Use of algae-derived biochar for soil amendment

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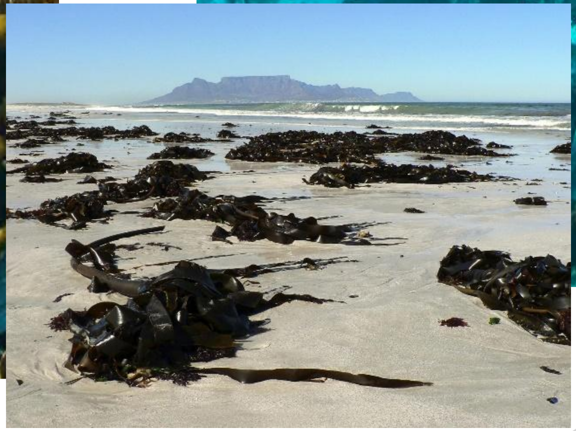
Macroalgae as a Sustainable Biomass Resource

- The cold waters of the Western Cape Province, South Africa, are rich in the brown macroalga Ecklonia maxima.
- Large amounts of algae accumulate on local beaches, creating environmental and aesthetic concerns.
- Ecklonia maxima can be valorised as a biomass feedstock for biochar production by slow pyrolysis.
- Biochars were produced at 450 °C and 720 °C to investigate the effect of pyrolysis temperature on their properties and performance.
- The biochars were evaluated as soil amendments in a 12-week plant-growth experiment using commercial nutrient soil, with NPK fertiliser and untreated soil as references.
- After 12 weeks, the 720 °C biochar treatment resulted in the highest plant growth.

Macroalgal Biomass

Biomass

- **Macroalgae:** *Ecklonia maxima*
- Origin: cold seas of the Western Cape, South Africa
- Algae were dried and milled to approximately **3 mm**



Algae → Drying → Milling → Pyrolysis → Biochar → Soil amendment → Plant growth test

Summary of Taurus Cape Kelp Specification

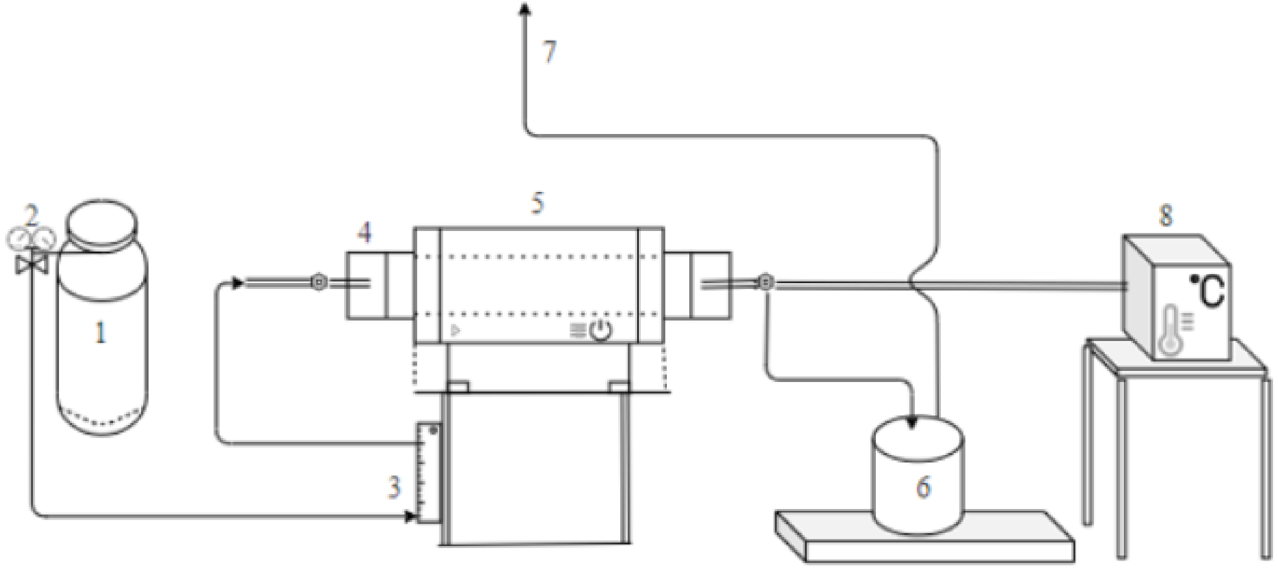
Composition	
Moisture	15.38 g/100g
Crude Ash	17.14 g/100g
Crude Protein	7.76 g/100g
Nitrogen	43.81 g/100g
Chlorides	1.59 g/100g
Sulphur	9 800 mg/kg
Phosphorus	931 mg/kg
Sulphurated Amino Acids	Cystine: 0.50 g/100g, Methionine: 0.09 g/100g
Alkali Metals	Calcium: 22 100 mg/kg, Potassium: 19 600 mg/kg

Taurus is a manufacturing and trading organisation specialising in seaweeds and phycocolloids in Southern Africa, with a focus on the development of seaweed-based products.

Pyrolysis Equipment

Labofurn furnace with a cylindrical steel reactor

- Reactor internal diameter: **30 mm**
- Reactor length: **1000 mm**
- Slow pyrolysis under an inert atmosphere
- Nitrogen used as sweeping gas



Key

1. Nitrogen tank cylinder
2. Regulator
3. Rotameter
4. Reactor Tube
5. Furnace
6. Separator Vessel
7. Vent Line
8. Thermocouple

Biochar Production

Biochar production conditions

- Algae were oven-dried at **105 °C for 75 min.**
- Dried algae were milled and loaded into the reactor.
- Pyrolysis temperatures: **450 °C** and **720 °C**
- Heating rate: **15.8 °C min^{-1}**
- Soak time: **90 min**
- N_2 flow: **98.6 mL min^{-1}**

❖ In the second phase of the project, the growth rates of „Microgreen seeds“, fast-germinating and growing common sprouts, were investigated with biochar and fertiliser additions.

Biochar Characterisation

- ❖ BET (Brunauer-Emmett-Teller) analysis of surface area measured using nitrogen gas at 77K.
- ❖ C, N, S elemental analysis (IR spectroscopy)
- ❖ P, K analysis (ICP)
- ❖ FTIR spectroscopy

Plant Growth Experiment

Ordinary potting soil and all-purpose „Gardenmaster“ NPK (1.9: 1.4: 2.95) fertiliser were purchased at a local supermarket.

Plant growth experiment

1) Control - Soil only
2) 450 °C biochar - 338 g soil + 12 g biochar
3) 720 °C biochar - 338 g soil + 12 g biochar
4) Fertiliser - 338 g soil + 12 g NPK fertiliser

Control: 350 g soil

Microgreen seeds: 2 g per pot

Growth period: 12 weeks

Plant growth was monitored for 12 weeks and final dry biomass was determined.

Plant Growth Experiment

The effect of the addition of 450°C and 720°C biochars to the soil compared with the soil with and without the addition of a fertiliser, or 350 g soil alone.

A greenhouse was placed in a location with sufficient exposure to sunlight. Plant seeds were equally divided into separate pots.

Temperature of 23.6 ± 8.4 °C
Relative humidity of 76.4 ± 16.5 %

Results and Discussion

Pyrolysis conditions: 450 °C and 720 °C | 15.8 °C min^{-1} | 90 min

Mass of Algal Biomass [g]	Pyrolysis Temperature [℃]	Mass of Biochar After Pyrolysis [g]	Yield [wt.%]
225.0-226.0	450	117.4 - 170.1	60.4 ± 15.2
225.0-225.2	720	81.5 - 102.4	41.3 ± 5.1

- **Biochar yield decreased with increasing pyrolysis temperature.**
- The **450 ˚C biochar showed a higher yield** than the **720 ˚C biochar**.
- The obtained yields were within the range reported in previous studies (**24-77%**) .
- Higher temperatures promoted greater **decomposition and volatilisation of the biomass**, resulting in lower solid yields.

BET Analysis Results of Algal Biochar

Higher pyrolysis temperature increased the specific surface area.

- **720 °C biochar exhibited a higher BET surface area and greater microporosity.**
- Higher-temperature pyrolysis promotes **decomposition and volatilisation of organic matter**, contributing to pore development.
- The increase in microporosity resulted in **smaller average pore size**.

Temperature of pyrolysis [°C]	BET Surface Area [m^2/g]	Pore Size [Å]
450	18	61.2
720	304	49.5

Elemental Composition of Algal Biochar

- Higher pyrolysis temperature → higher **Carbon** content, indicating a higher degree of carbonisation.
- The average **Nitrogen** content in both 450 °C and 720 °C biochar samples was 1.57 % and 3.54 %, respectively, compared to the fertiliser content of 1.9%.
- The average **Sulphur** content remained nearly unchanged (~0.6%).
- Both biochars contained more **Phosphorus** than the fertiliser (1.4 %).
- **Potassium** content was lower than in the fertiliser (2.95 %).

Analysis of algal biochar

Algal Biochar mean composition [wt. %]					
Temperature of pyrolysis [°C]	Carbon	Nitrogen	Sulphur	Potassium	Phosphorus
450	39.02	1.57	0.64	2.3	2.26
720	42.65	3.54	0.62	1.75	2.26

Effect of pyrolysis temperature on functional groups

Fourier Transform Infrared (FTIR) Spectra

450 °C biochar

- More aliphatic structures and oxygen-containing functional groups are retained.
- Organic functional groups are more pronounced at lower pyrolysis temperature.

720 °C biochar

- Greater decomposition of aliphatic structures occurs.
- Higher temperature promotes **carbonisation and aromatisation**.
- Formation of more condensed aromatic structures is expected at temperatures above ~600 °C.

Higher pyrolysis temperature → decomposition of aliphatic structures → increased aromatic character of the biochar

Results and Discussion

Early growth – first 6 weeks

The fertiliser promoted faster initial growth, likely due to the readily available N, P and K.

Treatment	Plant height after 6 weeks (cm)
NPK fertiliser	20.0 - 24.0
720 °C biochar	15.5 - 17.0
450 °C biochar	14.5 - 15.4
Control	12.5 - 13.3

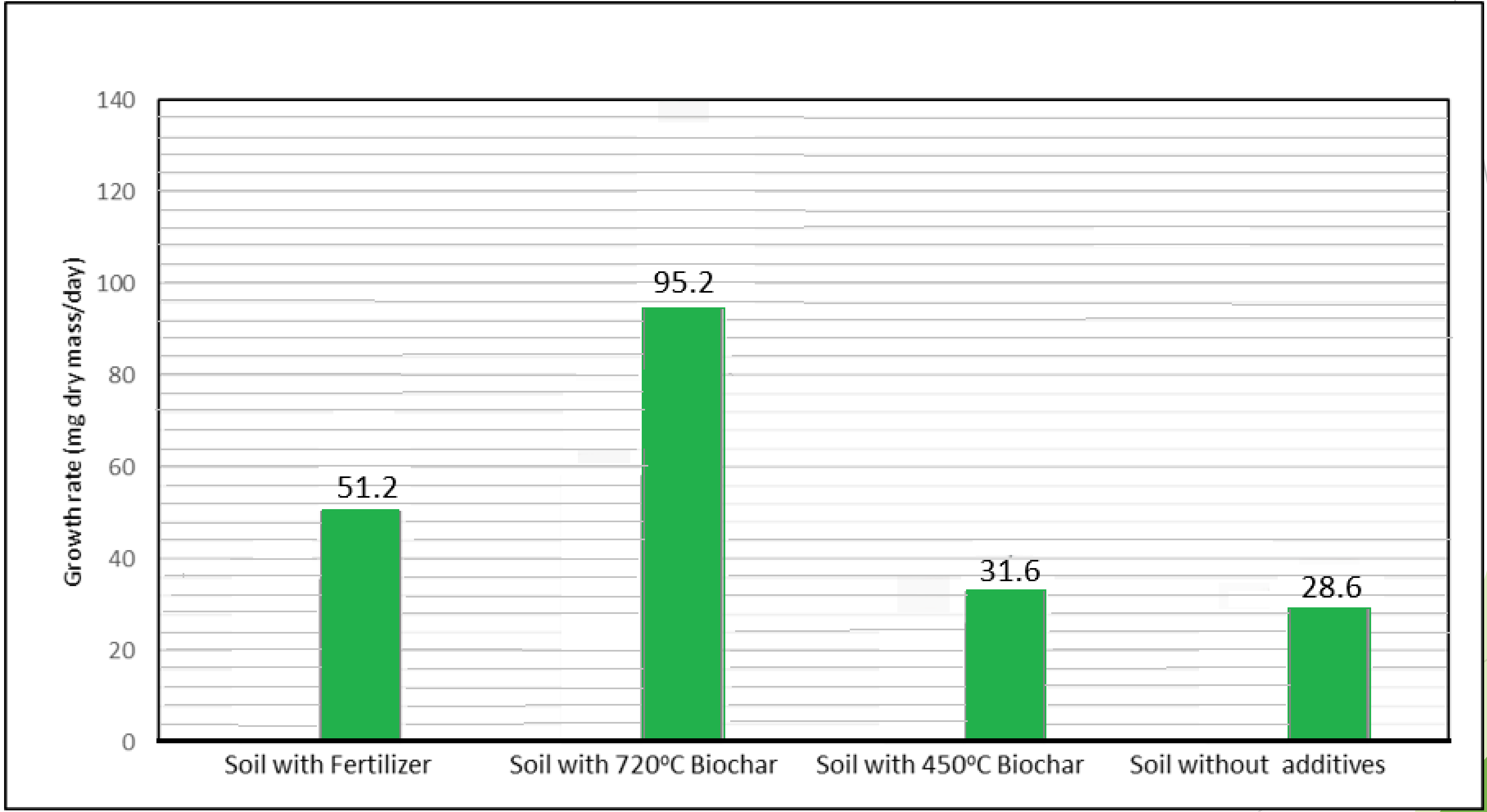
Later growth

Biochar → slower initial response, but stronger long-term effect

- Biochar can **retain nutrients and water** in the soil.
- Its **ion-exchange capacity** may improve nutrient availability.
- Biochar can also act as a **pH buffer**.
- Over time, these properties may contribute to **improved soil fertility and plant growth**.

The 720 ℃ biochar-amended soil showed a higher growth rate in mass than the fertilizer-amended soil, the 450 ℃ biochar-amended soil and pots with soil only.

Growth Rate of "Heirloom Microgreen" after 12 Weeks



Conclusions

Algal biochars were successfully produced at **450 °C and 720 °C**

Increasing pyrolysis temperature resulted in:

- **lower biochar yield:** 60.4 % → 41.3 %
- **higher BET surface area:** 18 → 304 m^2/g
- carbon, nitrogen and trace element contents (higher **C and N contents in biochar 720 °C).**

Nutrient composition

- Both biochars contained more **P (2.26 %)** than the commercial fertiliser (1.4 %).
- **N content** was higher in 720 °C biochar (3.54 %) than in fertiliser (1.9 %).
- **K content** was lower in biochar than in fertiliser.

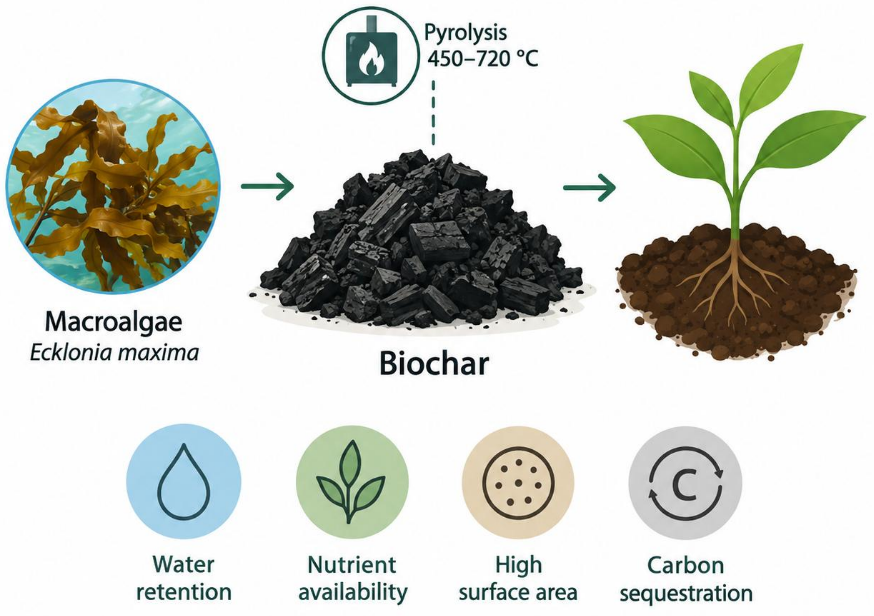
Conclusions

Plant growth

- Fertiliser promoted **faster initial growth.**
- After 12 weeks, **720 °C biochar resulted in the highest plant dry-matter growth rate**, exceeding the fertiliser treatment.

Higher-temperature pyrolysis produced a biochar with greater surface area and higher C and N content, which was associated with improved long-term plant growth.

Algal biochar, particularly at 720 °C, shows strong potential as a soil amendment and a sustainable alternative to conventional fertilisers.



Thank you for your attention

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