Efficacy of biochar to improve physiological parameters of vegetable crop: Experiential summer learning for an undergraduate student

Francisco Trevino, Erik Zamora, Mahima Gumadala, Saoli Chanda, and Sanku Dattamudi

Texas A&M University- Kingsville, Kingsville, TX

Introduction:

Clay loam soils in South Texas are dense, compacted, and poorly draining, limiting crop productivity and long-term soil health. The summer internship was part of an ongoing research effort on sustainable soil management practices for clay heavy soils. The main objective of the project was to compare the effects of organic amendments (cow manure, vermicompost), synthetic fertilizer, Biostimulants, against biochar paired with a cover crop system Okra Clemson Spineless in clay loam soils . Eight treatments with three replications were arranged in 24 pots, and growth measurements such as plant height, leaf width, and chlorophyll content (Soil Plant Analytical Development Meter; SPAD), were collected. The study aimed to identify which treatments improved soil quality and okra growth, while also observing plant resilience under environmental stress. During the trial, a heatwave provided an unplanned test of plant resilience, in which amended pots supported stronger recovery compared to controls. Overall, manure and vermicompost improved soil structure, fertilizer increased early plant growth, and biochar emerged as a strong competitor to both organic and synthetic treatments by improving soil while supporting steady crop performance.

Objectives:

Objective 1: Experiential learning about scientific research projects

Objective 2: Evaluate how Various organic and Inorganic Soil Amendments (particularly biochar) interact with a cover crop system (okra) to improve soil structure, fertility and tolerance of clay loam soils in South Texas.

Objective 3: Compare Organic and Inorganic treatments

Objective 4: determine which strategies most effectively support plant growth and soil recovery In tandem with cover crop systems.

Learning Opportunities:

- **Experimental Design:** Hands on experience in setting up treatments, replicates, and randomized layouts provided practical training in how research trials are structured.
- **Soil Science Skills**: Direct handling of regional clay loam soils builds understanding of soil texture, compaction, drainage, and how amendments like biochar or composts can physically alter soil properties.
- **Plant Propagation & Care**: Managing germination trials, transplanting, thinning, and watering routines provided practical horticultural skills and crop management knowledge.
- **Data Collection & Analysis**: Measuring plant height, leaf width, and SPAD readings, offers practice in recording consistent, quantifiable growth data.
- **Troubleshooting & Adaptability**: Overcoming failed germination batches and responding to stress events (heatwave, etc.) develops problem-solving and resilience.

Application of Experience:

- Gained experience in designing and maintaining a replicated greenhouse experiment, including treatment application, pot layout, and cover crop management.
- Developed practical skills in soil handling and amendment incorporation, working with materials such as biochar, manure, vermicompost, and fertilizers.
- Learned to monitor plant performance using quantitative measurements including height, leaf width, and chlorophyll content (SPAD; unitless).
- Observed how environmental stress (heatwave and cooling system failure) impacts plant growth and gained insight into soil amendments as tools for crop resilience.
- Acquired problem-solving skills through troubleshooting seed germination failures, adjusting practices, and ensuring reliable plant establishment.

Materials and Methods:

Treatments were evaluated for effectiveness through measurements of okra growth and soil conditions. Plant growth was measured using plant height, leaf width, and stem diameter, while chlorophyll content was recorded using a SPAD meter. Data was collected on four dates (Aug 1, 11, 19, and 25, 2025), with additional observations during and after a Sept. 1 heat stress event. Eight treatments were arranged in 24 replicated pots under greenhouse conditions in a semi random design.

Project Soil Treatments:

- Control (no amendment)
- Biochar – 6 t/ac equivalent (16 g/pot)
- Biochar – 12 t/ac equivalent (32 g/pot)
- Cow manure (~4 handfuls/pot)
- Vermicompost (~3 handfuls/pot)
- Synthetic fertilizer (4 g Osmocote 12-12-12)
- Biostimulant
- 50/50 Synthetic fertilizer + Biostimulant

Figure 1: Presenting the greenhouse experiment setup and preliminary results to visiting students as part of an experiential learning and outreach activity

Figure 2: (A) Seedlings germinated in cell trays prior to transplantation. (B) Preparation of growth containers with biochar-amended and control soil treatments. (C) Transplanting of seedlings into treatment pots. (D–E) Experimental layout within the greenhouse showing replicated treatments. (F) Measurement of morphological parameters, including leaf area and stem height. (G–H) Progressive growth stages of plants under controlled environmental conditions. (I) Representative seedlings at the final growth stage prior to data collection.

Figure 3: The okra exhibits partial recovery from severe heat stress (sept 1 event), characterized by leaf chlorosis, marginal necrosis, insect problems and reduced turgor despite some regrowth.

Research outcomes:

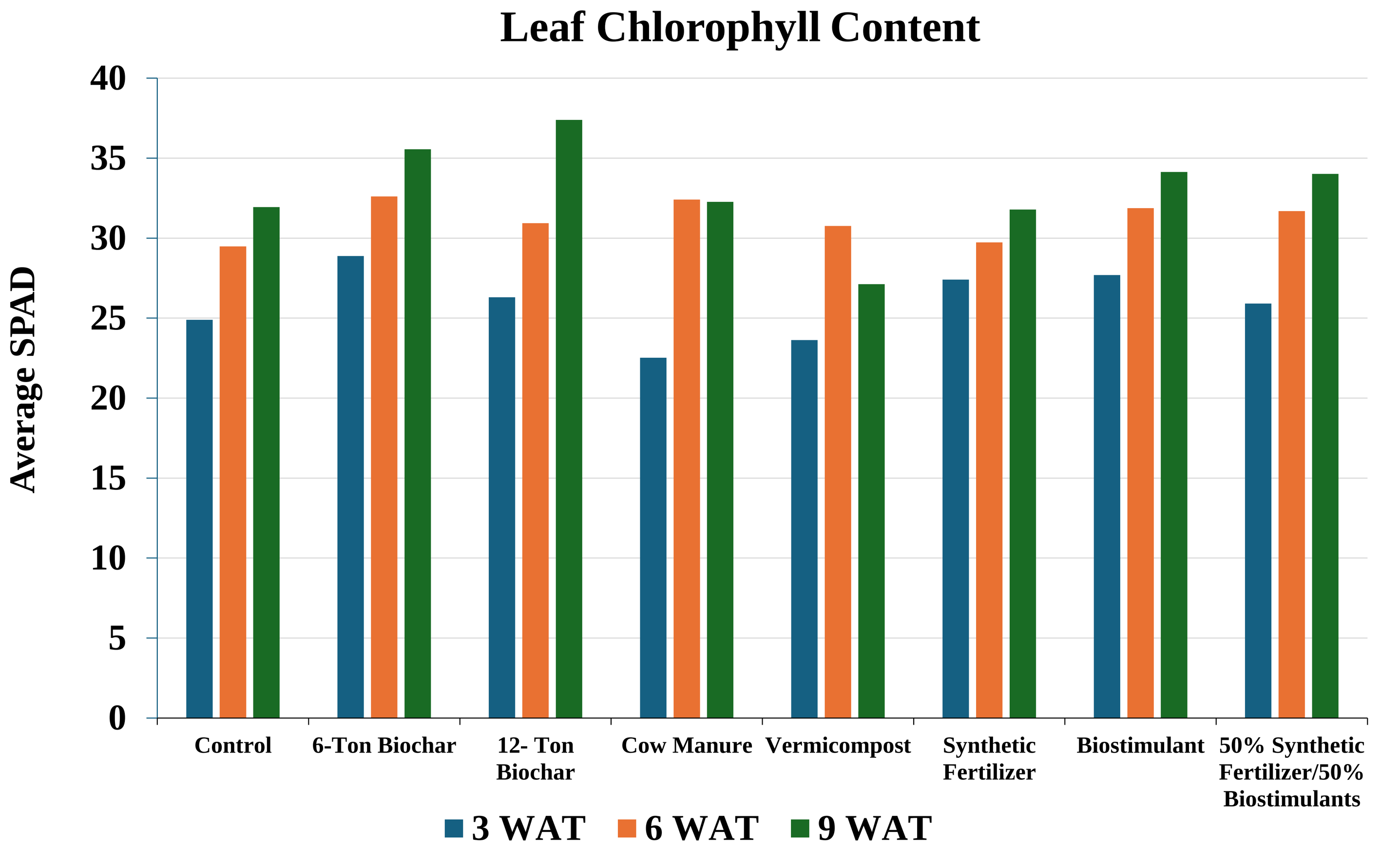

Figure 4: An overview of Greenhouse treatments to evaluate leaf productivity, photosynthetic capability and relative nitrogen availability; SPAD readings increased by roughly 25–30% from week 1 to week 6 across all treatments, with 12-ton biochar and synthetic fertilizer showing the highest chlorophyll content overall

WAT: Weeks after transplanting

Table 1: an overview of the quantitative growth of the okra amongst treatments; On average, okra plants grew between 49 and 78 cm tall, with the 50% Synthetic / 50% Biostimulant and biochar treatments producing the tallest plants. Stem diameters increased by about 2–3 mm from week 4 to week 6 across all treatments, showing steady growth and nutrient response.

Treatments	Height (cm)	Stem Diameter Avg (mm)	Height (cm)2	Stem Diameter Avg (mm)
	4 Weeks after Planting		6 Weeks after Planting	
Control	57.15	6.19	77.25	8.39
6-Ton Biochar	67.52	9.33	80.86	10.74
12- Ton Biochar	69.01	9.2	80.43	10.6
Cow Manure	52.71	6.6	81.07	10.71
Vermicompost	56.09	6.02	77.89	8.51
Synthetic Fertilizer	69.85	9.31	83.4	10.28
Biostimulant	67.53	8.5	86.57	9.89
50%Synth /50% Bio	69.64	9.42	86.78	10.51

Discussion:

- Organic amendments (manure and vermicompost) visibly improved soil structure, making the clay loam lighter and easier for roots to penetrate.
- Synthetic fertilizer produced the fastest early plant growth but did not improve soil physical properties.
- Biochar acted as a strong competitor to the organic amendments, enhancing soil friability and supporting steady, balanced plant growth.
- The Sept. 1 heatwave and greenhouse cooling failure provided an unplanned stress test, where amended soils (especially biochar and organics) supported faster recovery than control pots.
- These results suggest that amendment–cover crop systems can provide both productivity gains and resilience under environmental stress.
- Overall, biochar shows potential as a sustainable soil management strategy, bridging the gap between short-term growth benefits and long-term soil health improvements.

Acknowledgement:

This undergraduate research was funded by a grant from the USDA Southern SARE (LS 24-399) under Young Scholar Enhancement (YES) program