Biochar and Vermicompost to Produce Sustainable Containerized Ornamentals

Soils, Agriculture, and Agroforestry
High Value Crops
Biochar & Bioenergy 2019
July 3rd 2019

Carbon Management and Sequestration Center
School of Environment and Natural Resources
The Ohio State University

Huelva University Spain

José Mª Álvarez de la Puente

About me

Bachelor and Master Degrees in Forestry Engineering
Agroforestry specialization
E.T.S.I.M. Polytechnic University,
Madrid, Spain

PhD in Industrial and Environmental Science and Technology
Departments of Environmental Biology and Public Health and Agroforestry Sciences,
Polytechnic School, Huelva University,
Huelva, Spain

Acknowledgements

- Dr. Manuel Fernandez Advisor UHU Huelva Spain
- Dr. Rattan Lal Co-Advisor OSU C-MASC
- Dr. Klaus Lorenz Assistant Director OSU C-MASC
- MSc. Basant Rimal OSU Soil laboratory support
- Laura Conover and Tess Phinney Program Coordinators C-MASC
- Dr. Claudio Pasian OSU Horticulture Dept.
- Dr. Manuel Jesús Díaz Blanco, UHU Huelva Spain
- Dr. Rafael Lopez IRNAS CSIS Seville Spain
- Mrs. Loewe and Dr. J. Altland from Application Technology Research Unit at Wooster OSU campus .
- Ms. S. Stieve and Dr. Pablo Jourdan of the Ornamental Germplasm Center of the OSU.
- Biochar Solutions and Black Diamond Vermicompost

This work was partially supported by the project CTQ 2013-46804-C2-1-R and, and CGL2016-76498-R of the Spanish Ministry of Economy and Competitiveness and the European Regional Development Funds (ERDF).

PUBLICATIONS

- *Alvarez, J. M.; Pasian, C.; Lal, R.; Lopez-Nuñez, R.; Fernández, M. (2018). A biotic strategy to sequester carbon in the ornamental containerized bedding plant production: A review. Spanish Journal of Agricultural Research, Volume 16, Issue 3, e03R01. https://doi.org/10.5424/sjar/2018163-12871*

- *Alvarez J.M., Pasian C., Lal R., Lopez R., Fernandez M.. (2017). Vermicompost and Biochar as growing media replacement for ornamental plant production. J. Appl. Hortic.19(3), 205-214. https://doi:10.17605/OSF.IO/PZBFS*

- *Alvarez J.M., Pasian C., Lal R., Lopez R., Díaz M.J., Fernandez M. (2018). Morpho-physiological plant quality when biochar and vermicompost are used as growing media replacement in urban horticulture. Urban For Urban Green. 34 175-180 https://doi.org/10.1016/j.ufug.2018.06.021*

- *Alvarez J.M., Pasian C., Lal R., Lopez R., Fernandez M. (2019) Nutrients leachates when biochar and vermicompost are used as growing media replacement. HORTIC BRAS 37 (1) 047-053 http://dx.doi.org/10.1590/S0102-053620190107*

OUTLINE

Introduction

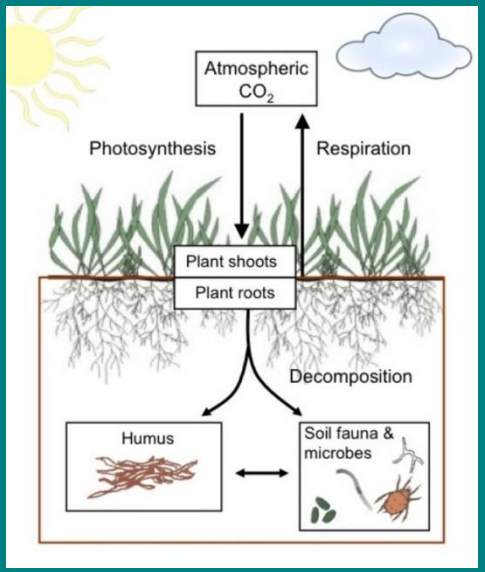
- *Vermicompost and biochar as growing media replacement for ornamental-plant production*
- *Morpho-physiological plant quality*
- *Nutrients leachates*

Overall conclusions

Biochar and vermicompost as substitutes of growing media in ornamental-plant production

Introduction

- An increase in the atmospheric concentration of carbon dioxide (CO_2) may alter the Earth's mean temperature and precipitation.
- Much of the work on reducing greenhouse gas emissions and carbon (C) sequestration using biotic strategies has been conducted in **row crop and forest systems**.



- However, **no so much work** has focused on contributions from sectors of the specialty crop industry such as **ornamental horticulture**.
- There are uncertainties regarding the **best practices for lowering GHG emissions and increasing C storage in the ornamental horticulture industry**; this is an area deserving investigation (Christopher et alt.2011).

Biochar and vermicompost as substitutes of growing media in ornamental-plant production

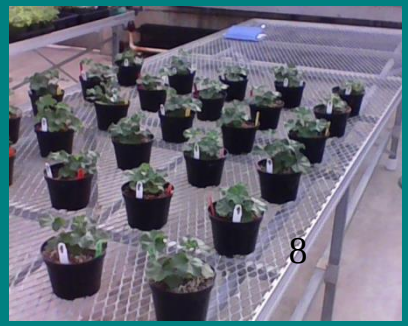
Introduction

- In the production of containerized plants in floriculture the most used soilless substrate is **peat moss**. Worldwide over 11 million tons (Tg=teragram) of peat are used annually in horticulture (U.S. Dept., 2013) due to its **consistent physical characteristics and high nutrient exchange capacity.**
- Environmental concerns about draining peat bogs and the fact that **peatland mining eliminates the carbon sink function of the peatland** (Waddington et al.,2002) have enhanced interests in research on complementary products that can be added to peat.
- Since 1980´s research had focused on different kinds of composts and lately biochar has been addressed as a possible perlite and **peat replacement in horticulture** (Bedussi et alt., 2015). There are evidences that Bioochar / vermicompost have a synergy when added together to soil (Fisher 2012).

- Thus, 3 different comparative greenhouse studies were conducted to assess the suitability of **biochar (B) and vermicompost (V) as partial substitutes for peat-based growing media** for ornamental plant production.

A biotic strategy to sequester carbon in the ornamental containerized bedding plant production: A review

- First experiment was focused on determining if it was possible to grow containerized ornamental bedding plants (as petunia and geranium) with commercial quality using 24 different biochar / vermicompost mixes.
- In the second one, we selected from the first one the 5 best performing growing media and, verified the physiological plant answer when growing those species with our selected mixtures.
- Finally we checked containers leachates to verify if less nutrients were lost by irrigation when growing those species with our selected mixes.



1st EXPERIMENT
Substrate characterization and morphological plant answer
METHODOLOGY

- **Biochar:** pyrolysis Pinus monticola wood at 600 to 800 ºC.
- **Vermicompost** dairy manure solids first pre-composted 15 days in an aerated composting system and then processed by vermicomposting during 70-80 days
- **23 different blends** of Biochar **(B)** at a volume fraction of **(0, 4, 8, 12) %** and Vermicompost **(V)** at **(0, 10, 20, 30, 40, 50) %** were compared to a baseline peat-based substrate **(S)** as control in the cultivation of **geranium (Pelargonium peltatum) and petunia (Petunia hybrida).**

Notation S: V: B	Biochar (%)			
	0	4	8	12
Vermicompost (%)				
0	100:00:00	96:00:04	92:00:08	88:00:12
10	90:10:00	86:10:04	82:10:08	78:10:12
20	80:20:00	76:20:04	72:20:08	68:20:12
30	70:30:00	66:30:04	62:30:08	58:30:12
40	60:40:00	56:40:04	52:40:08	48:40:12
50	50:50:00	46:50:04	42:50:08	38:50:12

1st EXPERIMENT
Substrate characterization and morfological plant answer
METHODOLOGY

Experimental design

- OSU Horticulture Department Greenhouses
- A random 5 block design for each species.
- One set of 2 species x 24 treatments x 5 blocks = 240 containers.
- First seedlings were produced on 200 plugs (21.8 cm^3) plastic germination tray for 40 days under an average 54% moisture and at 24° C in a glasshouse with a micro sprinkler irrigation system.
- Seedlings transferred to 800 cm^3 plastic containers on 15 m^2 benches per species at a greenhouse with an average temperature of 20 °C and 29 % humidity. Containers were watered manually as needed.
- Growing period: 8 weeks Petunia. 11 weeks Pelargonium.

1st EXPERIMENT
Substrate characterization and morfological plant answer
METHODOLOGY

- **Experimental design**

240 pots, 5 blocs /2 species/ 24 substrate mix

PETUNIA					
13	3	23	10	12	24
14	21	5	4	19	16
6	8	2	1	20	7
11	18	22	15	9	17
5	7	15	9	3	24
12	16	11	21	10	19
1	23	22	18	6	20
2	8	13	14	17	4
24	13	2	14	21	16
19	6	22	15	12	18
11	8	20	23	4	3
5	1	10	7	9	17
16	4	7	24	15	10
3	1	22	8	6	5
17	13	11	14	21	23
19	18	9	20	12	2
18	8	3	12	13	19
7	9	2	21	24	1
4	6	15	5	14	10
20	22	17	16	23	11

PELARGONIUM					
21	6	17	8	10	3
18	14	16	5	11	7
15	9	1	19	4	24
23	22	12	20	2	13
13	18	16	8	12	23
24	7	21	4	9	6
15	11	14	1	22	5
3	2	19	10	17	20
6	10	14	12	11	1
17	8	16	4	9	18
19	22	20	7	23	24
15	21	3	2	5	13
14	23	9	4	24	18
12	16	1	8	13	21
15	17	10	19	2	11
20	7	22	6	3	5
23	4	17	3	12	19
18	20	5	7	15	8
16	24	9	13	1	10
11	21	22	14	2	6

1st EXPERIMENT
METHODOLOGY

A. Substrates were characterized for

1.physical NCSU porometer (Fonteno and Bilderback, 1993)

2.chemical properties water extract 1:6 as (Ansorena Miner, 1994)

B. Plants commercial quality was evaluated as

1.plant growth by measuring shoot dry weight (SDW)

2.flower production Petunia number of flowers. Pelargonium number of open inflorescences and inflorescence-buds

C. Nutrient concentrations were assessed

1.in leaves (Miller, 1998) Samples digested HNO_3 (Miller, 1998) P,K,Ca,Mg,S,Fe,Mn,B,Cu,Zn,Na, determined as Dahlquist and Knoll, 1978. Total nitrogen determined by spectrophotometry in a flow autoanalyser after Kjeldahl digestion.

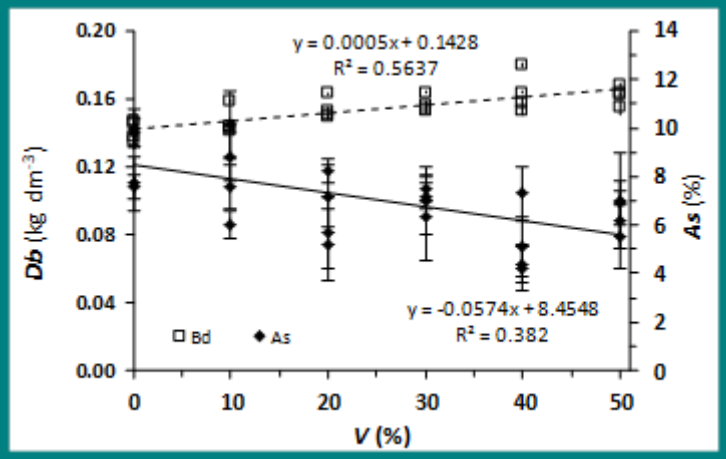
2.in substrates before and after cultivation determined by ICP-OES after extraction, and were expressed on a volume basis (Dahlquist and Knoll, 1978).

1st EXPERIMENT
RESULTS

Substrates physical parameters

Air space decreased as V% increased.

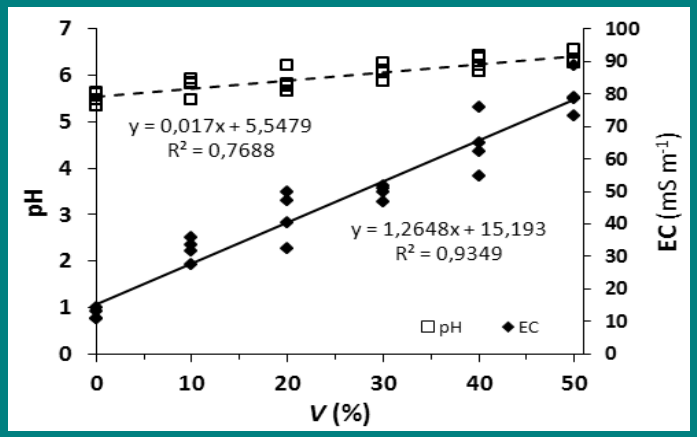
Bulk density increased as V% increased.



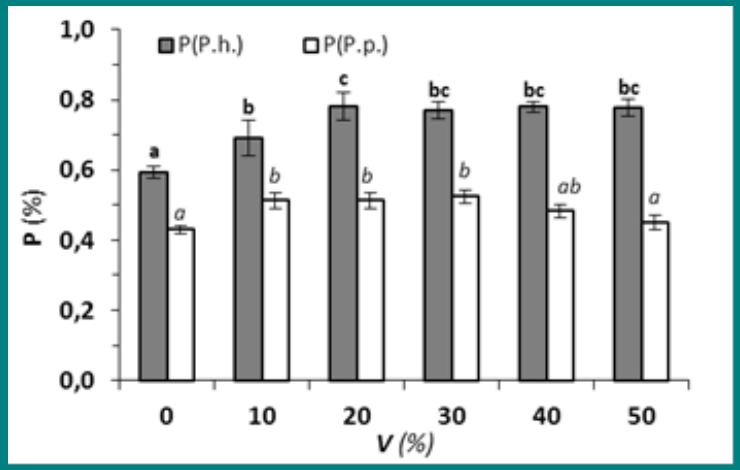
Treatment SP:V:B[x]	Db (kg m^{-3})	Va (%)	Pt (%)	As (%)
100:00:00	135 a	70.1 a	81.0 abcde	10.0 e
96:00:04	137 ab	70.8 bc	80.5 abcd	9.8 de
92:00:08	147 bcdef	72.1 abcd	79.8 abcd	7.7 abcde
88:00:12	146 bcde	72.4 abcde	80.0 abcd	7.6 abcde
90:10:00	141 abc	71.0 bc	81.1 abcde	10.1 e
86:10:04	144 abcd	71.0 abc	80.3 abcd	8.8 cde
82:10:08	159 ghijk	72.8 bcde	79.0 ab	6.0 abc
78:10:12	144 abcd	72.4 abcde	80.0 abcd	7.6 abcde
80:20:00	149 cdefg	75.1 efgh	82.2 cde	7.2 abcde
76:20:04	150 cdefg	74.6 defgh	80.3 abcd	5.7 abc
72:20:08	163 ghik	73.2 bcdef	78.0 a	5.2 abcd
68:20:12	153 defghi	72.3 abcde	80.6 abcd	8.2 bcde
70:30:00	154 defghi	74.0 cdefg	81.2 abcde	7.2 abcde
66:30:04	153 defgh	76.4 gh	83.9 e	7.5 abcde
62:30:08	156 efghij	73.5 bcdef	79.9 abcd	6.3 abcde
58:30:12	164 ghik	74.8 defgh	81.9 bcde	7.0 abcde
60:40:00	153 defghi	74.7 defgh	82.0 cde	7.3 abcde
56:40:04	158 ghijk	74.3 cdefg	79.3 abc	5.1 abc
52:40:08	164 hik	75.8 fgh	80.0 abcd	4.2 a
48:40:12	180 l	74.9 defgh	79.2 abc	4.4 ab
50:50:00	162 hijk	75.8 fgh	82.1 cde	6.2 abcde
46:50:04	155 efghij	73.4 bcdef	80.5 abcd	7.0 abcde
42:50:08	164 ik	77.0 h	83.9 e	6.9 abcde
38:50:12	168 k	77.0 h	82.4 de	5.5 abc
p	***	***	***	***
Guide ranges[y]	100-140	45-65	78-88	6-13

1st EXPERIMENT
RESULTS

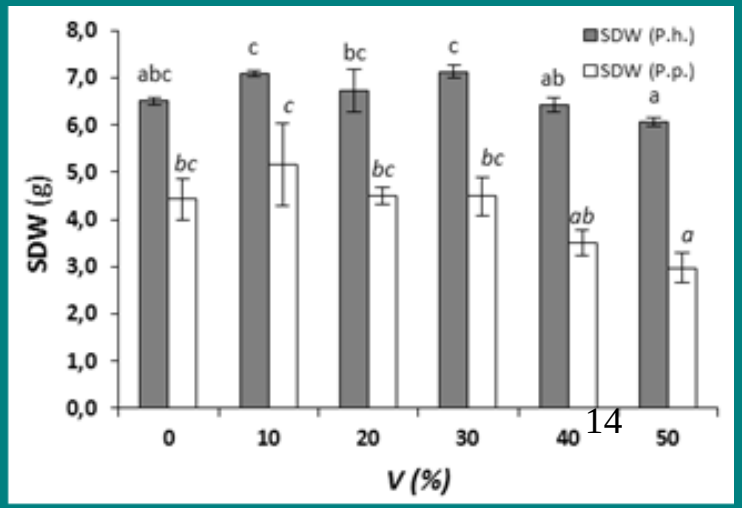
- Use of both V and B increased the substrate pH from 5.2 to 6.6.



- Leaf nutrients (P, K, Ca, Mg, S) contents increased with the increase in volume fraction of V.



- Mixtures with low–medium V levels (10 -30%) and high B level (8 – 12 %) in Petunia and Pelargonium induced more growth and flower production than that of the control.



1st EXPERIMENT
RESULTS
Environmental effect

- *Some studies (Steiner and Harttung, 2014) have shown reductions in GHG emissions when biochar is used as peat substitute for growing plants.*
- *Biochar decomposes slowly (Kuzyakov et al., 2009) and can be stored for relatively long periods, but V has a faster decomposition rate, so no significant C storage in soil is expected by V and that is why we only are going to calculate it based in the biochar potential effect.*
- *Peat volume substituted by V has a CO_2 sink role and it has been included in our calculation.*

Mg	biochar	2.8	Mg CO_2eq
Mg	peat	1.7	Mg CO_2eq

1st EXPERIMENT
RESULTS
Environmental effect

Let´s consider the mix 68:20:12 (S:V:B, volume basis) and its obtained Db measurement.

It would be possible to store <u>up to</u> 85.21 gr of CO_{2e} per 800 cm^3 container for long periods of time.

This sequestration first will happen in the plant´s growing container and then in the garden/backyard soil after transplanting.

gr CO_{2eq}/ pot 800 cm^3	B(%)			
V (%)	0	4	8	12
0	0.00	23.76	47.09	69.98
10	12.24	34.91	57.15	78.95
20	21.76	43.34	64.49	85.21
30	28.56	49.06	69.12	88.74
40	34.00	52.05	71.02	89.56
50	39.44	52.32	70.21	87.66

2nd EXPERIMENT
Physiological plant answer

Hypothesis

The experiment was designed to test the hypothesis that it is possible to produce plants of petunia (Petunia hybrida) and geranium (Pelargonium peltatum) with similar/better physiological characteristics while reducing the use of substrates from non-renewable sources.

2nd EXPERIMENT
Physiological plant answer
METHODOLOGY

Petunia	*Pelargonium*
100-0-0	100-0-0
86-10-4	86-10-4
68-20-12	68-20-12
82-10-8	88-0-12
78-10-12	70-30-0
58-30-12	66-30-4

***Five treatments plus a control** were selected because their good results from the previous experiment where 23 different mixes were compared with that control peat -based substrate (S).*

Three of those mixes were shared in both plant's species.

2nd EXPERIMENT
Physiological plant answer
METHODOLOGY

Experimental design

- A random 5 block design for each species.
- 2 sets x 2 species x 6 treatments x 5 blocks = 120 containers.
- First seedlings were produced on 200 plugs (21.8 cm^3) plastic germination tray for 40 days under an average 54% moisture and at 24° C in a glasshouse with a micro sprinkler irrigation system.
- Seedlings transferred to 800 cm^3 volume plastic containers and placed on 8 m^2 tables per species at a greenhouse with an average 20° C and 29 % humidity.
- Containers were watered manually as needed.
- Growing period: 20 weeks Petunia. 24 weeks Pelargonium.

2nd EXPERIMENT
METHODOLOGY

- **Plants commercial quality was evaluated as**

  1. **Plant growth by measuring shoot dry weight (SDW)**

  2. **Flower production** *Petunia number of flowers. Pelargonium number of open inflorescences and inflorescence-buds.*

- **Physiological parameters**

  1. **Cuticular Transpiration (CT)** *as Quisenberry et al. (1982) and Carevic et alt. (2010)*

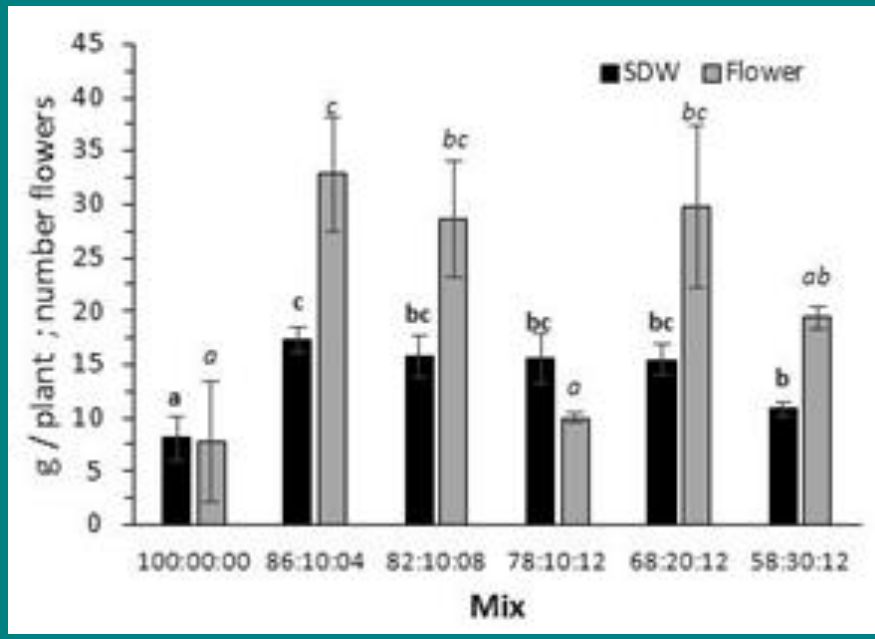
  2. **Root Growth Capacity (RGC)** *as Ritchie (1985)*

  3. **Damage Index of Freeze inducted electrolyte leakage (DI6.7)** *as Dexter et alt. (1932), McKay (1992), Landis (2010) and Burr (2001)*

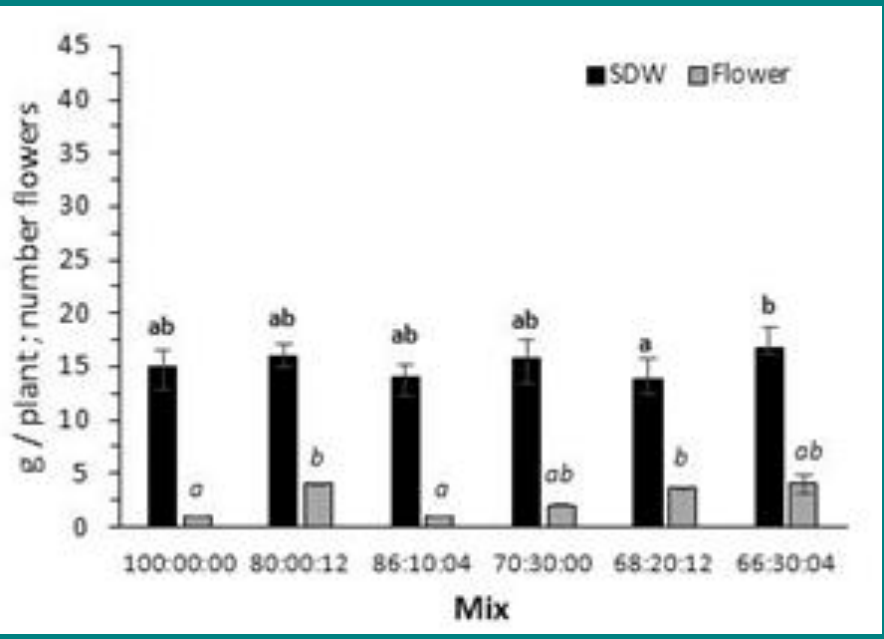
2nd EXPERIMENT
Physiological plant answer
RESULTS

Shoot Dry Weight (SDW) and flower production.

petunia



geranium

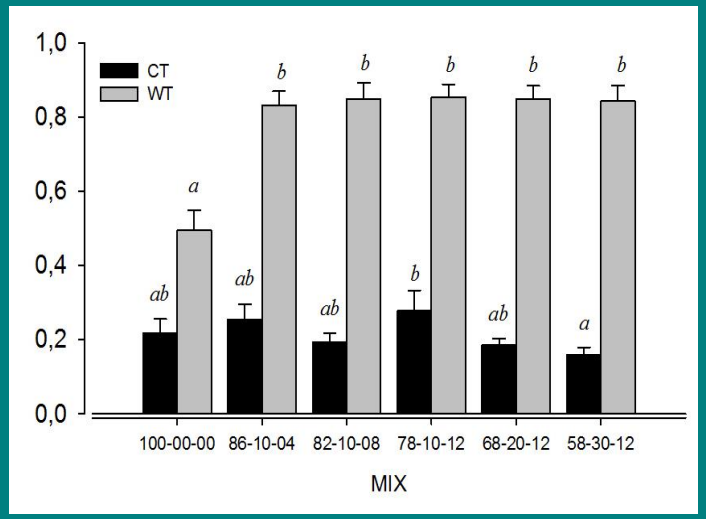


***Plant size and flower production improved** when peat-based substrate was substituted by vermicompost and biochar at rates of **B ≤ 12% and V ≤ 30%** volume fraction.*

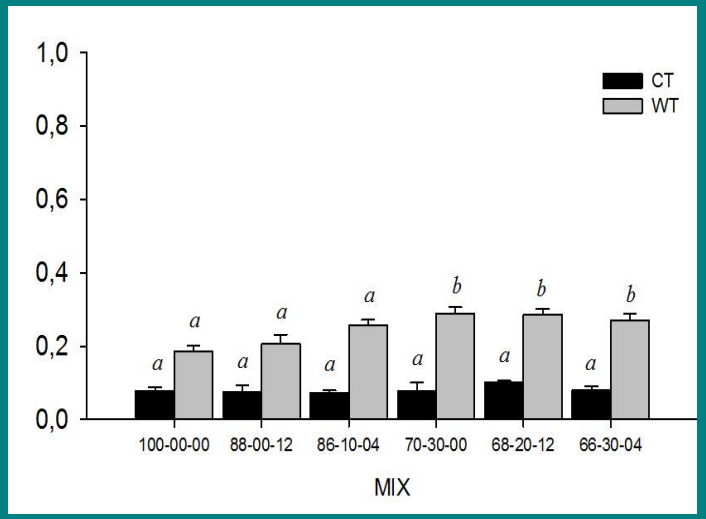
2nd EXPERIMENT
Physiological plant answer
RESULTS

Cuticular Transpiration (CT),

petunia



geranium



CT results in both species were not statistically significant. Physiological response due to the inclusion of V and B in the substrate mixture regarding this parameter was not detrimental to plants and in the event that the plants suffer from a short period of water stress, plants grown on the new substrates will not decrease their capacity to conserve water.

2nd EXPERIMENT
Physiological plant answer
RESULTS

- Root Growth Capacity (RGC)
- Damage Index of Freeze inducted electrolyte leakage (DI6.7)

Petunia			*Pelargonium*		
Treatment *S:V:B*	RGC (g)	$DI_{6.7}$ (%)	Treatment *S:V:B*	RGC (g)	$DI_{6.7}$ (%)
100:00:00	0.15 ± 0.02 a	50.5 ± 19.5 a	100:00:00	0.67 ± 0.03 ab	79.8 ± 19.9 a
86:10:04	0.20 ± 0.01 ab	74.8 ± 18.3 a	86:10:04	0.59 ± 0.05 ab	93.8 ± 3.9 a
68:20:12	0.22 ± 0.03 ab	54.7 ± 19.5 a	68:20:12	0.60 ± 0.01 ab	100.0 ± 0.0 a
82:10:08	0.18 ± 0.04 ab	58.9 ± 18.6 a	88:00:12	0.82 ± 0.12 b	78.2 ± 15.9 a
78:10:12	0.26 ± 0.03 b	53.7 ± 21.0 a	70:30:00	0.50 ± 0.05 a	73.9 ± 19.4 a
58:30:12	0.19 ±0.03 ab	43.5 ± 20.5 a	66:30:04	0.52 ± 0.01 a	77.3 ± 18.3 a
Average ± SE	0.2 0± 0.01	56.0 ± 7.5		0.63 ± 0.04	83.3 ± 6.2
P	0.025	0.050		0.031	0.050

***RGC* and *DI6.7* results in both species were not statistically significant, so physiological answer differences due to the inclusion of V and B were not shown by those two species in our experiments.**

2nd EXPERIMENT
Physiological plant answer
CONCLUSIONS

It is possible to grow containerized Petunia hybrida and Pelargonium peltatum plants with commercial quality after 3 or 4 months of cultivation, using substrates comprising a peat-based substrate mixed with biochar and/or vermicompost at least 42 % between both.

Petunia and Pelargonium growth in these substrates showed that plants will be able to adapt themselves, at least similarly well as the plants grown in peat-based growing media, to the new environment after transplanting to garden.

3rd EXPERIMENT
Leachates

Goal

The main focus of the third study was assessing the leaching of nitrogen and other nutrients from peat based blends including biochar and vermicompost in comparison with usual fertilized peat substrates.

Hypothesis

Our hypothesis is that the inclusion of biochar and vermicompost, in a peat based growing media could reduce the leaching of nutrients while maintaining an adequate plant quality.

3rd EXPERIMENT
Leachates
METHODOLOGY

- *I used same biochar and vermicompost that in the first / second experiments.*
- *Three growing media were prepared with the following volume fractions (S:V:B): 100:00:00, 86:10:04 and 68:20:12.*
- *Being, respectively, the control treatment and two treatments containing a slight and a moderate peat-based substrate replacement.*
- *The last two treatments were selected based on the first experiment good performance.*

3rd EXPERIMENT
Leachates
METHODOLOGY

- **Experimental design**
- A random 5 block design for each species.
- 5 leachate samples of common treatments in both species, 2 species x 5 days x 3 treatments x 5 blocks = 150 samples.
- First seedlings were produced on 200 plugs (21.8 cm^3) plastic germination tray for 40 days under 54% moisture and at 24° C in a glasshouse with a micro sprinkler irrigation system.
- Seedlings transferred to 800 cm^3 plastic containers and placed on 8 m^2 tables per species at a greenhouse with average temperature of 20 °C and 29 % humidity. Containers watered manually as needed.
- Growing period: 8 weeks Petunia. 11 weeks Pelargonium.

3rd EXPERIMENT
Leachates
METHODOLOGY

- **Plant growth and flowering parameters**
- **Nutrients leachates.** Daily collection of leachates after watering and **nutrients analysis** (Nitrate, nitrite, ammoniac, phosphorus, phosphate, sulfate, and potassium)

GER	mixtures		
%	1	10	21
P	100	86	68
V	0	10	20
B	0	4	12

PET	mixtures		
%	1	10	21
P	100	86	68
V	0	10	20
B	0	4	12

PELARGONIUM				
10_1	21_1	1_1	10_2	21_2
1_2	10_3	1_3	21_3	1 4
21_4	10_4	21_5	1_5	10_5

PETUNIA				
1_1	10_1	21_1	21_2	10_2
1_2	21_3	10_3	1_3	10_4
21_4	1_4	1_5	21_5	10_5

3rd EXPERIMENT
Leachates
RESULTS
Nutrients N P K Concentration

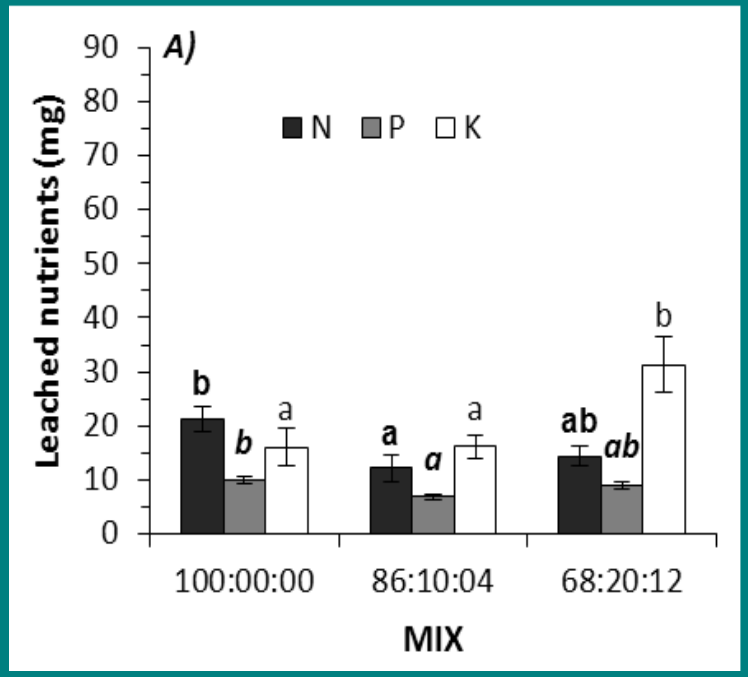
(mg L^{-1})	*Petunia*			*Pelargonium*		
	N	**P**	**K**	**N**	**P**	**K**
Treatment						
100:00:00	52.1 (3.8) b	23.1 (0.7) a	46.5 (4.4) a	247 (14) c	18.2 (1.3) a	208 (22) a
86:10:04	40.8 (4.0) a	21.6 (0.6) a	47.1 (3.6) a	205 (13) b	19.0 (0.9) a	269 (21) ab
68:20:12	42.9 (2.5) ab	24.4 (0.9) a	91.6 (5.6) b	148 (9) a	18.5 (1.2) a	318 (28) b
p	0.031	0.052	0.034	0.016	0.958	0.034
Date						
1^{st} day	55.7 (5.5) c	21.5 (1.1) a	71.9 (9.3) b	246 (28) b	19.7 (1.5) a	356 (32) b
2^{nd} day	53.1 (3.8) bc	22.7 (0.7) a	69.7 (8.0) ab	230 (21) ab	19.3 (1.4) a	290 (21) b
3^{rd} day	48.2 (3.6) bc	23.1 (1.2) a	66.5 (9.8) ab	190 (14) ab	20.1 (1.7) a	229 (27) b
4^{th} day	39.6 (4.0) ab	23.3 (0.6) a	56.9 (6.9) ab	180 (11) a	18.1 (1.1) a	203 (22) ab
5^{th} day	30.8 (4.3) a	24.5 (1.4) a	48.9 (6.9) a	173 (12) a	15.6 (1.4) a	186 (23) a
p	0.006	0.131	0.039	0.013	0.056	0.003

N concentration in leachates significantly decreased for both species as V and B increased. K concentration increased as B increased in both species.

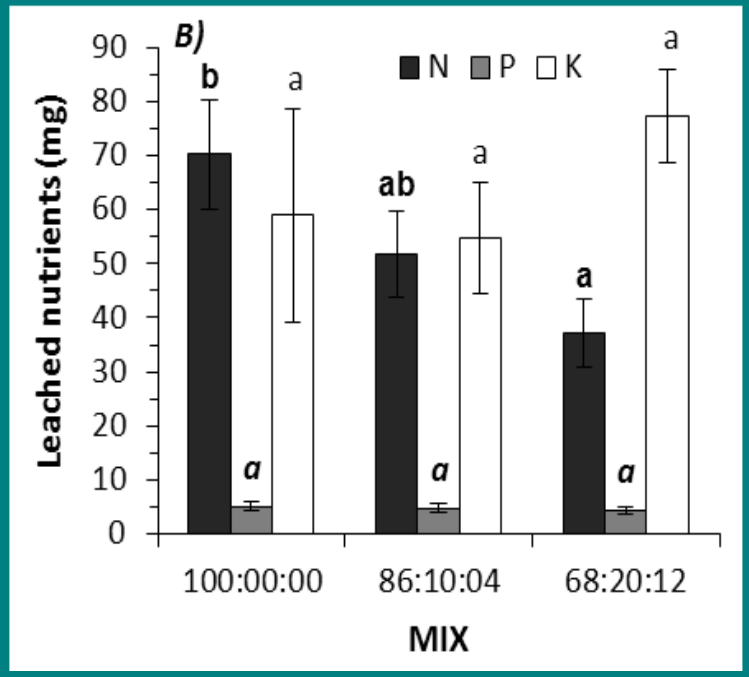
3rd EXPERIMENT
Leachates
RESULTS

Nutrients N P K Content

(A) Petunia



(B) Pelargonium



N content in leachates significantly decreased for both species as V and B increased.

K content for Petunia raised as the ratio of biochar applied increased.

REVIEW+3 EXPERIMENTS
OVERALL CONCLUSIONS

- ***1st Experiment***

It is possible to grow petunia and geranium containerized ornamental bedding plants with commercial quality using different biochar / vermicompost mixes. It will be possible to store up to 88.74 gr of CO_2e per 800 cm^3 container for long periods of time, first in the plant´s growing container and then in the soil after transplanting.

- ***2nd Experiment***

Petunia and Pelargonium grown in best performing biochar/vermicompost substrates mixes shown a similar physiological answer than plants grown in a control commercial peat-based substrate.

- ***3rd Experiment***

Reduction on leachates nitrates concentration and content by biochar / vermicompost inclusion. Biochar addition may be a potassium fertilizer source when growing Petunia.

3 EXPERIMENTS
OVERALL CONCLUSIONS

These results obtained with different biochar and vermicompost associations are of interest to those who want:

- ***to reduce peat consumption for the production of ornamental plants in containers.***
- ***to reduce carbon footprint,***
- ***to reduce nitrate leachates of this commercially productive sector.***

1st EXPERIMENT
SOME CALCULATIONS
Environmental effect

- ***Considering that every year 11 millions Mg of peat are consumed in horticulture. If 50% would be in floriculture and 20 % in containers will have about one million Mg maximum C potential storage per year***

	Mg
World peat consumption Mg/year	11,000,000
Floriculture 50%	5,500,000
Containerized 20%	1,100,000
20% V 12 % B (Mg CO_{2eq} /Mg)	0.85
Carbon storage Mg CO_{2eq} /year	**978,064**

Thank you for your attention!

jose.alvarezpuente@gmail.com
josemaria.alvarez254@alu.uhu.es
614 619 7851