Dr. Inmaculada Ortiz Gómez
Technological center CTC

Friday 10th April 2026
09.00 -12:30 CEST

AGRO4AGRI

Engineering Forest-derived Biochar as a Nanoplatform for Sustainable Nutrient Delivery in Plants

Pathways to Impact in Sustainable Agrochemistry
A 360º Innovation Approach form Lab to Market

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CTC in Biochar production as nanoplatform for sustainable nutrient delivery in plants

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CENTRO TECNOLÓGICO 25 ANIVERSARIO CTC

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- **CTC** is located in the **Cantabria** Science and Technology Park (PCTCAN)

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- ➝Operating model
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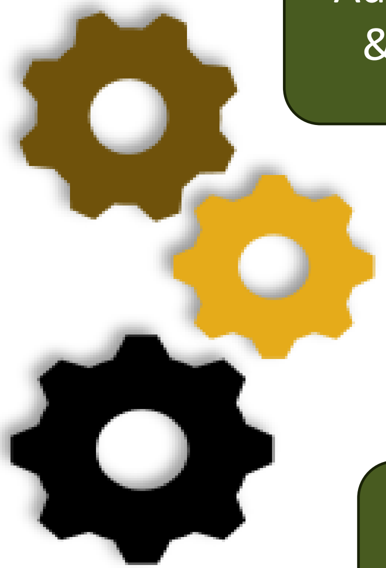
Pillars



- Advanced Materials & Nanomaterials
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Introduction – What is Biochar?

Forestry residues

Biochar is a charcoal-like material produced by heating **biomass** in the absence of oxygen through pyrolysis. As a by-product of this process, it exhibits versatile properties and a high adsorption capacity, which has led to its proposal as a bio-based nanocarrier for fertilizers, in addition to its common use in soil improvement and carbon storage.

Gorse (*Ulex europaeus*)

Biochar

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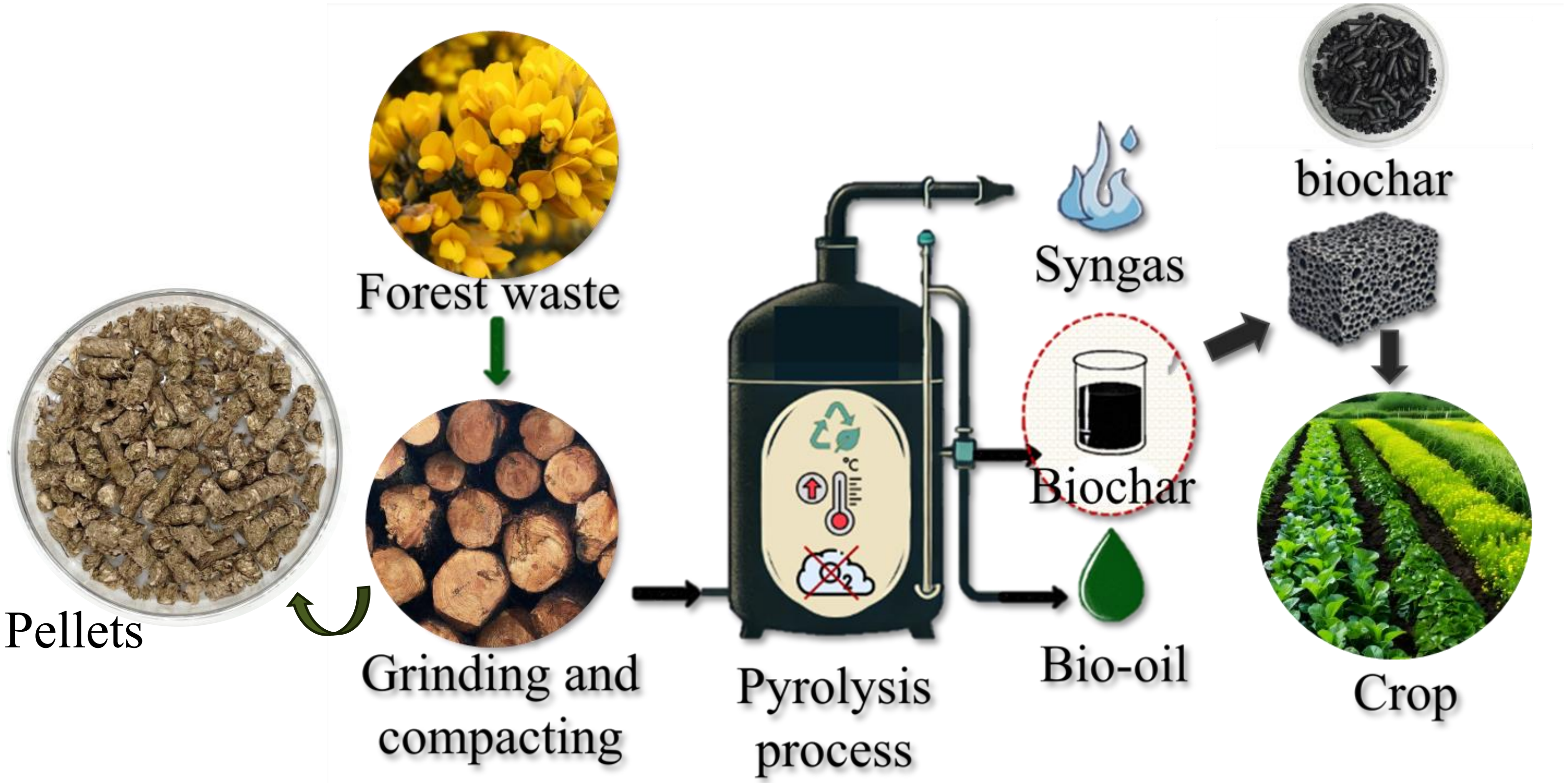
Introduction – Pyrolysis

Pyrolysis is a thermochemical process in which organic materials are heated to high temperatures in the absence (or near absence) of oxygen, causing them to decompose into **solid** (char), **liquid** (bio-oil), and **gaseous** products.



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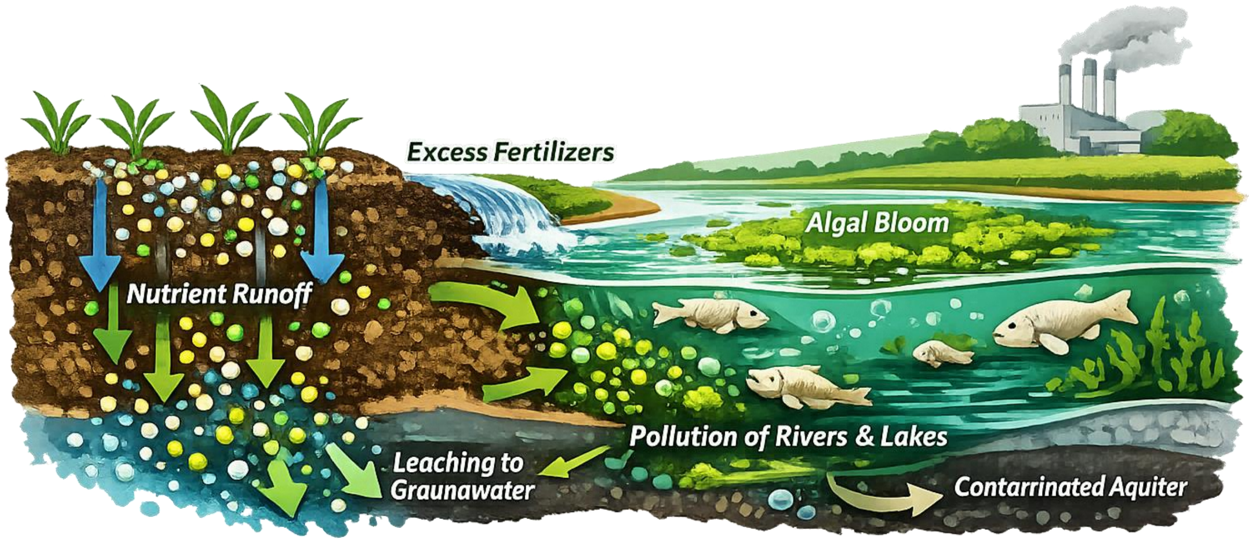
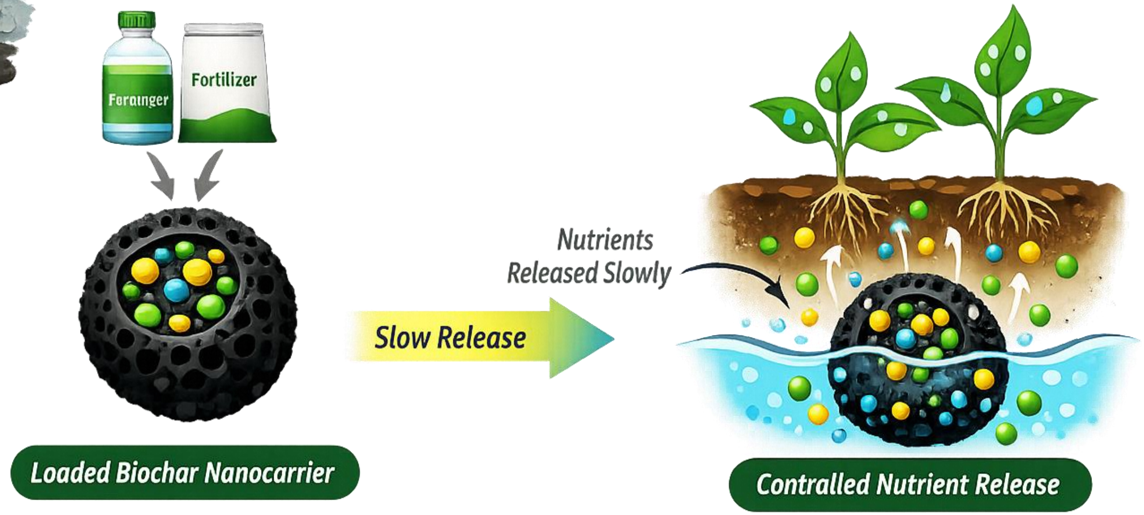
Introduction – Biochar application as nanoplatform for sustainable nutrient delivery



Conventional fertilization methods often lead to **nutrient losses** through leaching or volatilization, reducing plant uptake and impacting both crop productivity and environmental sustainability.



Biochar is an ideal candidate for designing of **controlled nutrient delivery systems**, which are essential for improving plant nutrition and enhancing fertilizer efficiency.

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Introduction - Control nutrient delivery systems

Biomaterial-based carriers, such as engineered biochar, can retain nutrients and release them gradually according to plant demands, minimizing losses and supporting sustainable agricultural practices.

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Obtention of biochar by pyrolisis process from biomass

Gorse is a thorny shrub that is very common in northern Spain, particularly in regions such as Cantabria. While it can be found in natural ecosystems, it often behaves as an invasive species or aggressive coloniser.

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Obtention of biochar by pyrolisis process from biomass

CTC´s pyrolisys system

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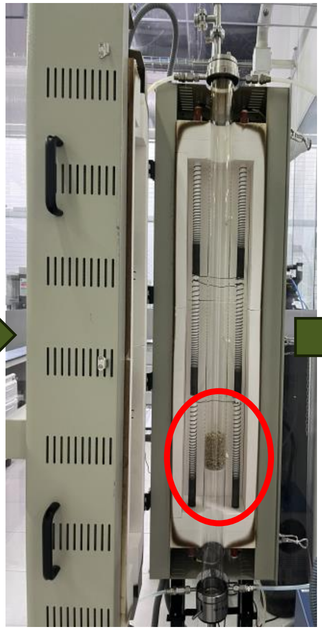
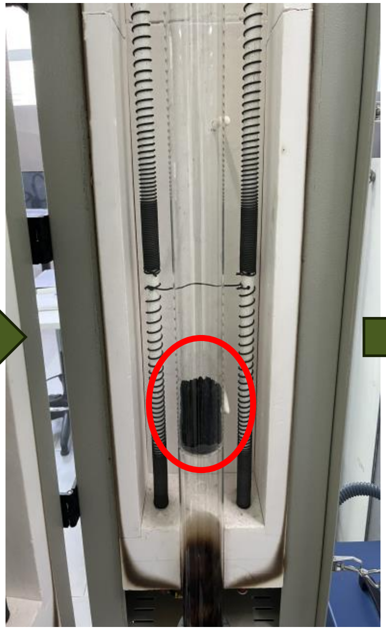
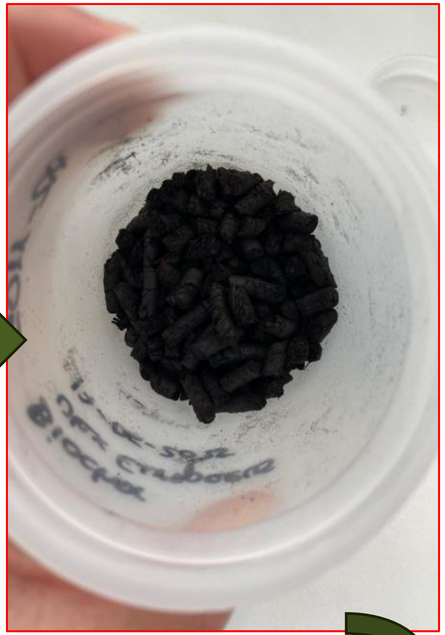




Biochar



Washing step to remove mineral salts

Gorse	Biochar	Yield (%)
102.81 g	43.844 g	**42.64%**

KCl impregnated into Biochar

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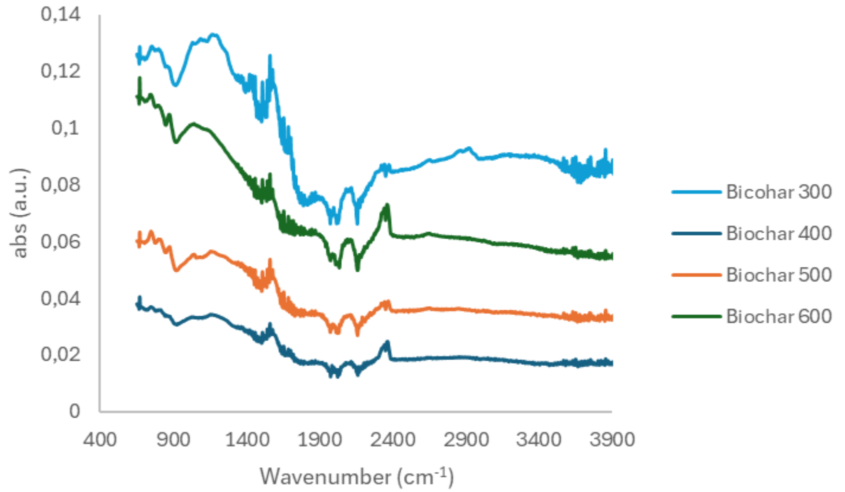
Characterization of biochar

FTIR analysis of biomass.

Wavenumber (cm^{-1})	Functional groups
3600-3000	O-H stretching
3000-2770	$C-H_n$ stretching
1785-1670	C=O stretching
1670-1530	C=C stretching
1278-1185	C-O-C stretching
1136-1088	C-O-C stretching
800	C-H stretching

FTIR spectrums of biochar



Results obtained of CO2 isothermal absorption on obtained biochar.

Product	Pyrolysis temperature (°C)	Gas used	Specific surface area (m^2/g)	Type of porosity
Biochar	300	CO_2	96.13	Microporous
	400	CO_2	287.48	Microporous
	500	CO_2	194.43	Microporous

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Development of biochar impregnation process for fertilizers adsorption

MIRAT fertilizantes

NPK Fertilizers	Fertilizers	Formula
Nitrogen based fertilizers	**Urea**	**$CO(NH_2)_2$**
	Ammonium sulfate	$(NH_4)_2SO_4$
	Potassium nitrate	KNO_3
	Calcium nitrate	$Ca(NO_3)_2$
	Ammonium nitrate	**NH_4NO_3**
Phosphorus based fertilizers	Superphosphate	CaH6O8P2+2
	Diamonic phosphate (DAP)	$(NH_4)_2HPO_4$
	Monoamonic phosphate (MAP)	**H_6NO_4P**
	Monopotasic phosphate	KH_2PO_4
	Phosphoric acid	**H_3PO_4**
Potassium based fertilizers	**Potassium chloride**	**KCl**
	Potassium sulfate	**K_2SO_4**
	Potassium nitrate	KNO_3

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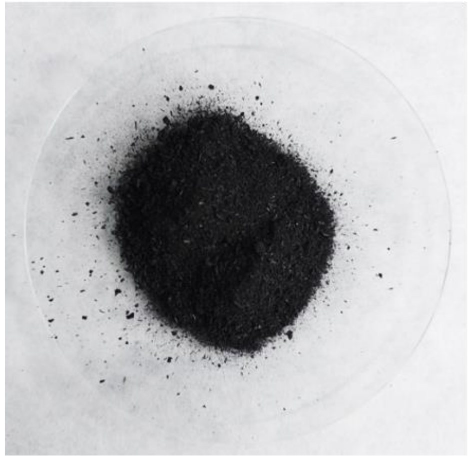
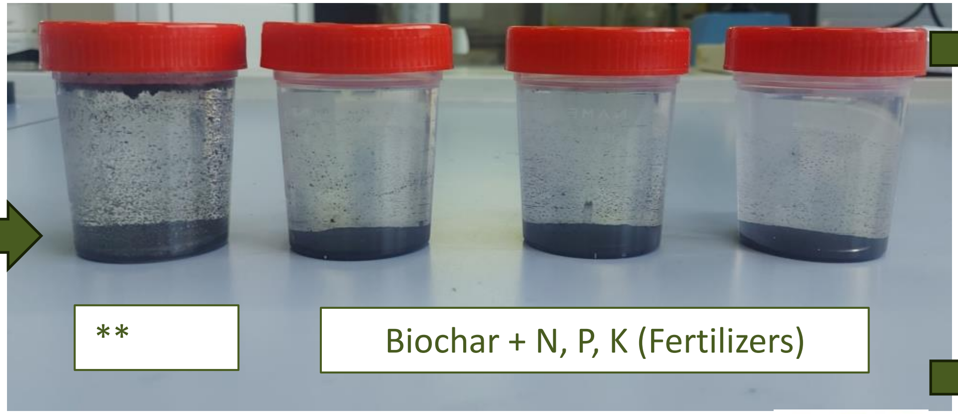
Characterization of controlled and slow delivery system based on biochar

Schematic experimental workflow for evaluated delivery systems in water assay

STEP 1: Weigh 1 g of impregnated biochar with fertilizers



STEP 2: Incubate the impregnated biochar with fertilizers in 50 ml of distilled water



**As a control, uncoated fertilizer impregnated Biochar was incubated under the same conditions.

Hydroponic

STEP 3: Carry out conductivity measurements to evaluate the slow and controlled release fertilizers

Slow and Controlled relase fertilizers conditions

- ✓ Room temperature (22ºC)
- ✓ With stirring
- ✓ 10 mL aliquouts for conductivity measurements

EC-method

Slow and Controlled relase fertilizers conditions

- ✓ Room temperature (22ºC)
- ✓ Without stirring
- ✓ 1 mL aliquouts for UV-Vis spectrophotometry

UV-Vis

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Characterization of controlled and slow delivery system

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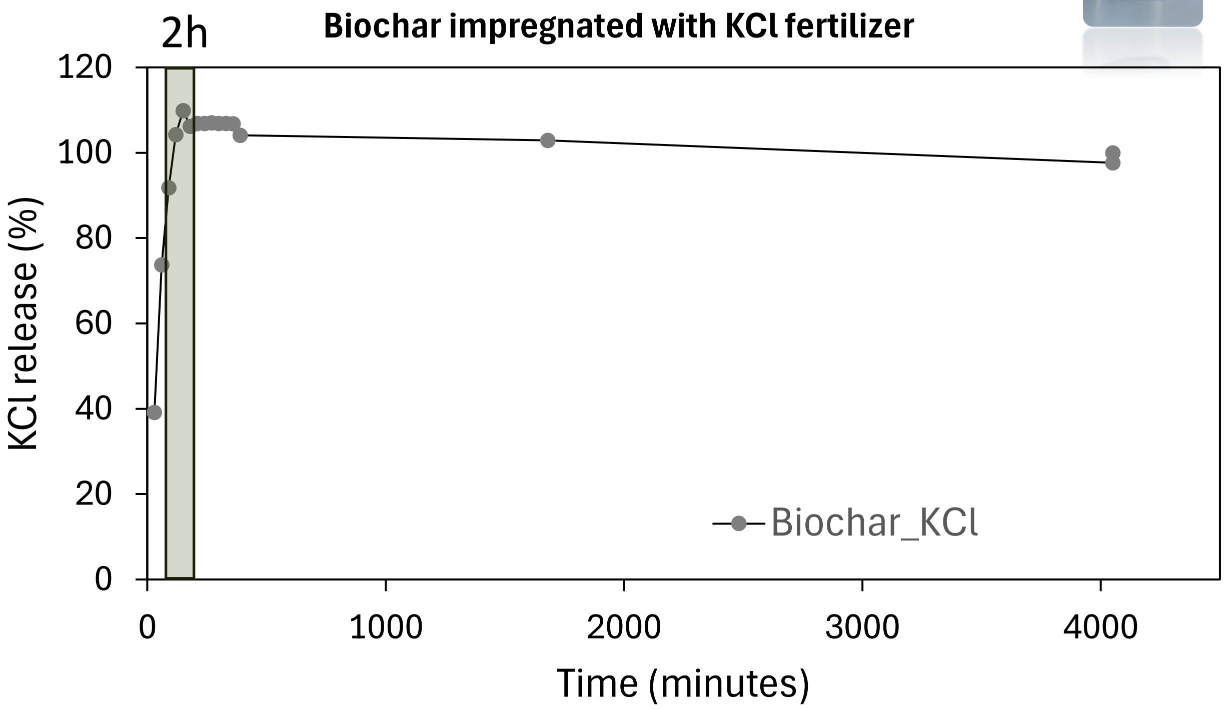

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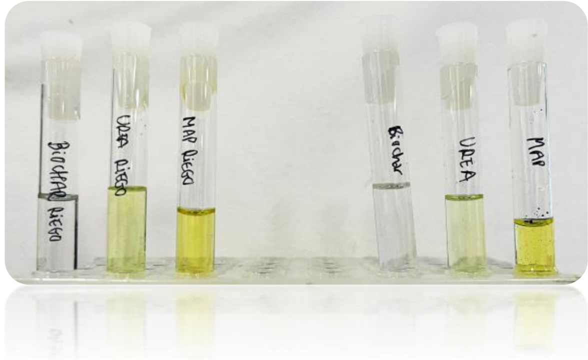
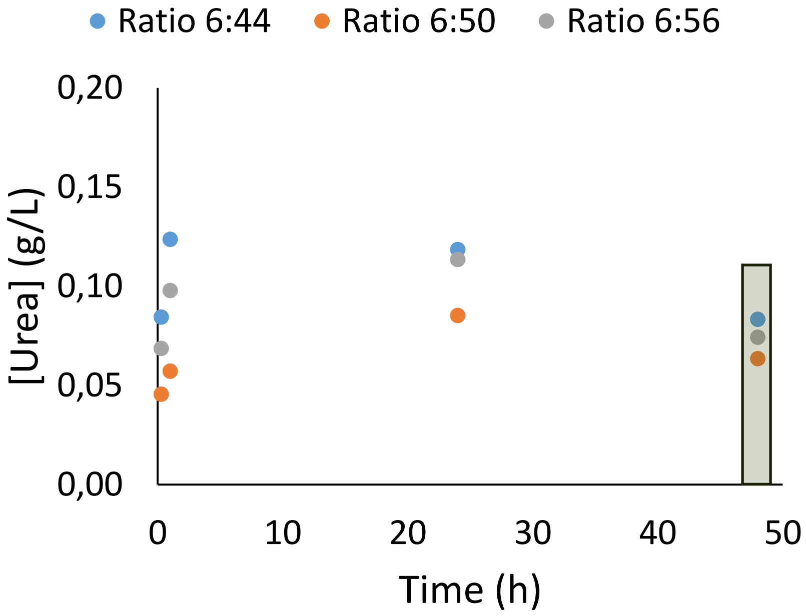
STEP 3: Carry out conductivity measurements to evaluate the slow and controlled release fertilizers

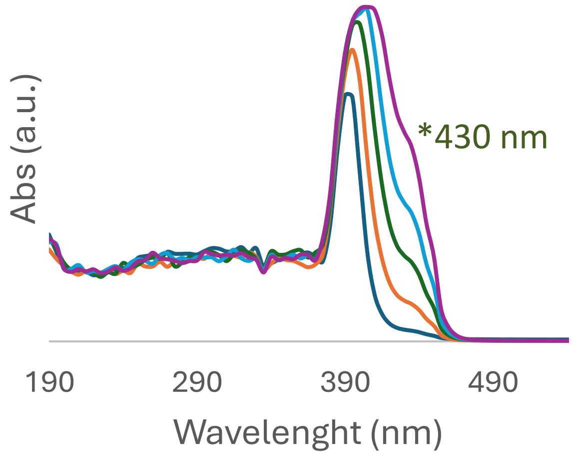
Slow and Controlled relase fertilizers conditions

- ✓ Room temperature (22ºC)
- ✓ Without stirring
- ✓ 1 mL aliquouts for UV-Vis spectrophotometry

UV-Vis







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Characterization of controlled and slow delivery system

Schematic experimental workflow for evaluated delivery systems in soil columns

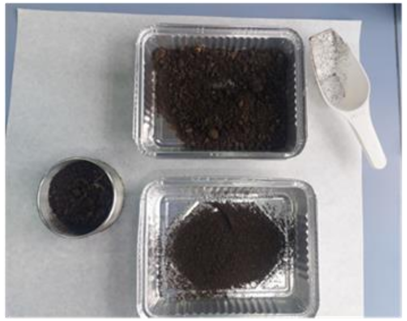
Maize crops soil

✓Divided soil samples in different batches

Soil sample drying at 110 °C

✓Reduction of water content (moisture) and autoclave soil

Sample sieving



✓Improved soil homogeneity

Mixing with perlite

✓Enhances drainage during irrigation

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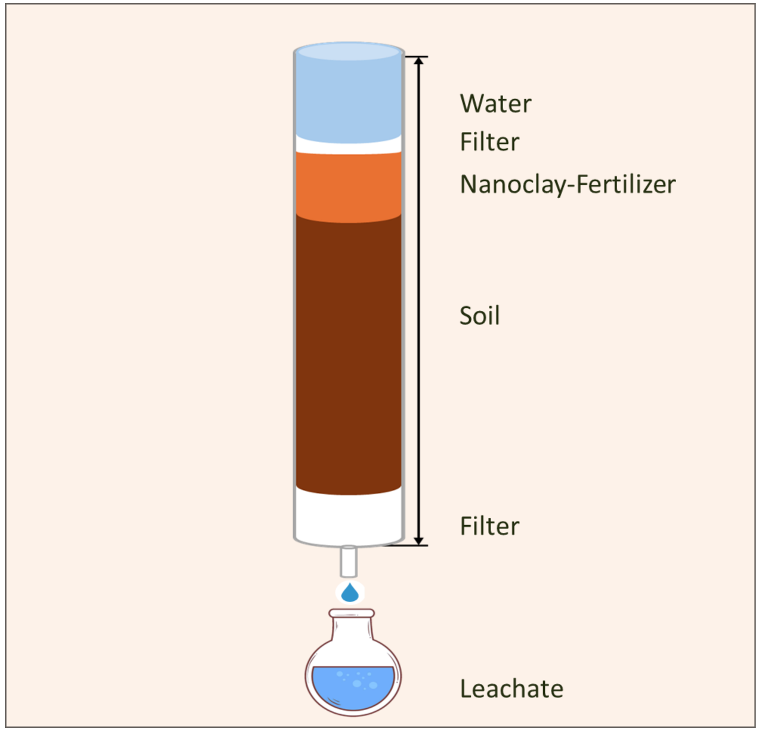
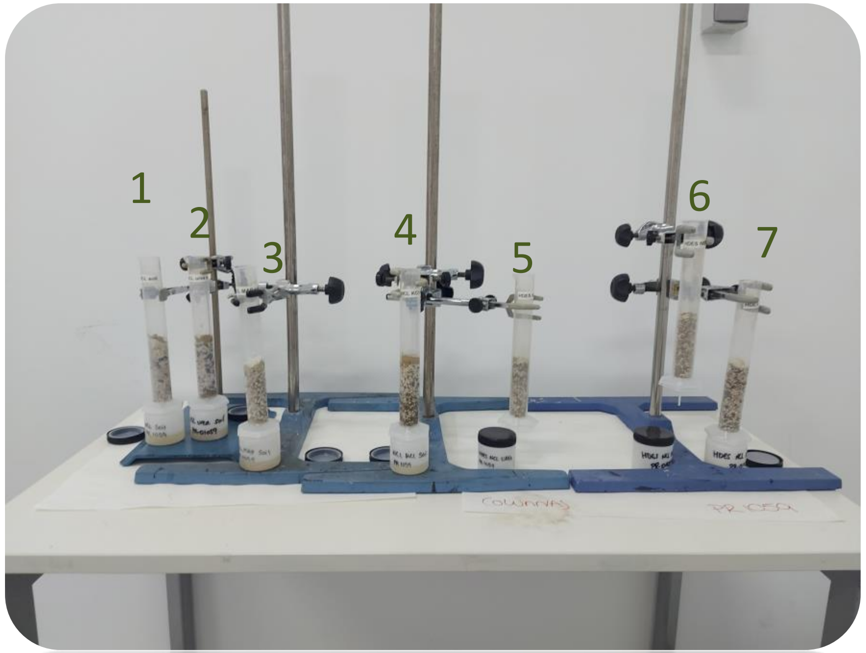
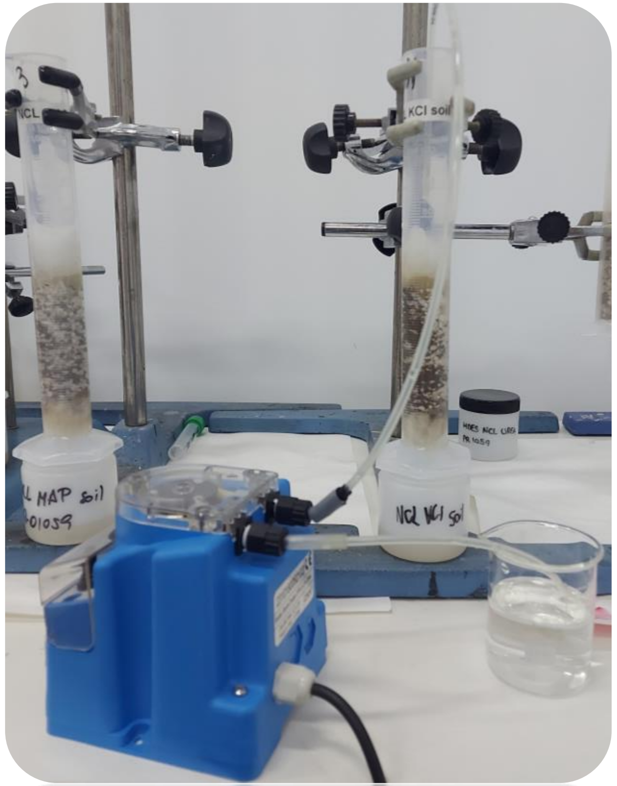
Characterization of controlled and slow delivery system

Evaluation of delivery systems based on biochar in soil columns







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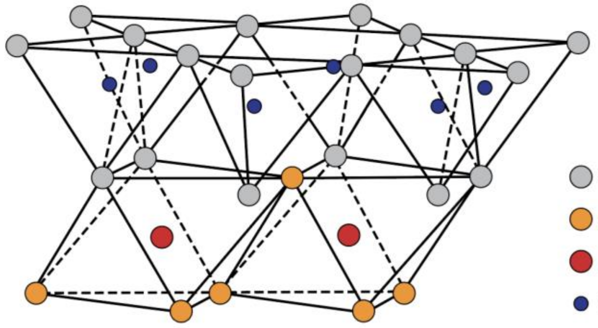
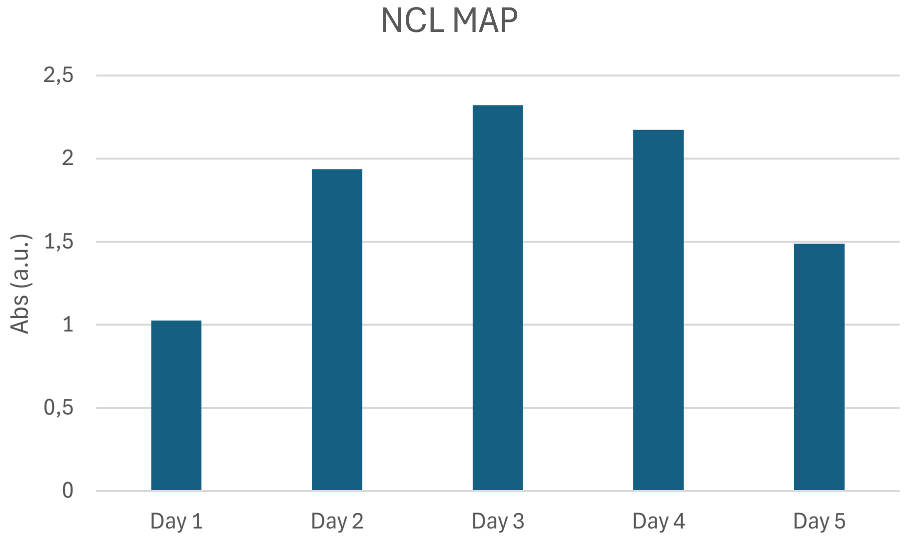
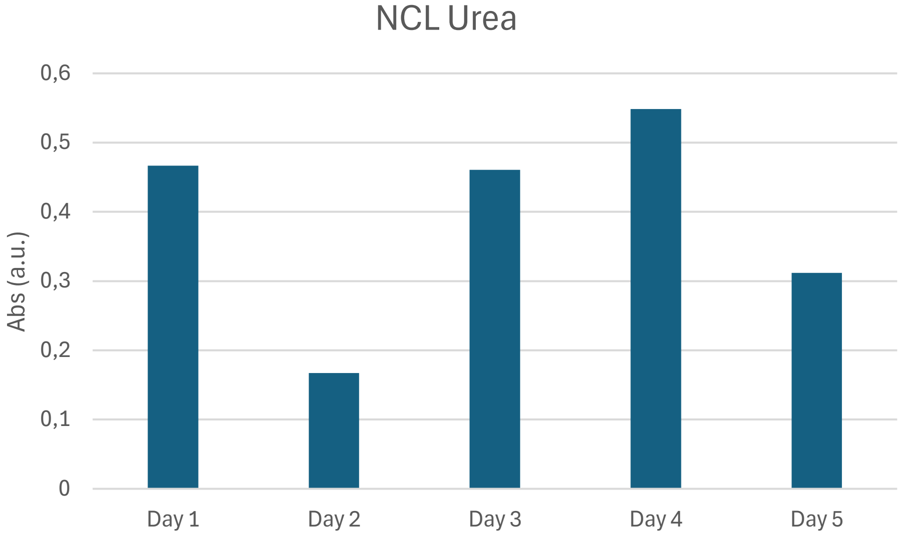


Nanoparticle-based systems evaluated as an example of fertilizer release systems at laboratory scale.





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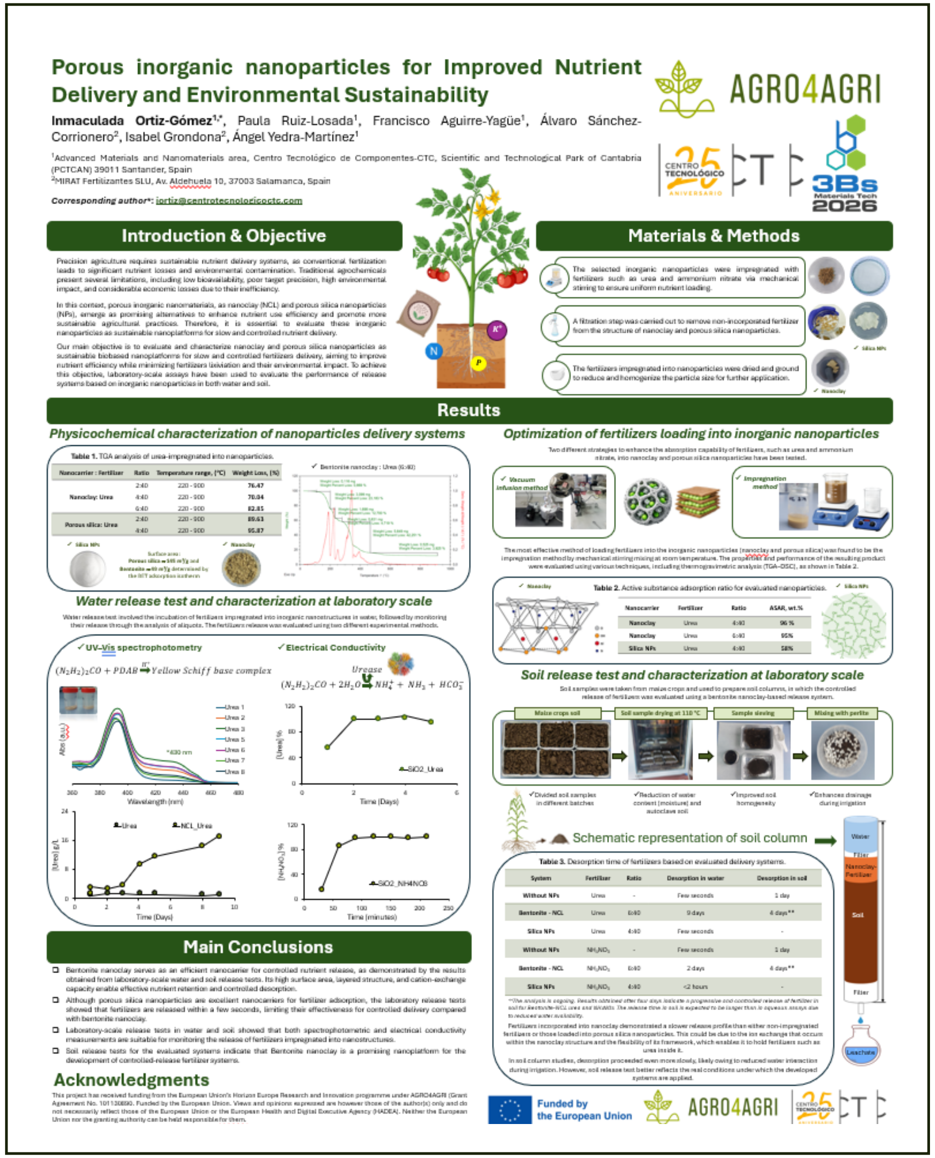
POSTER SESSION



3Bs Materials Tech 2026

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Main Conclusions

- ✓ Biochar serves as an **efficient nanocarrier** for nutrient release, as demonstrated by the results obtained from laboratory-scale water release tests.
- ✓ Laboratory-scale release tests in water showed that both **electrical conductivity** and **spectrophotometric measurements** are **suitable for monitoring the release of fertilizers** impregnated into biochar.
- ✓ Its **high surface area**, and **cation charge capacity** enable effective nutrient retention.

KPI. Active substance adsorption ratio (ASAR).

Nanocarrier	N fertilizer	Molar ratio	Adsorption rate wt%
Biochar (300ºC)	Urea	6:40	-
Biochar (400ºC)	Urea	6:40	41.10
Biochar (500ºC)	Urea	6:40	50.11
Biochar (600ºC)	Urea	6:40	64.09

- ✓ The **impregnation of fertilizers** into the structure of **biochar increases the release time** of nutrients into water, ensuring their persistence and assimilation by plants.

KPI. Desorption ratio of active substance in laboratory scale using a rapid water release test.

Nanocarrier	Fertilizer	Molar ratio	Desorption ratio %
Biochar (300ºC)	KCl	6:40	**100 %**
	NH_4NO_3	6:40	**100 %**
Biochar (500ºC)	KCl	6:40	**100 %**
	Urea	6:40	**100%**

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Thank you for your attention!

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