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Original Article

Potential of coffee straw biochal as a substrate conditioner in seed lettuce and sorghum germination and vigority

Potencial do biocarvão de palha café como condicionador de substrato na germinação e vigor de sementes alface e sorgo

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Abstract

The use of residues from coffee production to obtain biochar is a sustainable approach, which aims to minimize the environmental impact of these materials. In this study, the effect of adding coffee straw biochar on the physiological quality of lettuce and sorghum seeds was investigated. Thus, the objective of this work was to study the effect of adding different concentrations of coffee biochar in the substrate composition on the physiological quality of lettuce (*Lactuca sativa*) and sorghum (*Sorghum bicolor*) seeds. The experimental design used was completely randomized, with five concentrations of biochar (0; 7.5; 15; 30 and 60%), conducted with four replications of 25 seeds. The use of biochar in the concentrations studied does not provide an increase in the average germination percentage and vigor of lettuce and sorghum seeds. The increase in the concentration of biochar caused less seed vigor, suggesting a toxic effect. For seed germination, there was no significant difference between lettuce and sorghum species, regardless of treatment. For the germination speed index, sorghum seeds have higher means, except for the treatment with the addition of 15% coffee straw biochar. Lettuce seeds have higher shoot length averages, except for treatment with 100% commercial substrate. The sorghum seeds have higher mean root length and dry mass than lettuce, regardless of the treatment.

Keywords: plant residues, sustainability, *coffea* sp.

Resumo

A utilização de resíduos da produção de café para a obtenção de biocarvão é uma abordagem sustentável, que visa minimizar o impacto ambiental desses materiais. Assim, o objetivo deste trabalho foi estudar o efeito da adição de diferentes concentrações de biocarvão de café na composição do substrato sobre a qualidade fisiológica de sementes de alface (*Lactuca sativa*) e sorgo (*Sorghum bicolor*). As variáveis analisadas foram: teor de água das sementes, porcentagem de germinação, índice de velocidade de germinação, comprimento da parte aérea, comprimento da raiz e massa seca das plântulas. O delineamento experimental utilizado foi inteiramente casualizado, com cinco concentrações de biocarvão (0; 7,5; 15; 30 e 60%), conduzido com quatro repetições de 25 sementes. A utilização do biocarvão nas concentrações estudadas não proporciona aumento na porcentagem de germinação e no vigor das sementes de alface e sorgo. O aumento da concentração de biocarvão causou menor vigor das sementes, sugerindo efeito tóxico. Para germinação de sementes, não houve diferença significativa entre as espécies de alface e sorgo, independente do tratamento. Para o índice de velocidade de germinação, as sementes de sorgo apresentam maiores médias, excetuando-se para o tratamento com adição de 15% de biocarvão de palha de café. As sementes de alface apresentam maiores médias de comprimento de parte aérea, excetuando-se para o tratamento com 100% de substrato comercial. As sementes de sorgo apresentam médias de comprimento de raiz e massa seca superiores às de alface, independentemente do tratamento.

Palavras-chave: resíduos vegetais, sustentabilidade, *coffea* sp.

1. Introduction

Coffee production plays a prominent role in the Brazilian trade balance, with significant volumes being traded internationally. In 2022 alone, grain exports reached the mark of 39.75 million 60 kg bags, with the United States and Germany as its main destinations. As a result, coffee is considered one of the most popular and consumed beverages worldwide (Brasil, 2023).

Consequently, both the production and consumption of coffee generate waste, such as the straw resulting from wet processing, in addition to the dregs after being used as

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Table 1. Elementary[1] C, H, N and O contents and C/N, H/C and O/C ratios of coffee straw biochars, produced under pyrolysis temperature of 350 °C.

Biochar	Elementary content (%)			O	C/N	H/C	O/C
	C	H	N				
350 °C	59.87	4.57	2.54	33.02	23.57	0.08	0.55

[1]Determined on a Perkin Elmer Series II 2400 Analyzer. O (%) =100-CHN.

a beverage. In order to minimize the impacts generated by these residues, studies have been carried out to verify the viability of its use in the production of biochar, which can later be reused in the, thus promoting greater sustainability in the production chain.

Biochar, is a product obtained through the pyrolysis of biomass of animal or vegetable origin, being characterized by its richness in carbon, high stability, well-developed mesoporous structure, wide specific surface area, considerable amount of mineral components and presence of functional groups on the surface, in addition to having a low cost (Lu et al., 2019; Dissanayake et al., 2020; Li et al., 2020; Shan et al., 2020).

Thus, biochar in agriculture has been used as a soil conditioner, acting to improve the chemical, physical and biological characteristics of the soil, in terms of physical properties, a positive impact on soil porosity, hydraulic conductivity and water retention capacity has been demonstrated (Herath et al., 2013). As for the chemical properties, there is the possibility of changing the soil pH and increasing the cation exchange capacity (Lima et al., 2016). With regard to biological properties, biochar acts on soil composition, diversity and microbial activity (Pan et al., 2019).

Research has been carried out to study the use of various residues, such as biochar from plant residues, sewage sludge, cotton waste and mustard straw, materials from animal production, among others, in the composition of substrates for the production of seedlings, mainly because it represents an alternative that reduces costs and minimizes the negative environmental impacts resulting from waste disposal (Medeiros et al., 2015; Zhang et al., 2017, 2019; Zhou et al., 2017; Ramlow et al., 2018; Freitas et al., 2023; Khatana et al., 2022).

In view of the above, studying the feasibility of using biochar from coffee production residues in the process of plant propagation is of great importance to explore a sustainable and promising alternative in agriculture, aimed at improving the efficiency of the substrate and promoting healthy and sustainable development. vigorous growth of the plants, as well as in the contribution to the reduction of the environmental impact caused by the inadequate disposal of these residues. Thus, the objective of this work was to study the effect of different concentrations of coffee biochar in the substrate composition on the morphophysiological quality of lettuce (*Lactuca sativa*) and sorghum (*Sorghum bicolor*) seeds.

2. Material and Methods

The experiment was conducted at the Seed Analysis Laboratory, at the Center for Agricultural Sciences and Engineering at the Federal University of Espírito Santo, in Alegre, ES, using Lactuca sativa and Sorghum bicolor seeds, and a commercial substrate with five different additions of coffee straw biochar at the pyrolysis temperature of 350 °C (Tables 1 and 2), in the substrate composition. The treatments were: T1 - Commercial substrate 100%; T2 - Commercial substrate + 7.5% biochar; T3 - Commercial substrate + 15% biochar; T4 - Commercial substrate + 30% biochar and; T5 - Commercial substrate + 60% biochar.

Table 2. Total levels of macro and micronutrients[1] present in coffee straw biochars, produced under a pyrolysis temperature of 350 °C.

Nutrient	350 °C
	---dag/kg---
P	0.20
K	4.46
Ca	1.67
Mg	0.32
S	0.22
	---mg/kg---
Cu	23.70
Fe	451.55
Zn	12.20
Mn	109.65
B	81.92

[1]Obtained by nitroperchloric digestion (EMBRAPA, 1997).

The analysis of the physiological quality of the seeds was performed using the following variables:

Seed water content: determined by the oven method, at 105 ± 3 °C, for 24 hours, according to the instructions in the Rules for Seed Analysis (Brasil, 2009), using three repetitions of 10 seeds for each culture.

Germination: seed asepsis was performed by immersion in 70% alcohol (v/v) for two minutes and in a 2% sodium hypochlorite solution (v/v) for three minutes, between one procedure and another, the seeds were washed in distilled water, in order to remove any residue of the chemicals used. It was carried out with four replications of 25 seeds for each treatment, sowing was carried out on the following treatments: (T1 - 100% Commercial substrate; T2 - Commercial substrate + 7.5% biochar; T3 - Commercial substrate + 15% biochar; T4 - Commercial substrate + 30% biochar and; T5 - Commercial substrate + 60% biochar), in a gerbox box containing 150 mL of the same, moistened daily, which were kept in a BOD-type germination chamber, regulated at an alternating temperature of 20-30 °C, without the presence of light. The evaluations were made after five and 14 days (lettuce) and four and 10 days (sorghum) of sowing, computing the percentage of normal seedlings (Brasil, 2009), and the results expressed in percentage of germination.

Germination speed index (GSI) - concomitantly with the germination test, being computed daily, up to the 14th day for lettuce and the 10th day for sorghum, the number of seeds that presented primary root protrusion equal to or greater than 2 mm (Maguire, 1992).

Shoot length (SL) - determined after the 14th day (lettuce) and 10th day (sorghum) of sowing, with the aid of a millimeter ruler, by measuring the length between the collar and the apex of the last leaf of ten seedlings and the result expressed in cm plant^{-1}.

Root length (RL) - determined after the 14th day (lettuce) and 10th day (sorghum) of sowing, with the aid of a millimeter ruler, measuring ten seedlings from the neck to the tip of the largest root and the results expressed in cm plant^{-1}.

Dry mass of seedlings (DM) - determined after the 14th day (lettuce) and 10th day (sorghum), using an analytical balance (0.0001 g). The seedlings were placed in Kraft paper bags, kept in a convection oven at 65 °C for 72 hours (constant mass) and the results expressed in g seedling^{-1}.

The experimental design used was completely randomized. For the quantitative factor, regression analysis was performed and for the qualitative factors, the averages were compared using the F test at a 5% level. All statistical analyzes were performed using the R software (R Core Team, 2023).

3. Results and Discussion

Seed germination and early seedling growth tests can be used to assess the beneficial and toxicological impacts of adding biochar on crop growth (Gascó et al., 2016). The germination data (G) of lettuce and sorghum seeds (eudicotyledonous and monocotyledonous, respectively) submitted to different treatments with coffee straw biochar (Table 3), did not differ from each other. However, there was a difference in seed vigor, analyzed by GSI in which only the treatment with the addition of 15% biochar (T3) did not differ between the two species. However, the other treatments (100% commercial substrate; 7.5%; 30% and 60% biochar) showed a significant difference, with sorghum seeds showing higher averages of GSI compared to lettuce seeds. The results corroborate those obtained by Uslu et al. (2020) in which, they observed differences in the vigor index for the different species of forage plants and biochar treatments adopted.

When analyzing the species separately (Figure 1), there was no significant difference between treatments, with an average germination percentage of 93%. Similar behavior was observed for sorghum seeds, although the mean germination percentage was 87%.

These results suggest that the impacts of biochar on germination range from inhibitory to stimulatory in nature, depending on the raw material studied, the pyrolysis temperature, the amount used and the plant species used, corroborating the statements by Zulfiqar et al. (2022) and with the results obtained from rice straw biochar particles on seed germination and seedling growth of tomato (Zhang et al., 2020). However, the use of corn cob biochar (CCB) had neutral to positive effects on maize seed germination (Ali et al., 2021).

Similar behavior to the germination variable was observed in Figure 2, when analyzing the germination

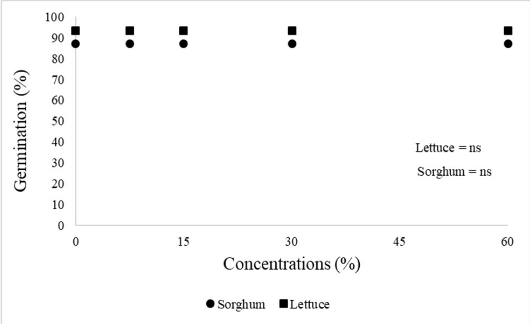

Figure 1. Seed germination lettuce and sorghum subjected to biochar of coffee straw. [ns]Not significant.

Table 3. Germination (G) and germination speed index (GSI) of seeds of lettuceand sorghum subjected to biochar of coffee straw at a pyrolysis temperature of 350 °C.

Treatments	Cultures			
	G (%)		GSI	
	Lettuce	Sorghum	Lettuce	Sorghum
T1	92^{ns}	92	4.276*	5.513
T2	94^{ns}	87	4.586*	5.306
T3	93^{ns}	82	4.432^{ns}	4.849
T4	94^{ns}	88	4.415*	5.135
T5	93^{ns}	86	4.249*	5.336

*Significant ($p<0.05$). [ns]Not significant by the F test, within each culture between treatments and variable. T1 - 100% Commercial substrate; T2 - Commercial substrate + 7.5% of biochar; T3 - Commercial substrate + 15% of biochar; T4 - Commercial substrate + 30% of biocharIt is; T5 - Commercial substrate + 60% of biochar).

speed index. In which, no significant difference was found between treatments in both species. For lettuce seeds, the mean GSI was 4.391, for sorghum seeds the mean was 5.228. The germination and GSI results for lettuce seeds were similar to those observed by Silva et al. (2019) in which there was no significant difference for these parameters, suggesting that the biochar used did not generate an initial imbalance in the retention of water and air, and, consequently, did not contribute to greater moisture retention in the porous structures of the biochar.

Regarding shoot length (SL), it was observed that only the treatment with 100% commercial substrate did not present a difference between species (lettuce and sorghum). In treatments with addition of 7.5; 15 and 30% of coffee straw biochar, lettuce seeds showed higher SL averages compared to sorghum seeds, with averages of 6.2; 6.2 and 5.6 cm, respectively. These higher SL averages of lettuce seedlings may be related to the high potassium content present in the coffee straw biochar (Table 2) and in parallel to the high requirement of this nutrient by the species, bearing in mind that in appropriate amounts, potassium plays several roles. essential functions in plants, such as: regulation of cell turgidity, activation of enzymes involved in respiration and photosynthesis, transport of carbohydrates, among others (Subbarao et al., 2017; Meure et al., 2018; Rengel et al., 2022). However, when the commercial substrate was added with

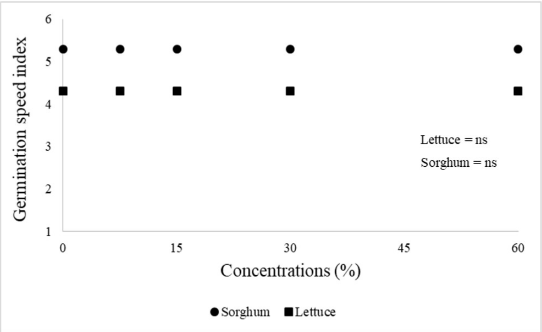

Figure 2. Germination index speed of seeds of lettuce and sorghum subjected to biochar of coffee straw. [ns]Not significant.

60% biochar, there was an inversion in the results. In this case, the sorghum seeds had a higher average SL (1.8 cm) compared to the lettuce seeds, which were evaluated as abnormal seedlings, due to the absence of roots (Table 4).

Considering root length (RL) (Table 4), significant differences were observed between species. Since the seedlings from sorghum seeds showed higher averages in all treatments (8.6; 6.3; 6.9; 3.5 and 1.4 cm, respectively), and as well as in the SL variable, when added 60% biochar, lettuce seedlings were abnormal.

Regarding the dry mass of seedlings from lettuce and sorghum seeds subjected to biochar, there was a significant difference between species. As for CR, the means of sorghum were higher than those of lettuce in all treatments (0.199; 0.217; 0.200; 0.123 and 0.100 g, respectively) (Table 4).

The average shoot length of seedlings from lettuce seeds submitted to treatment with 7.5% of biochar showed an increase when compared with the control, and from the treatment with 30% of biochar there was a decrease in the averages of shoot length. The increase may be associated with the ability of biochar to improve nutrient and water utilization by plants, improved soil pH, structure and water holding capacity, and changes in soil microbial dynamics (Agegnehu et al., 2017; Ali et al., 2017; Bohara et al., 2019).

However, for the length of the aerial part of the sorghum seedlings, there was a reduction in the averages from the seed treatments with biochar (Figure 3). This behavior may be associated with the presence of polycyclic aromatic hydrocarbons (PAHs) and terpenes, arising mainly from the pyrolysis process, which are potentially toxic compounds, already identified in other biochars (Sohi et al., 2009; Verheijen et al., 2010; Artiola et al., 2012).

When lettuce seeds were treated with 15% coffee straw biochar, there was an increase in root length averages, and from that point on, a decrease in averages was observed. According to Jabborova et al. (2021), the addition of biochar provided an increase in root length for the basil crop, which, in addition to effects on root length, also increased root surface area, volume and root diameter. However, additions above 5% of eucalyptus sawdust biochar in the substrate led to a drop in the root length of lettuce seedlings (Silva et al., 2019).

For the root length of seedlings derived from sorghum seeds, the results were similar to those reported for shoot

Table 4. Shoot length (SL), root length (RL) and dry mass (DM) of seedlings from seeds of lettuce and sorghum subjected to biochar of coffee straw at a pyrolysis temperature of 350 °C.

Treatments	Cultures					
	SL		RL		DM	
	Lettuce	Sorghum	Lettuce	Sorghum	Lettuce	Sorghum
T1	5.1[ns]	4.8	1.7*	8.6	0.001*	0.199
T2	6.2*	4.6	1.8*	6.3	0.015*	0.217
T3	6.2*	4.1	2.3*	6.9	0.014*	0.200
T4	5.6*	3.1	1.5*	3.5	0.009*	0.123
T5	0.0*	1.8	0.0*	1.4	0.000*	0.100

*Significant ($p<0.05$). [ns]Not significant by the F test, within each culture between treatments and Variable. T1 - 100% Commercial substrate; T2 - Commercial substrate + 7.5% of biochar; T3 - Commercial substrate + 15% of biochar; T4 - Commercial substrate + 30% of biocharIt is; T5 - Commercial substrate + 60% of biochar.

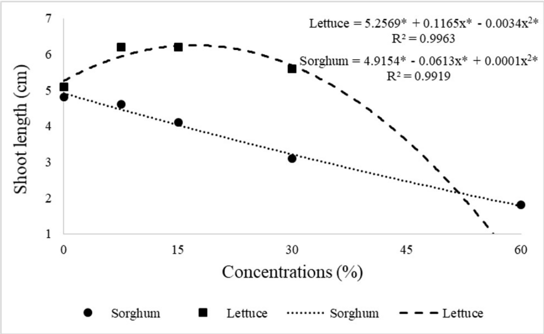

Figure 3. Shoot length (cm) of seedlings from seeds oflettuceand sorghum subjected to biochar of coffee straw. *Significant at the 5% probability level. R^2 = coefficient of determination of the regression fit.

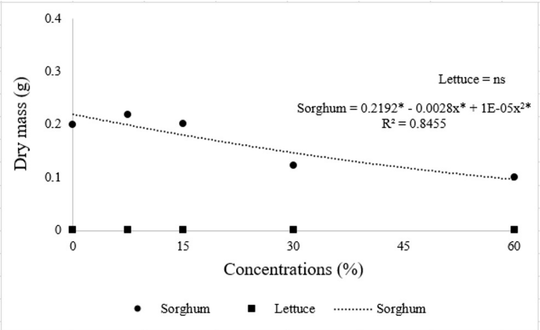

Figure 5. Dry mass (g) of seedlings from seeds oflettuceand sorghumsubjected to biocharof coffee straw. *Significant at the 5% probability level; nsNot significant. R^2 = coefficient of determination of the regression fit.

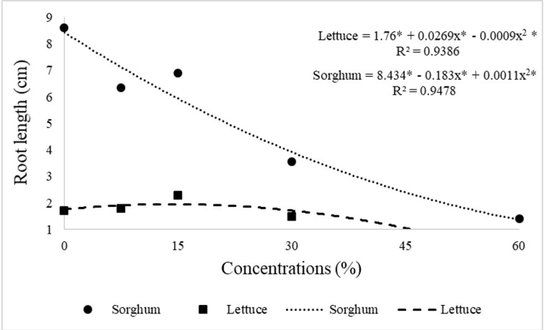

Figure 4. Root length (cm) of seedlings from seeds oflettuceand sorghum subjected to biochar of coffee straw. *Significant at the 5% probability level. R^2 = coefficient of determination of the regression fit.

length, that is, the greater the addition of biochar, the lower the average length of shoot and root, and there was a small increase in the mean root length when the seeds were submitted to a concentration of 15% (Figure 4). The negative effects of increasing the addition of biochar on the germination of lettuce and sorghum seeds may be related to a nutritional imbalance caused by excess organic matter or by modifying the adequate amount of micropores by biochar (Santos et al., 2010).

For data on seedling dry mass (Figure 5), there was no significant difference between treatments for lettuce seeds, with an average of 0.008 grams. A similar result was observed in soil correction with coffee grounds biochar, in which there was no difference when evaluating lettuce biomass (Christou et al., 2022). As for sorghum seeds, there was a small increase with the addition of 7.5 and 15% of biochar, and from 15% a decrease in the averages was observed. the occurrence of negative effects may be related to the decrease in the respiration rate of root cells, due to the increase in water retention in the substrate resulting from the use of high concentrations of biochar (Petter et al., 2012), while the smallest increments in production of sorghum biomass may be associated with increased pH nutrient retention capacity and soil moisture content. These changes can similarly increase the availability of nutrients for plants and, consequently, promote the accumulation of biomass (Scotti et al., 2015).

4. Conclusions

The use of biochar in the concentrations studied does not provide an increase in the average germination percentage and vigor of lettuce and sorghum seeds.

The increase in the concentration of biochar caused less seed vigor, suggesting a toxic effect.

For seed germination, there was no significant difference between lettuce and sorghum species, regardless of treatment.

For the germination speed index, the sorghum seeds have higher averages, except for the treatment with the addition of 15% of coffee straw biochar.

Lettuce seeds have higher shoot length averages, except for treatment with 100% commercial substrate.

The sorghum seeds have averages of root length and dry mass higher than that of lettuce, regardless of the treatment.

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