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Effects of biochar use on drought and salinity stresses for cowpea production

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Effects of biochar use on drought and salinity stresses for cowpea production

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Abstract. Climate change is unavoidable and compromises future food availability. The aim of this research is to identify the physiological behaviour of *vigna unguiculata*. It is a common plant in Africa with drought's resilience. An experiment was conducted at the University of Life Science "King Michael I", Romania in 2023. Four treatments included C (Control soil without stresses), B (soil with 5% of biochar without stresses), D (soil with 5% of biochar with drought stress) and S (soil with 5% of biochar with salinity stress) were compared under total randomized experimental design. The biochar used during experiment come from rice husk. The drought-stress starts with 90% of plant watering and finished to 22% of plant watering and the salinity stress starts at 250 mM and finished at 450 mM. Evaluation are focussing on leaf area, chlorophyll content and stomatal conductance. The results show that water stress does not affect leaf area until 22% of plant watering. Also at this stage, stomatal conductance shows significant difference of 22.51 ± 0.95 mmol/m^{2}s^1 compared to control 59.96 ± 0.37 mmol/ m^{2}s^1. Under salinity stress at 450 mM of concentration, the leaf area are 111.40 ± 6.77 cm^2 compared to control 174.88 ± 3.91 cm^2. The treatment with biochar improves positively leaf area 266.56 ± 7.34 cm^2, the leaf area is correlate of the fresh biomass weight result. Total chlorophyll is not affected by the various stresses. These results contribute for having better knowledge that *vigna unguiculata* can offer response to climate change and also how biochar can preserve crop production under stresses.

Keywords: *vigna unguiculata*, biochar, salinity, drought

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1.   Introduction

Current climate change is affecting agriculture and crippling plant growth. Water stress can alter physiological characteristics such as reduced rates of photosynthesis, transpiration, and stomatal conductance, thereby limiting productivity [1]. Salinity is another important factor leading to reduced growth and productivity [2]. Salinity stress can reduce crop yields by affecting physiological leaf growth [3], but also by reducing the ability of plant roots to absorb water and nutrients from the soil [4]. Approximately 30% of Sub-Saharan soils are affected by 10 mM of salinity [5].

Biochar, a carbon-rich product derived from biomass, has emerged as a promising soil amendment to mitigate the effects of abiotic stress. It can improve soil structure, enhance water retention, and increase nutrient availability, thus promoting better root growth and reducing the impact of water and salinity stress on plants [6]. Biochar's ability to modify soil physico-chemical properties creates a favorable environment for plant resilience under adverse conditions [7]. Furthermore, biochar's porous structure can adsorb and retain salts, reducing their deleterious effects on plants and mitigating ion toxicity [8]. By enhancing the soil's capacity to buffer against environmental stressors, biochar has the potential to support sustainable agricultural practices under changing climatic conditions.

The aim of this study is to determine the tolerance of *vigna unguiculata* to water and salt stress under biochar use, exploring its role in improving plant performance in these challenging environments

2.   Materials and methods

2.1 Plant material
Vigna unguiculata or cowpea is an annual plant of the Fabaceae family. Indigenous to West Africa, cowpea is adapted to heat and tolerates, drought conditions, making it a valuable crop in arid and semi-arid regions [9]. It is rich in protein and is the main food legume in tropical Africa. In various parts of the world, it is also used as a cover crop and worm manure.
The variety used in the experiment is a local variety.

2.2 Experiment
The experiment was carried out in the field of the Universitatea de Stiintele Vietii "Regele Mihai I" in Timisoara - Romania from May to July 2023.
The soil used was neutral (pH 7.6), brown and it is dedicated for organic experimentation (without mineral fertilizer).
The experiment was set up in a completely randomised block design with four treatments and five replications.

The following treatments and their codifications were used during the experiment:

- Soil (C)
- Soil with biochar (5%) – (B)
- Soil with biochar (5%) + drought stress – (D)
- Soil with biochar (5%) + salinity stress – (S)

The level of stress applied during the experiment is shown in Table 1.
The salinity tress was applied once a week during each development phase. It was increased because the level applied do not affect plant physiology.
The drought stress was evaluated by the regular quantity of water that the plant need each week.

Table 1: Level of stress applied during different vegetative stade

Vegetation stade	Vegetative phase		Flowering phase
	13 (21 days after sowing)	16 (28 days after sowing)	59 (40 days after sowing)
Salinity stress (mM) Level of irrigation salinity [10]	250 Highly salinity	350 Very highly salinity	450 Very highly salinity
Drought stress %	67	50	22

2.3 Measurements
The parameters measured are: total chlorophyll using the SPAD 502 Plus KONICA MINOLTA chlorophyll meter, stomatal conductance using the SC-1 Decagon device leaf porometer and leaf area measured physically.
All measure was taken 4th days after stress application: d-25, d-33 and d-45.
For having replication, the measurement was made for total cholophyll and stomatal conductance with 5 leaves in each treatment.

2.4 Data processing
The results obtained were subjected to an analysis of variance (ANOVA) to determine the significant differences between the treatments followed by the PPDS test with a probability level of $P< 0.05$ using XLSTAT.

3.   Results and discussion
3.1 Impact of stresses on leaf area and fresh biomass
Table 2 shows the development of leaf area according to the different phases of the plant.

From the beginning of the flowering phase, the leaf coverage of B was much higher 162.61 cm² than 138.13 cm² for C. For S treatment, it was 95.88 cm², the plant do not increase as same as C and B treatments. And for D, the result showed a significant difference 55.98 cm² and ity is the less one in all treatments.

Table 2 : Leaf area cm² of cowpea plants

Treatments	Vegetative phase		Flowering phase
BBCH-Code	13	16	59
C	58.43±4.52	97.54±8.55	138.13±3.95 [b]
B	59.60±0.31	84.33±3.71	162.61±6.79 [b]
D	48.00±1.63	59.29±1.79	55.98±2.10 [a]
S	45.64±4.05	65.37±4.30	95.88±7.08 [b]

Numbers followed by the same letter are not significantly different at a probability of 0.05 for the LSD test.

For not damage plant, biomass was weight at the end of experimentation.
The results was shown in the table 3

Table 3: Fresh biomass weight at the end of experimentation

Treatments	Weight (g)
C	14.98±1.31 [b]
B	16.68±0.61 [b]
D	5.32±0.83 [a]
S	6.61±0.77 [a]

Numbers followed by the same letter are not significantly different at a probability of 0.05 for the LSD test.

Photo 1 : Fresh biomass of cowpea

For fresh biomass, the weight was similar than the leaf area coverage.
Vigna unguiculata can withstand salt content of 450 mM.
Salinity stress reduces root growth, impairing water and nutrient uptake, and leads to a significant decline in leaf area and fresh biomass, as the leaf surface is among the first to be affected. Biochar improves soil properties by enhancing water retention, nutrient availability, and microbial activity, thus alleviating osmotic stress. These enhancements promote better root development and preserve physiological growth under saline conditions.

Studies have shown that biochar-treated soils help maintain higher leaf area and fresh biomass compared to untreated controls [11].

3.2 Impact of stresses on the total chlorophyll content
As shown in Table 4, the applied salinity and water stresses had no effect on total chlorophyll.

Table 4: Total chlorophyll content of cowpea (μmol per m^2 leaf area)

Treatments	Vegetative phase		Flowering phase
BBCH-Code	13	16	59
C	59.23±4.9	60.20±5.7	60.95±8.4
B	59.40±7.4	58.68±4.9	60.08±4.6
D	58.95±5.3	60.20±4.8	57.73±7.2
S	56.43±14.4	57.48±2.1	65.85±15.8

No significant difference at a probability of 0.05

The 58-191 cowpea genotype did not react to salinity stresses of 100 mM on total chlorophyll [12]. This is identical to our results since the stresses did not have significant effects on total chlorophyll. Cowpea, as a plant adapted to live in arid conditions, is capable of spontaneously implementing this osmotic adjustment mechanism, so that the thermal optimum is not exceeded.

3.3 Impact of stress on stomatal conductance
A significant difference compared with the control was observed towards the beginning of the flowering stage for the biochar treatment (152.99 mmol/m^{2}s^1), whereas the S treatment had a value of 50.54 mmol/m^{2}s^1 with 450 mM of concentration. And compared to C, D was very suffering with 22.51 mmol/m^{2}s^1

Table 5: Changes in stomatal conductance in mmol/m^{2}s^1

Treatments	Vegetative phase		Flowering phase
BBCH-Code	13	16	59
C	160.70±1.62	115.02±7.18	59.96±3.69 [c]
B	147.67±7.56	86.25±0.17	152.99±6.57 [b]
D	140.83±4.52	80.95±4.14	22.51±0.95 [a]
S	160.35±10.1	117.08±5.09	50.54±1.63 [c]

Numbers followed by the same letter are not significantly different at a probability of 0.05 for the LSD test.

At advanced stages of drought stress, *vigna unguiculata* adopts a survival strategy by closing its stomata to conserve water, resulting in reduced stomatal conductance. While this mechanism helps stabilize cellular water content, it compromises gas exchange and photosynthesis, ultimately slowing down growth. Biochar has been shown to improve soil

properties by enhancing water retention and nutrient availability, which can facilitate leaf transpiration and mitigate some of the effects of drought stress.

However, under severe stress conditions like 22 % of watering, even biochar may not fully prevent the reduction in stomatal conductance or the slowdown in growth. These findings contrast with studies on bean crops by [13], where biochar application effectively attenuated stress effects, maintaining higher stomatal activity and growth. Such differences likely arise from variations in crop-specific stress tolerance mechanisms, environmental factors, and the physical or chemical properties of the biochar used. This underscores the need for tailored biochar applications and further research to optimize its benefits under varying stress levels [11,14].

4.   Conclusion

This study enabled us to determine some of the physiological responses of the *vigna unguiculata* plant to water and salinity stress. It is a tolerant plant that can be promoted in the face of climate change and with biochar use, it is more resistant. The results will be used to guide the development of other plants with nutritional value and also to reduce the amount of water consumed by agriculture. This study is a preliminary approach. However, it is still essential to confirm the results with more diversified and in-depth experiments.

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