Greenhouse application of boron carbon oxynitride (BCNO) nanocomposite material as novel luminescent solar concentrator: Effects on growth and organoleptic quality of lettuce and basil plants

S.A. Barla[1], V. Giannakopoulos[1], E. Pitsika[2], E. Stathatos[2], G. Lykokanellos[1], C. Stefanou[1], A. Alexopoulos[3] and G. Salachas[1]*

[1]Department of Agriculture, University of Patras, Mesolonghi, Nea Ktiria 30200, Greece
[2]Department of Electrical and Computer Engineering, University of the Peloponnese, Patras GR26334, Greece
[3]Department of Agriculture, University of the Peloponnese, Antikalamos, Kalamata, 24100, Greece

*Corresponding author: E-mail: gsal@upatras.gr, Tel +30 6944691415

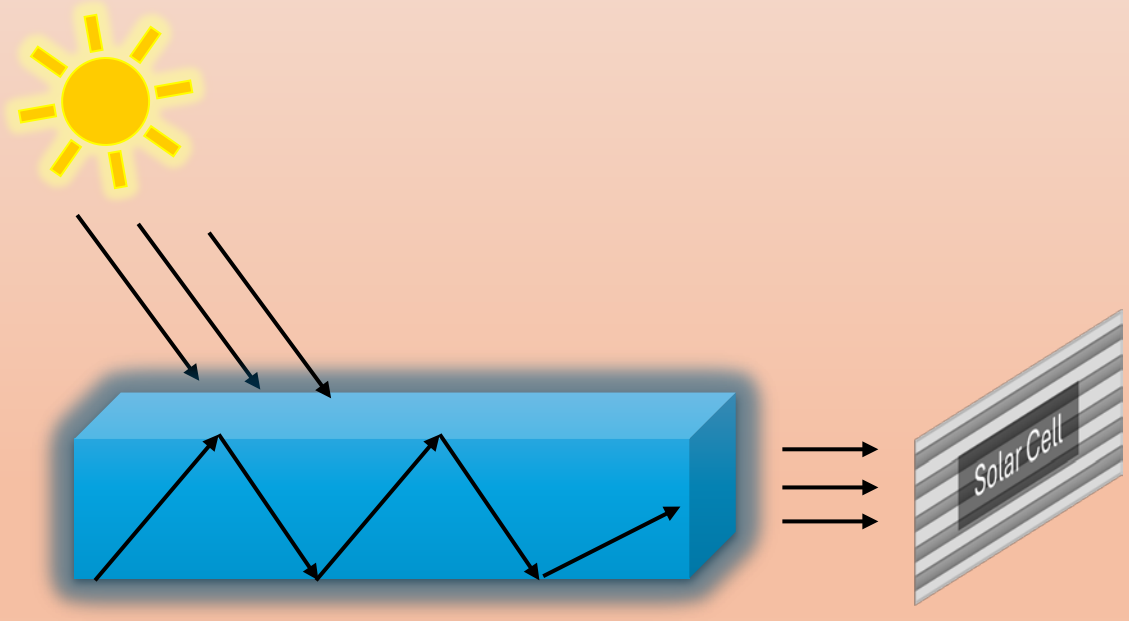
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Aim of the study

- *In this study, we focus on the boron carbon oxynitride (BCNO) nanocomposite material as solar concentrator.*
- *We examine its potential as a luminescent solar concentrator to improve greenhouse energy efficiency and enhancing plant growth*
- *Our goal is mainly focused to study the effects of BCNO as coated greenhouse material on growth, morphological and physiological parameters of lettuce and basil plants*

Introduction to Luminescent Solar Concentrators (LSCs)

✓ **Luminescent solar concentrators** (LSCs) utilize phosphors or fluorescent molecules to capture solar energy, re-emitting it at different wavelengths.



LSC Structure

✓ **Light-absorbing materials:**

The luminescent material (or luminophore) is the substance that absorbs solar energy.

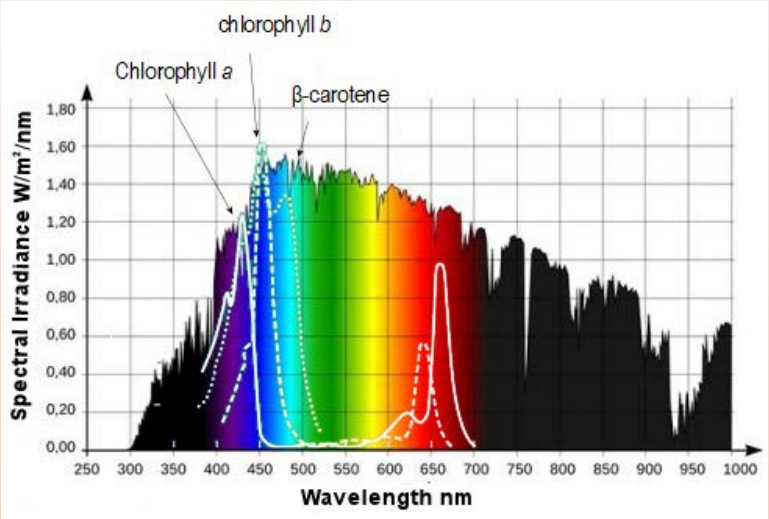
✓ **Transparent light-guiding Matrix:**

It is typically applied as a coating or as a dopant in a transparent matrix or glass substrate, which acts as a lightguide.

The concentrated light collect at the edges or top surfaces of LSCs by a photovoltaic cell, resulting in the conversion of light energy into electricity.

LSCs are particularly attractive due to their **low cost, easy integration into buildings and greenhouses, and ability to function even under diffuse sunlight**.

LSC in agriculture



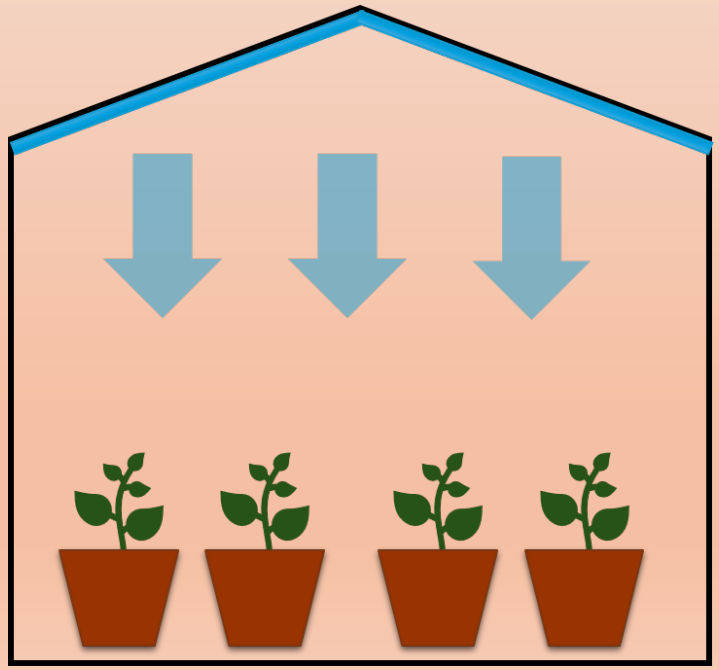
The integration of Luminescent Solar Concentrators (LSCs) in agriculture represents an innovative solution aimed at improving the energy efficiency of greenhouses and enhancing plant growth.

Optimization of Solar Radiation

- ✓ LSCs absorb sunlight and re-emit it at specific wavelengths that are more beneficial for photosynthesis.
- ✓ They can increase the amount of **red and blue light**, which are crucial for plant growth.

Electricity Generation

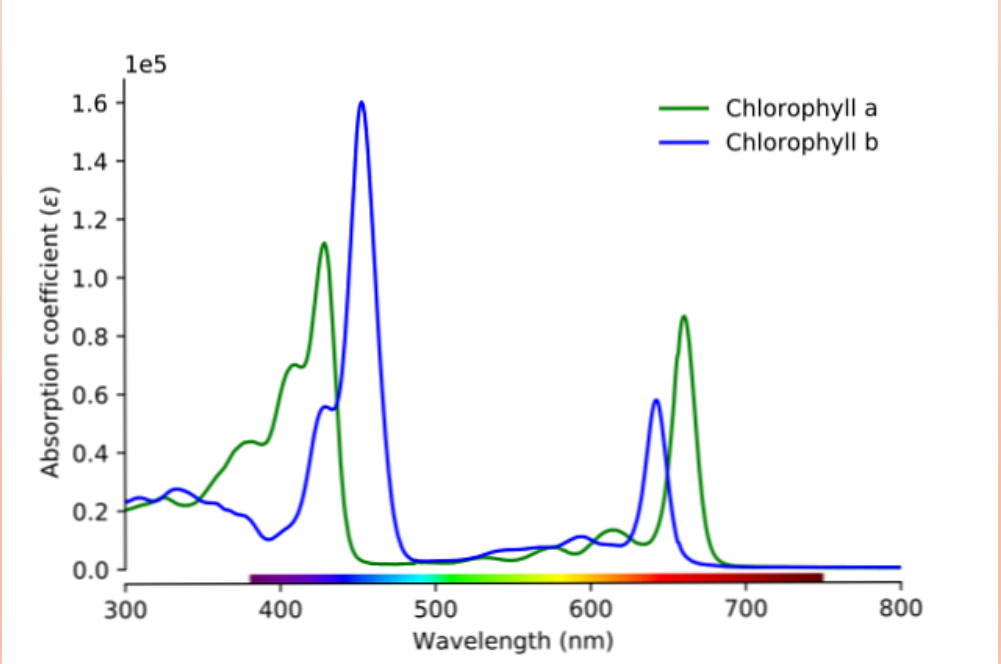
- ✓ LSCs can be integrated into **transparent greenhouse surfaces**, acting as **solar collectors**.
- ✓ This **converts part of the solar light into electricity** by placing semi-transparent PV cells at the edges or top faces, **reducing greenhouse energy needs**.



BCNO Material: The choice

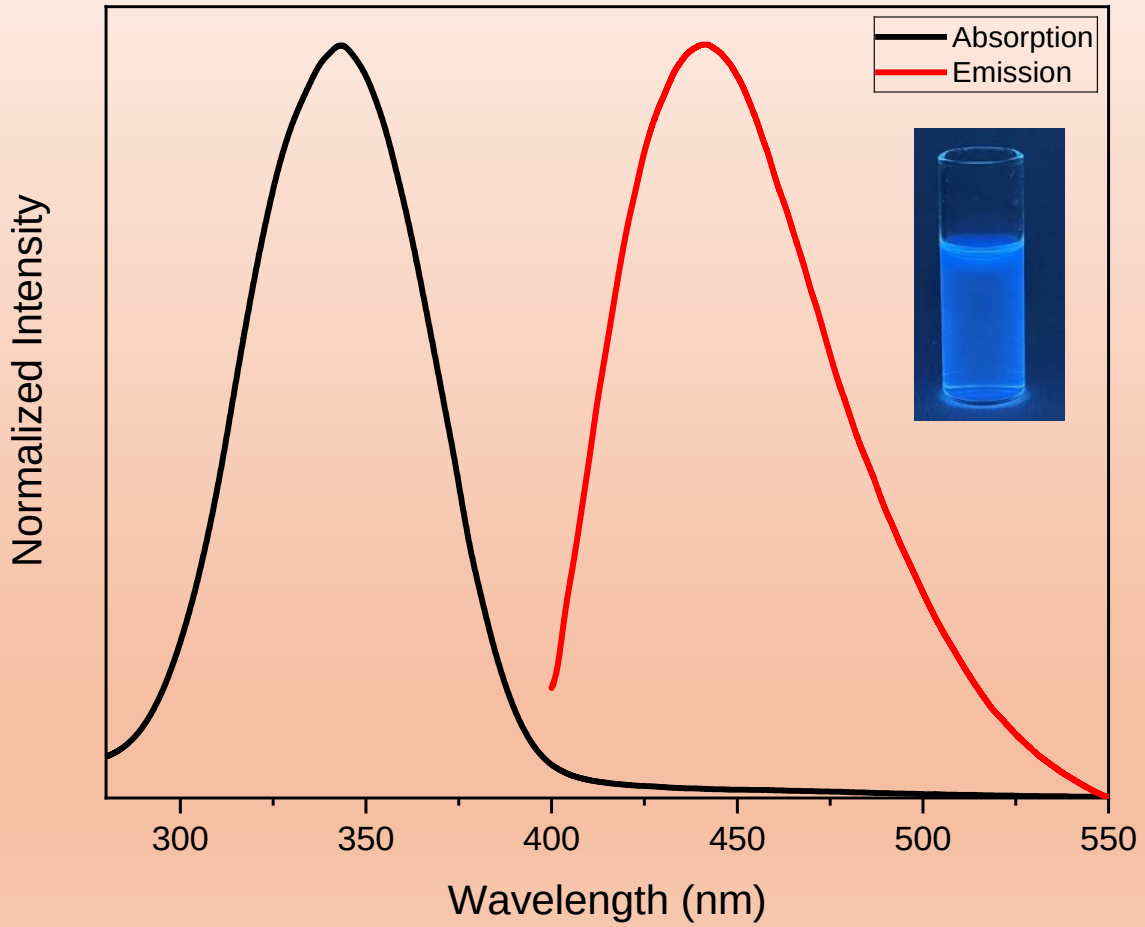
BCNO material is an **environmentally friendly material** as it is composed of **non-toxic materials, and low-cost raw materials.**

- ✓ Plant **growth** occurs through **photosynthesis**.
- ✓ This process takes place in the leaves, where **chlorophyll** mainly **absorbs blue** (400-500 nm) and **red light** (600-700 nm)
- ✓ We developed a material that absorbs ultraviolet radiation and re-emit it in visible light.
- ✓ BCNO material **emitted in the blue region** where the first photosynthetic peak of chlorophyll is located.

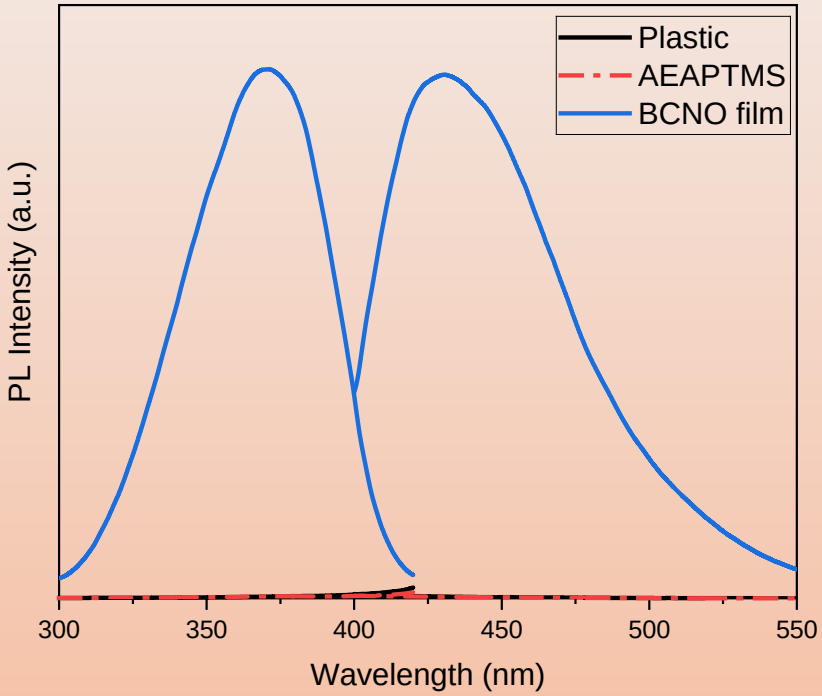


BCNO Material: Synthesis and Characterization

- ✓ The optical properties of BCNO solution were determined by UV-vis absorption and photoluminescence (PL) spectra at room temperature.
- ✓ The **absorption spectrum** has a single broad peak ranging from **300 to 400 nm** with a maximum at 344 nm.
- ✓ The **emission spectrum** was obtained after excitation at 384 nm and appears to have a broad peak with a range from **400 to 550 nm** and a maximum at 440 nm.
- ✓ *The BCNO material was deemed suitable for application to plants as LSC.*

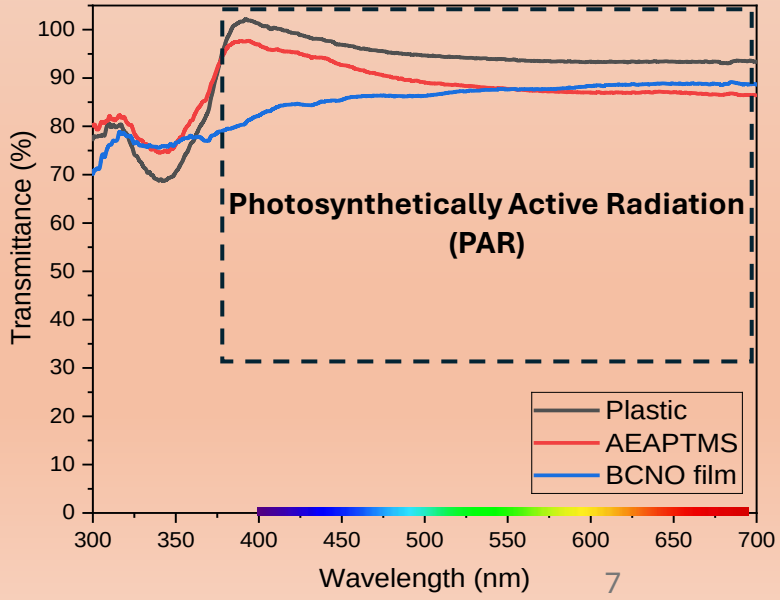


BCNO as a Luminescent Solar Concentrator (LSC)



- ✓ The **absorption spectrum** has a single broad peak ranging from **300 to 420 nm** with a maximum at 344 nm.
- ✓ The **emission spectrum** was obtained after excitation at 384 nm and appears to have a broad peak with a range from **400 to 550 nm** and maximum at 430 nm.

- ✓ The transmittance is **high** in the visible region of the spectrum (400-700nm)



APPLICATION IN GREENHOUSES: THE PROCESS

BCNO was pilot tested in lettuce and basil plants cultivation to assess **plant growth** and **qu**

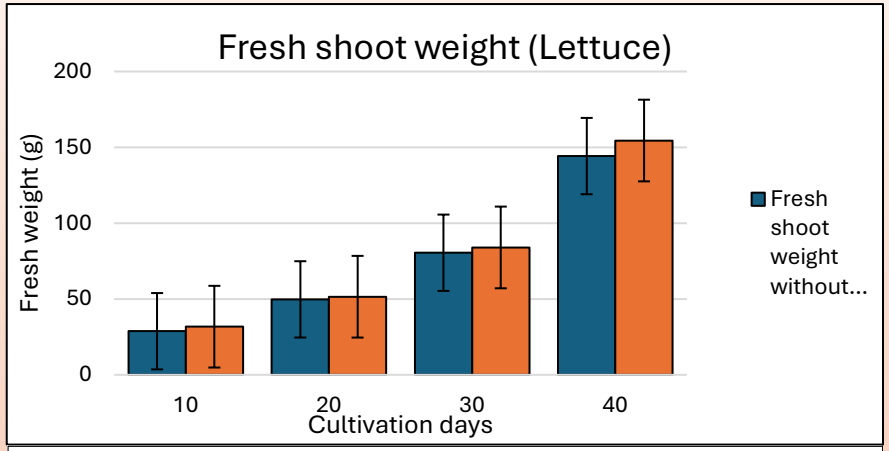
- ✓ Two greenhouses were constructed, one of which was coated with the BCNO material using the **doctor blade method**.
- ✓ The cultivation of plants in the greenhouses was carried out using the **hydroponic method**.

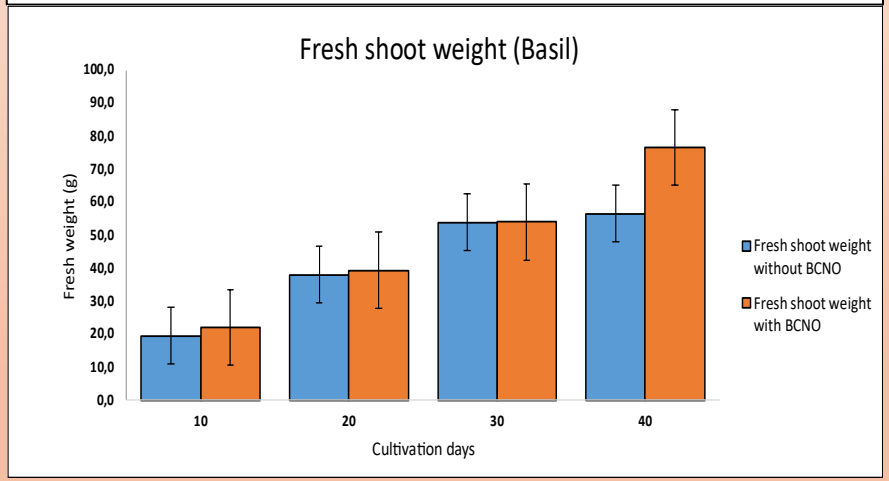
Hydroponic cultivation improves plant growth by regulating water, minerals, and dissolved oxygen for maximum yield and quality.

- ✓ The plants were supplied with a **nutrient solution of inorganic elements**, while the roots developed in a **coconut coir dust**.

The duration of cultivation was for 40 days

RESULTS (FRESH AND DRY WEIGHT)



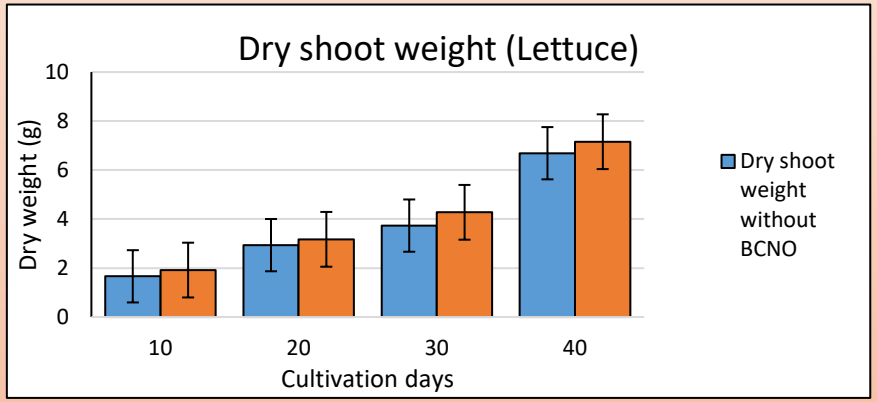


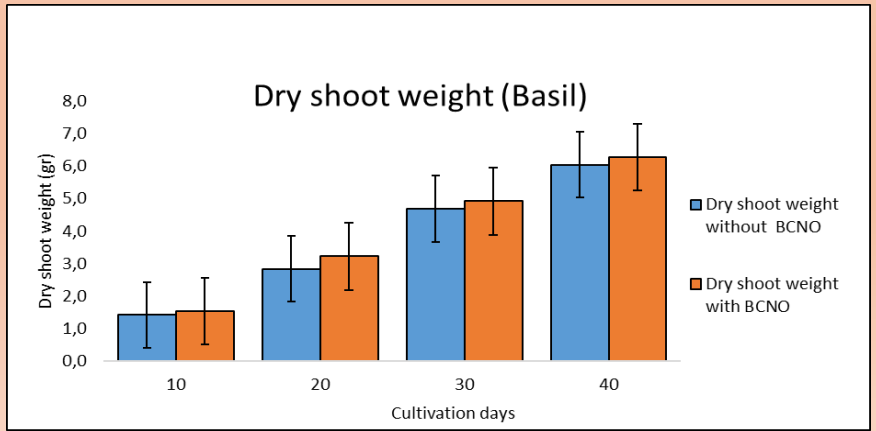
Fresh Weight (FW): INCREASE under BCNO

- Includes the water content within the plant.
- The **increase** in **fresh weight** shows that the plant absorbs sufficient water, maintaining its structure and physiological functions.

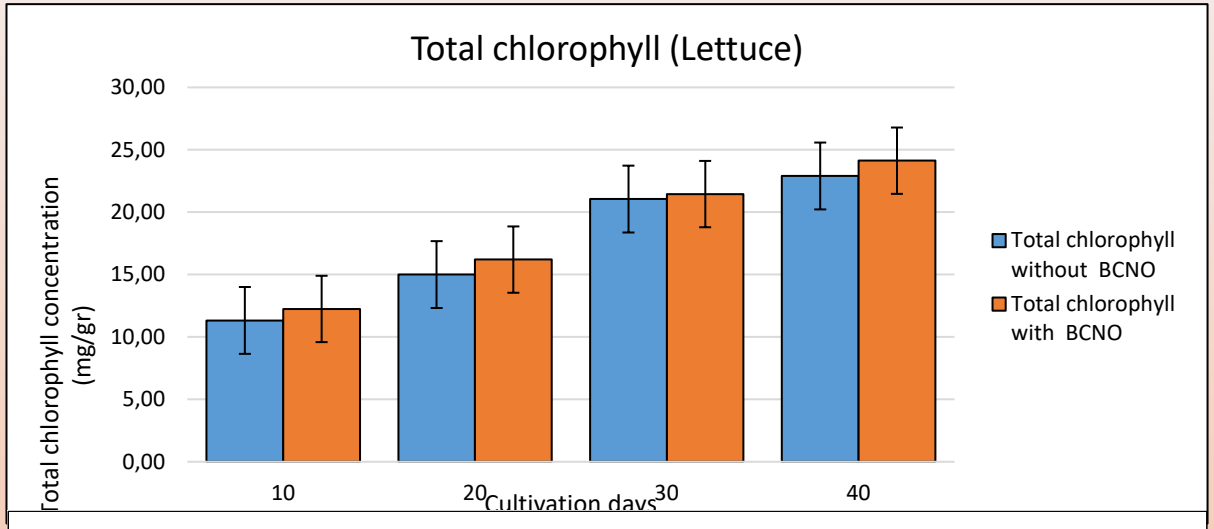
The increase in Dry Weight (DW) under BCNO:

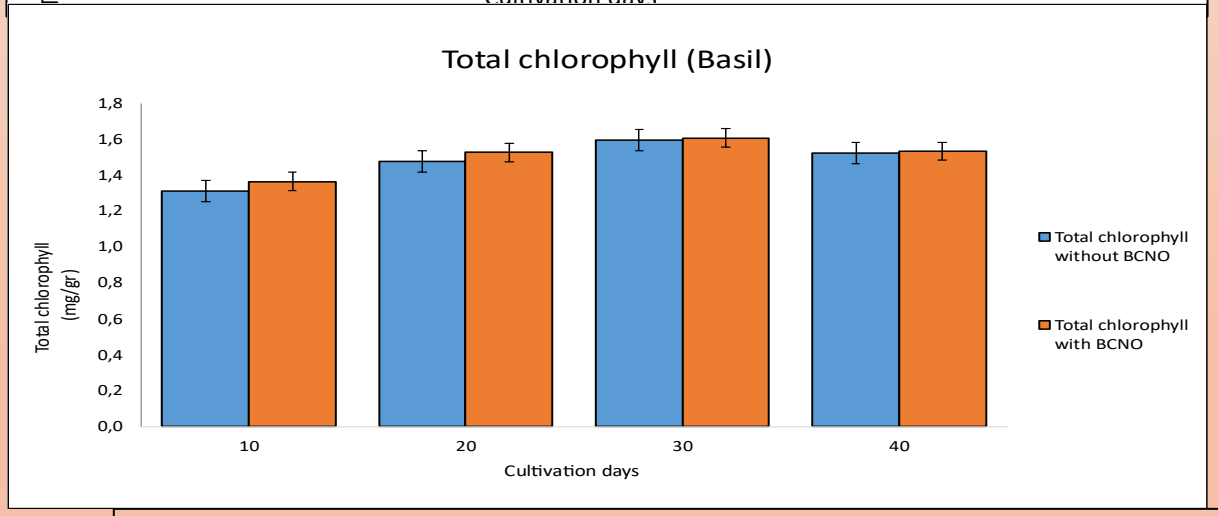
- Reflects the biomass produced through photosynthesis (sugars, cell walls, proteins).
- The rise in dry weight means that photosynthesis produces more organic matter, contributing to biomass development.





RESULTS (TOTAL CHLOROPHYLL CONTENT)

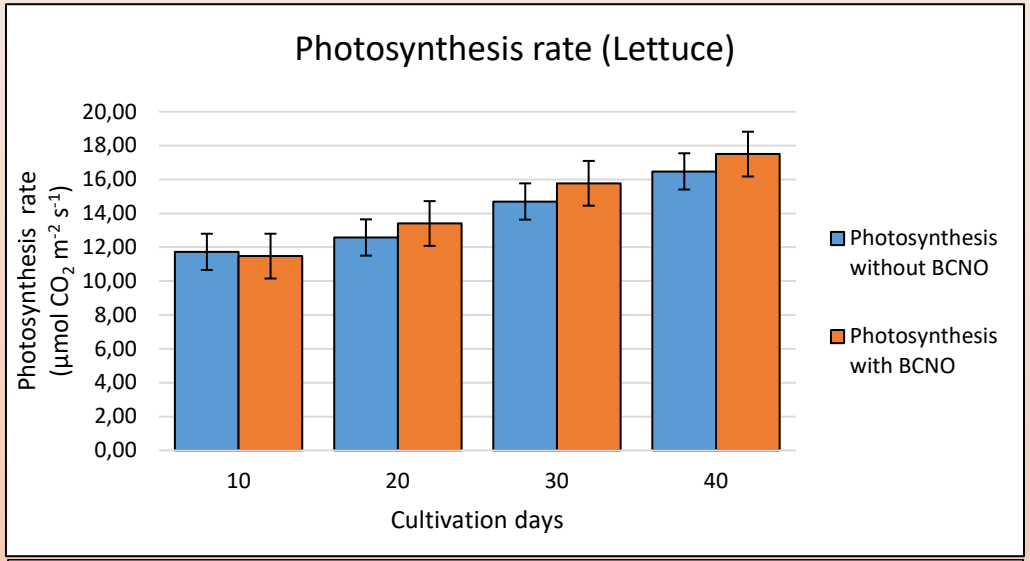


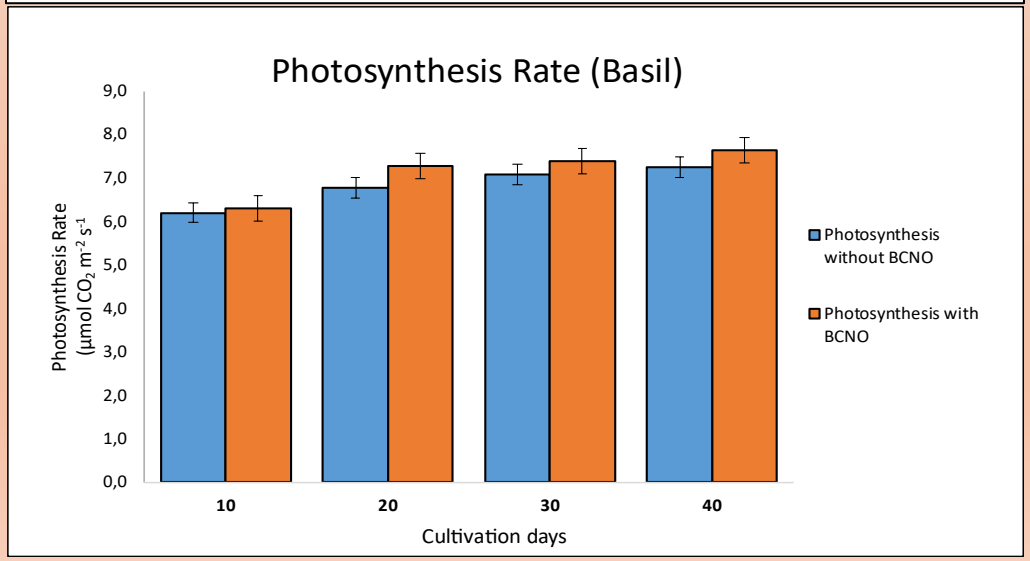


- ✓ **Total chlorophyll** (chlorophyll a and chlorophyll b) in plant leaves is a key indicator of a plant's photosynthetic capacity.
- ✓ A higher concentration of total chlorophyll typically indicates **better photosynthetic activity** and **optimal plant health growth**.

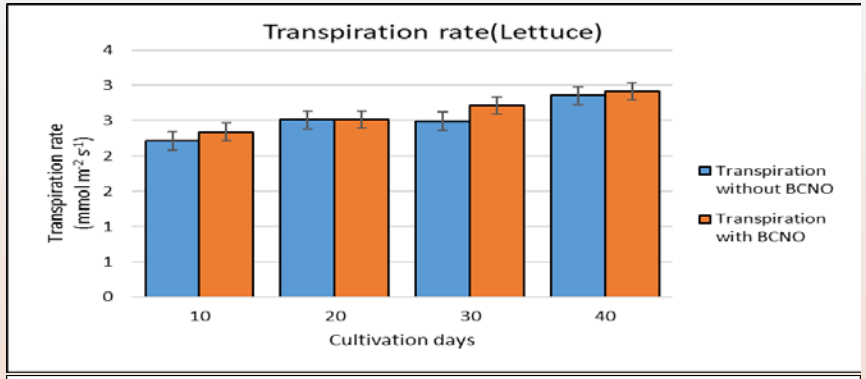
The coating of the BCNO material has a positive effect on the chlorophyll concentration, leading to greater plant growth compared to plants without the material.

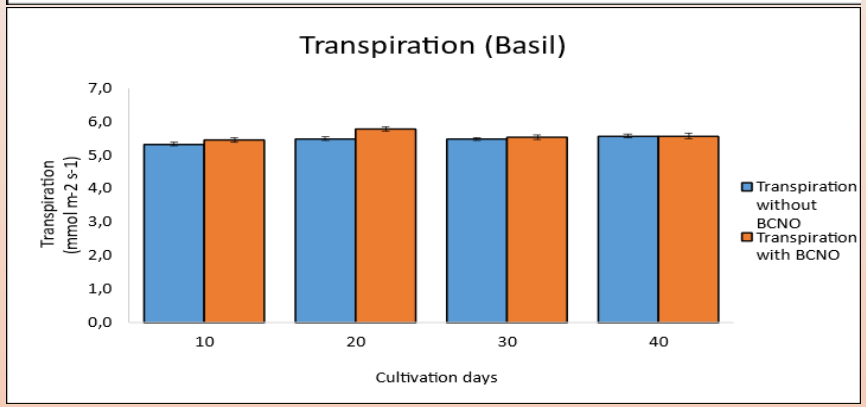
RESULTS (PHOTOSYNTHESIS RATE)





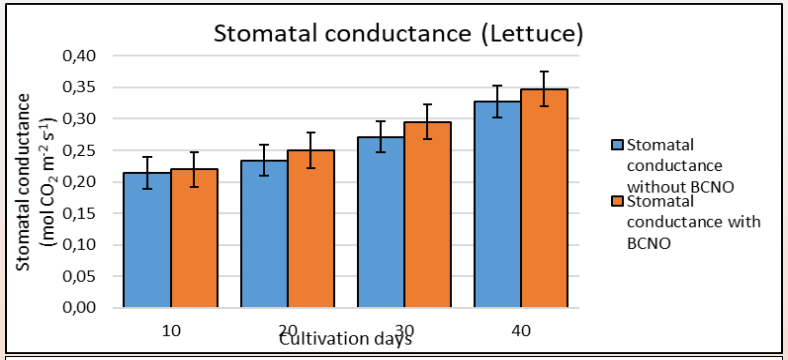
- ✓ **Higher photosynthetic rates** ensures greater CO_2 uptake, boosting energy production and the biosynthesis of plant tissues.
- ✓ The simultaneous increase in fresh weight and dry weight, combined with enhanced photosynthesis, **indicates that the plant is in optimal growth conditions.**

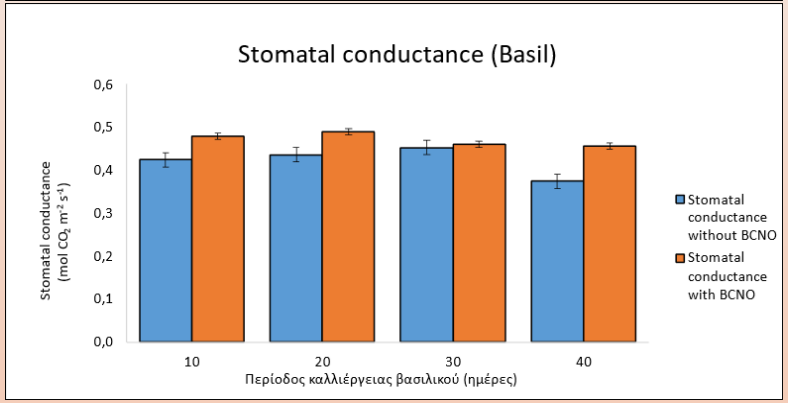




RESULTS

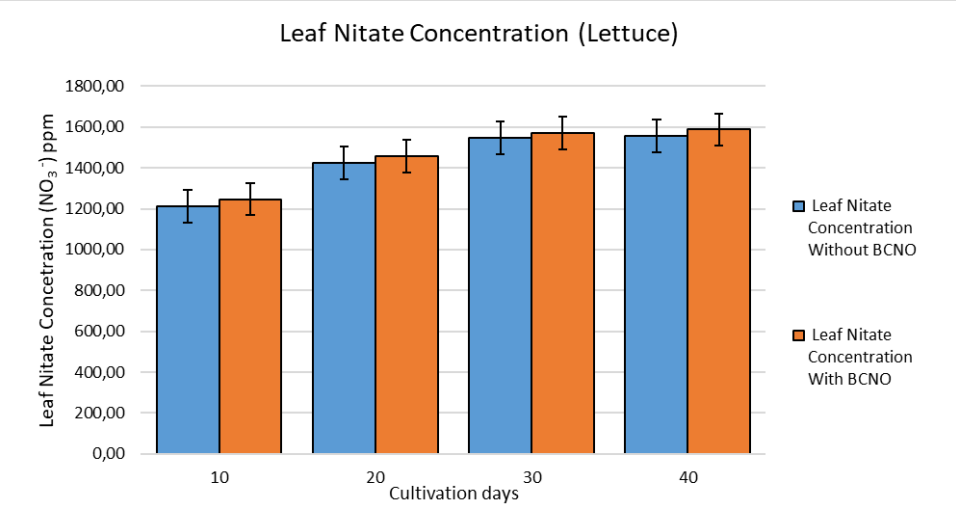
(TRANSPIRATION RATE – STOMATAL CONDUCTANCE)

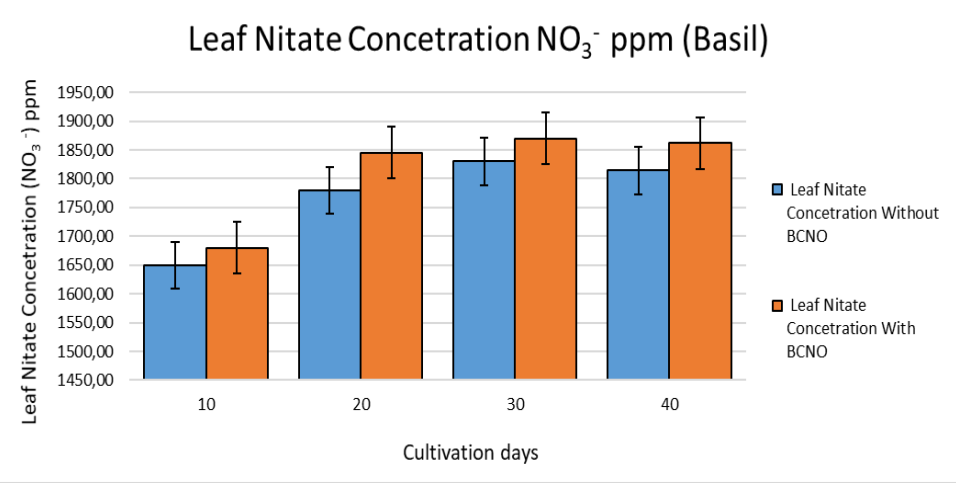




- ✓ **Higher Transpiration rates** ensures more efficient absorption of water and nutrients.
- ✓ Combined with enhanced photosynthesis, **indicates increased assimilation rates and metabolism.**
- ✓ **Considering that the diffusion pathways for both CO_2 and H_2O are similar,**
- ✓ **CO_2 fixation seemed to increase in parallel to transpiration rate and stomatal conductance in the leaves of lettuce plants, but not in the leaves of basil plants.**

RESULTS (LEAF NITRATE CONCENTRATION)





- ✓ Nitrate (NO_3), the primary form of nitrogen absorbed by plants, accumulates in the edible parts of vegetables, posing health risks to humans, affects their nutritive value.

- ✓ The results shows that during cultivation time of Lettuce and Basil plants, nutritive value is not affected in the case of the presence of the covering nanocomposite material (BCNO).

CONCLUSIONS & FUTURE PERSPECTIVES

Conclusions

- ✓ experimental results showed improved plant growth rates during cultivation time of Lettuce and Basil plants in the case of the presence of the covering nanocomposite material (BCNO).

- ✓ Similar results were obtained regarding the morphological and Physiological characteristics of the plants (dry biomass production, photosynthesis rate, transpiration rate and stomatal carbon dioxide (CO_2) conductance.

- ✓ These marginal consistent positive effects indicates that materials such as BCNO are promising for such an application in protected farming but needs more extend experimental investigation.

- ✓ The organoleptic quality of lettuce and basil plants (nitrate content) is not affected.

From our results these marginal consistent positive effects indicates that materials such as BCNO are promising for such an application in protected farming and enhancing crop production in greenhouses. but needs more extend experimental investigation.

Future Perspectives

- ✓ Focus on extending the application of BCNO upper 40 days.
- ✓ Application of BCNO material to larger size greenhouses.

THANK YOU FOR YOUR ATTENTION!

QUESTIONS ARE WELCOMING

Acknowledgement

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