* (Appendix 1). It proposes to follow the qualitative track of the roots in rhizotrons.The growth of the roots can be followed by painting the roots in the transparent face of rhizotrons. Each time roots should be painted using a different color, in order to know how was the growth in each period of time.

Figure 16. Rhizotrons of CL treatment with the track of the roots followed by painting

Schools found this recipe very interesting and suitable to apply at school.

Figure 17. Explanation about the qualitative track of the roots

8. CONCLUSIONS

The addition of amendments to the soil caused the following beneficial changes in soil parameters and plant growth:

Soil compaction was reduced; ANC and WHC were improved, especially by adding high doses of compost, humidity was improved too, especially by adding biochar.

The effect of these amendments could have an important impact in urban soils, by improving their structure, buffering capacity towards acid stress and water retention in dry seasons.

- The three parameters assessed in sunflowers: shoot hight, number of leaves and plant biomass; increased by adding compost and compost with biochar.
- GA and plant biomass of Salvia and Melissa increased by the addition of amendments, this being more evident at high doses. For Ruda, non-significant differences between treatments were observed due to its slow growth in the time period studied.
- The mixing of both amendments at high doses lead to most beneficial effects in plant and soil. Moreover, this mixture requires a low amount of compost and allows sequestration of carbon by the use of biochar.

On the other hand, the learning-service actions carried out in City Station, led to the following conclusions:

- “Moviment Biochar” gave to the participants a broad view about biochar. They were very interested and motivated with using it as amendment.
- The workshops were useful for the students, because they could see reliable differences by adding biochar. They showed interest during the session and acquired knowledge about biochar.
- In general, citizens who participated were motivated to take part of the improvement of the environmental health in the city.

9. REFERENCES AND NOTES

1. Cabrero, S; Use of compost and biochar for the improvement of the quality of urban soils in the framework of an exhibition with public participation. Universitat de Barcelona. **2018**.

2. CCCB. After the end of the world. **2017**. http://www.cccb.org/en/exhibitions/file/after-the-end-of-the-world/224747

3. Estació Ciutat. 2017. www.estaciociutat.org/receptes/

4. FAO; GTIS. Estado Mundial del Recurso Suelo (EMRS) – Resumen Técnico. **2015.**

5. Fiji – ImageJ. **2017**. https://imagej.net/Fiji

6. Glaser, B.; Haumaier, L.; Guggenberger, G.; Zech, W. The 'Terra Preta' phenomenon: a model for sustainable agriculture in the humid tropics. *Naturwissenschaften.* **2001,** *1,* 37-41.

7. Gómez-Arnau, J. El cultivo del girasol. Hojas divulgadoras. Núm 20/88.**1989**.

8. International Biochar Initiative. **2017**. http://www.biochar-international.org/

9. McLaughlin, H - Biochar: A Powerful Tool for Carbon Farming. https://www.youtube.com/watch?v=AUh1vwDjaVo

10. López, E.C. Beneficios en la implementación de áreas verdes urbanas para el desarrollo de ciudades turísticas. *Revista de Arquitectura, Urbanismo y Ciencias Sociales del Centro de Estudios de América del Norte, El Colegio de Sonora*. Vol IV. Número 1. **2013.**

11. Salva la selva. Declaración: Biochar, una nueva amenaza para los pueblos, la tierra y los ecosistemas. **2009**. https://www.salvalaselva.org/noticias/1149/declaracion-biochar-una-nueva-amenaza-para-los-pueblos-la-tierra-y-los-ecosistemas

12. Schmidt, H.-P., et al., Biochar and biochar-compost as soil amendments to a vineyard soil: Influences on plant growth, nutrient uptake, plant health and grape quality. *Agric. Ecosyst. Environ.* **2014**. http://dx.doi.org/10.1016/j.agee.2014.04.001

13. UJA. Ensayos de campo para determinar diferentes propiedades físico-químicas del suelo.

14. Venegas, A.; Evaluación de la adición de materiales de origen orgánico para la remediación de suelos contaminadors con metales pesados. Universidad de Barcelona, **2015.**

15. Venegas, A.; Rigol, A.; Vidal, M. Changes in heavy metal extractability from contaminated soils remediated with organic waste or biochar. *Geoderma.* **2016,** *279,* 132-140.

16. Yu, S.; Clark, O.G.; Leornard, J.J. Estimation of vertical air flow in passively aerated compost in a cylindrical bioreactor. *Canadian Biosystems Engineering*. Vol 50. **2008**.

10. ACRONYMS

ANC: Acid neutralization capacity

CEC: Cation exchange capacity

DOC: Dissolved organic carbon

GA: Green area

WHC: Water holding capacity

APPENDICES

APPENDIX 1: DOCTOR X RECIPE

Aplicació de biochar als sòls urbans: millora del creixement de la vegetació

Context

Els sòls urbans són ecosistemes emergents que ofereixen la oportunitat de crear nous espais naturals a les ciutats. Tot sovint però, són sòls degradats, de baixa qualitat ambiental pel correcte desenvolupament de la vegetació i es fan necessàries accions de restauració de les funcions del sòl (serveis ecosistèmics) com són el subministrament d'aigua i nutrients per a les plantes.

Objectius

L'addició de biochar, producte d'origen orgànic reciclat a partir de la transformació de biomassa (per exemple, residus de poda), es proposa com a esmena per millorar el desenvolupament de la vegetació als sòls urbans. L'objectiu d'aquest protocol és avaluar la millora del creixement vegetal en sòls urbans on s'ha aplicat biochar. Es mesurarà el creixement de la part aèria de la vegetació, s'estimarà el índex d'àrea foliar (LAI) i s'estimarà el creixement de les arrels, la part amagada de les plantes.

Competències científiques

- Aprendre el concepte de fertilitat del sòl.
- Aprendre a mesurar el creixement de les plantes i el concepte de producció vegetal.
- Aprendre a estudiar les arrels.
- Relacionar la capacitat de retenció d'aigua al sòl amb el creixement vegetal
- Relacionar el pH i els nutrients amb el creixement vegetal

Materials

Per dur a terme aquest experiment necessitarem els següents materials:

- Test o recipient opac rectangular o quadrat de volum suficient per fer créixer una planta
- Làmina rígida de plàstic transparent
- Tela plàstica opaca per cobrir la làmina de plàstic
- Cinta aïllant i pegament de poliuretà
- Sòl
- Planta

- Biochar
- Retoladors permanents
- Fil de cordill
- Centímetre

Passes a seguir

Per tal d'avaluar la millora del creixement de la planta quan el sòl s'esmena amb biochar, es proposa el següent experiment que es pot realitzar a casa o a l'escola:

1. Construïu dos rizotrons, un pel sòl original i un segon per la barreja sòl-biochar, identificant-los amb una etiqueta diferent. Un rizotró és un test o recipient adequat pel creixement d'una planta amb un costat transparent que permet visualitzar el creixement de les arrels. Es fabrica tallant un dels costats del test i substituint la paret original per una làmina transparent, tot fixant-la amb pegament i cinta aïllant si és necessari.
2. Prepareu la barreja sòl-biochar aplicant un 5% de biochar al volum final de barreja sòl-biochar.
3. Planteu una planta (el gira-sol és una bona opció) a cada un dels rizotrons.
4. Col·loqueu els dos rizotrons amb una inclinació de 30° respecte la vertical per afavorir la visualització de les arrels. La paret transparent s'ha de mantenir a les fosques mitjançant tela plàstica opaca.
5. Feu un seguiment setmanal del creixement radicular a la paret transparent de cada rizotró resseguint amb un retolador el creixement de les arrels, mesurant la longitud amb l'ajut d'un cordill si és necessari. Cada setmana utilitzeu un retolador de color diferent, apunteu la data i feu fotografies. Compareu les dades obtingudes pel rizotró amb sòl i pel rizotró amb sòl-biochar. L'experiment pot durar 1-2 mesos.
6. Feu un seguiment setmanal del creixement de la part aèria de la planta als dos rizotrons mesurant l'alçada i l'amplada de la planta i compareu les dades.
7. Estimeu l'índex d'àrea foliar (LAI) quantificant el nombre de fulles a mesura que van apareixent fulles noves. Compareu les dades obtingudes per a cada tipus de rizotró.

APPENDIX 2: EVOLUTION OF THE SUNFLOWER GROWTH

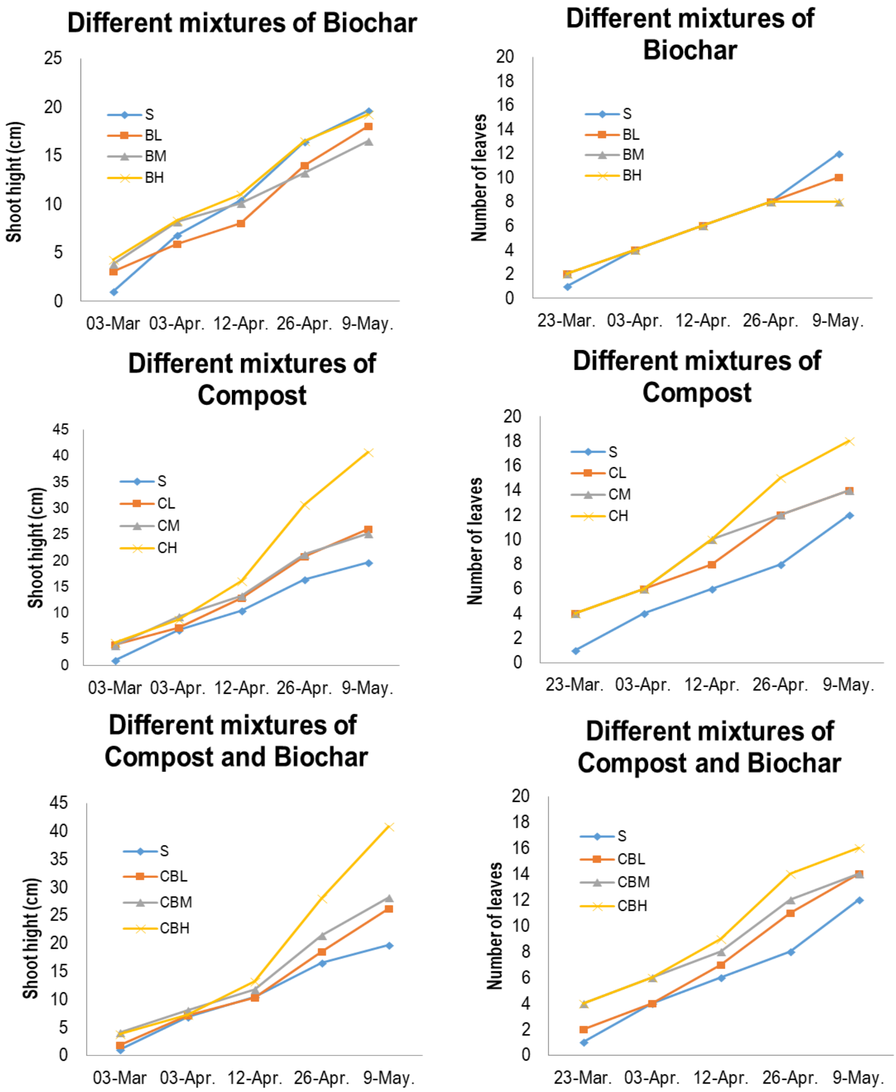


Figure 18. Evolution of the number of leaves (right) and the shoot hight (left) of sunflowers

APPENDIX 3: GREEN AREA OF MELISSA AND RUDA

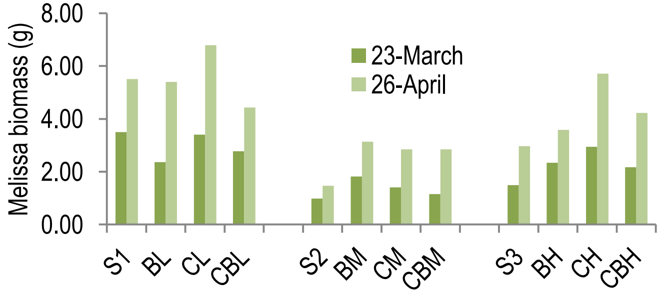


Figure 19. GA of *Melissa officinalis* determined twice with a month of difference

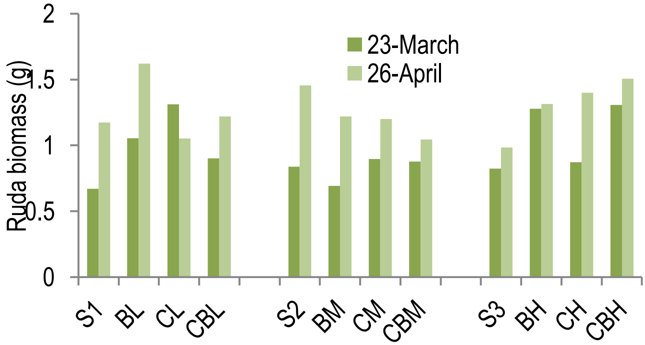


Figure 20. GA of *Ruda graveolens* determined twice with a month of difference

APPENDIX 4: RUDA AND MELISSA BIOMASS

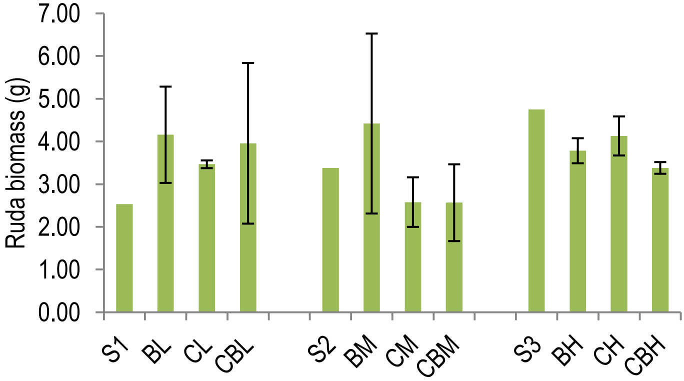


Figure 21. *Ruda graveolens* biomass (g)

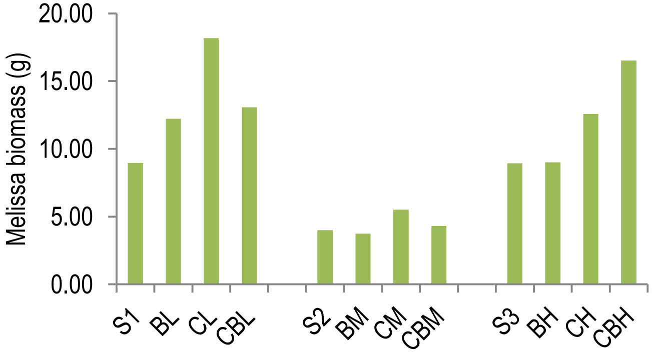


Figure 22. *Melissa officinalis* biomass (g)