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Original Research Article

'Dedo-de-moça' pepper seedlings were produced using basic slag in alternative substrate

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ABSTRACT

Studies related to the use of steel mill slag have become essential, because of the possibility of its use as a component of substrates in the production of seedlings and because this use minimizes the risk of environmental contamination, resulting from inadequate disposal. Thus, the objective of this work was to evaluate the effect of increasing levels of steel slag in substrates composed of soil with tanned bovine manure and sand, on the growth variables and the quality of "Dedo-de-moça" pepper (*Capsicum baccatum* L.) seedlings. A randomized block design was used with five slag concentrations (0%, 2.5%, 5%, 10% and 20%) and four repetitions. Evaluations occurred at 55 days after sowing, consisting of counting the number of leaves, measuring plant height and collar diameter, quantifying the dry mass of leaves and roots and determining the Dickson Quality Index. Regression models were fitted ($P < 0.05$) to treatments with increasing levels of steel slag. The addition around 10% of slag to the substrate provided the highest values of growth variables, in seedlings of Dedo-de-moça pepper.

Keywords: *Capsicum baccatum* L; Steel Mill Residue; Substrate

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1. Introduction

Chili peppers are agronomically classified as oleraceous, belonging to the Solanaceae family, of the Capsicum genus. Among the best known and cultivated in Brazil are the chili peppers *Capsicum frutescens* L. Ruiz & Pav. (malagueta pepper) and *Capsicum baccatum* L. Ruíz & Pav. (Dedo-de-moça)[1]. Due to its high capacity to generate employment and income, especially for small producers, chili peppers of the genus Capsicum are positioned within Brazilian agriculture as crops of high socioeconomic importance.

The Dedo-de-moça pepper is commonly used in the process of making sauces, in medicinal use, due to the several components with pharmacological properties, and as ornamental plants, because of its dwarf shape and its fruits with different colors when ripened.

The success of the plants' performance in the field is directly linked to the quality of the seedlings, and the choice of substrate is a key factor for a satisfactory final result.

For Freitas *et al.*[2], the production system is highly dependent on the use of commercial substrates, making the production of seedlings in Brazil expensive. For this reason, alternative materials to commercial substrates have been sought, using agricultural and industrial waste in the composition of substrates, as a way to minimize production costs and promote higher quality seedlings. Moreover, Neves *et al.*[3] emphasize that the use of waste in the formulation of substrates has become a sustainable agricultural practice, because it seeks to minimize the environmental impact that would be caused by the inadequate disposal of these wastes.

Among the industrial waste generated in high quantities, and with potential for substrate components, steel mill slag stands out. According to Prezoti & Martins[4], steel mill slag can be considered important options, since it has soil acidity neutralizing compounds, such as silicates, and nutrients such as calcium, magnesium and phosphorus, among others. Prado & Natale[5] affirm that steel mill slag has a corrective and fertilizing effect, and can improve the fertility of soils that are used as substrates for seedling production, which are often of low fertility. Thus, the improvement of the chemical properties of the substrate may benefit plant nutrition and, consequently, seedling quality. The same authors reinforce that the response of the crop to the application of steel mill slag is dependent on the plant species and the type of steel mill waste, i.e., whether it is slag generated in blast furnace, steel mill or ferrochrome steel mills. According to Pinto Júnior *et al*.[6], steel mill slag has a CaO/SiO_2 ratio (around 4.6), higher than that of blast furnace slag, which according to Rossa & Portela[7] is 1.05 to 1.18, and that of ferrochrome slag, which according to Prado & Natale[5] is 0.9.

Caetano *et al*.[8] reinforce that, although slag contains heavy metals, the application of doses up to 10 t ha^{-1} to the soil does not result in levels higher than those considered critical for agriculture. Moreover, according to the same authors, the concentrations of heavy metals found in the dry matter of corn plants submitted to the application of the residue were lower than the critical toxicity levels of these elements, for most plants.

Because of these characteristics, the use of industrial slag as a component of substrates has been studied by some authors, such as Prado *et al*.[9], using steel slag for guava seedlings; Prado & Natale[5], using ferrochrome slag in the production of passion fruit seedlings and Santos *et al*.[10], using blast furnace slag in the production of paricá seedlings. As for the effect of this waste on the quality of Dedo-de-moça pepper seedlings, there is no study to substantiate its use as a substrate component. However, the hypothesis that steel mill slag is an important component of the substrate as a source of nutrients, especially calcium, in an adequate proportion is considered, which needs confirmation by experimentation. Thus, the objective of this work was to evaluate the effect of increasing levels of steel mill slag, in a substrate composed of soil with tanned bovine manure and sand, on the growth variables and the quality of pepper (*Capsicum baccatum* L.) seedlings.

Materials and methods

The experiment was implanted and conducted in the seedling production nursery of Ifes—Campus Santa Teresa, in the municipality of Santa Teresa, Espírito Santo (18°48’ S; 40°40’ W; 130 m altitude). The climate, according to Koppen’s classification, is Cwa (subtropical with dry winter), with an average annual temperature of 24.6 °C and annual precipitation ranging from 700 to 1200 mm. The air temperature and relative humidity during the experimental period ranged from 18.5 to 39.2 °C and 54.85 to 90.22%, respectively.

The nursery where the work was carried out was covered with propylene mesh, reducing solar radiation by 50%.

As substrate, a mixture of sterile soil (corrected with lime), tanned bovine manure and sand, in the proportion 3:1:1, completely homogenized, was used. The mixture was then sieved to eliminate clods that could harm the development of the seedlings.

The soil used is classified as Red-Yellow Latosol dystrophic, medium texture, taken from the B horizon. The tanned bovine manure was obtained from the cattle raising sector of the campus itself.

The slag used in the experiment was obtained as powder from a steel mill located in Vitória, ES.

As an experimental model, a randomized block design was adopted, with five increasing levels of steel slag (0%, 2.5%, 5%, 10% and 20%), added to a substrate composed of a mixture of soil, manure and sand (3:1:1), based on volume, with four repetitions, with 25 plants each, totaling 500 plants. Five plants were considered useful for each experimental unit, resulting in the evaluation of 20 plants per treatment.

Homogeneous samples of the substrates with the respective levels of steel slag (treatments) were collected and sent to the soil analysis laboratory of the Instituto Federal do Espírito Santo—Itapina campus, for the determination of the chemical attributes, presented in **Table 1**.

The seedling production system was in suspended trays, placed on masonry benches, with 500 mL tubes. The addition of slag concentrations to the substrate occurred seven days before sowing, which was done at a density of one seed per tube at a depth of 1.0 cm.

The seeds used were from the Capsicum genus, species *Capsicum baccatum* var. *pendulum* (Wild) Eshbaugh, known as Dedo-de-moça.

Irrigation was done manually, three to five times a day. No pesticides were applied, nor was any other correction process carried out on the substrates.

Evaluations occurred at 55 days after sowing, during December 2016 and January 2017, consisting of counting the number of leaves, measuring plant height and collar diameter, quantifying the dry masses of leaves and roots of the plant, and determining the Dickson Quality Index (DQI).

To obtain the height of the aerial part, a millimeter ruler was used, measuring from the base of the stem to the apical bud that gave rise to the last leaf. The diameter of the collar was obtained with a precision digital pachymeter. The dry mass of the aerial part was obtained by cutting the seedlings at the height of the collar. To obtain root dry mass, the roots were carefully washed in running water, over a sieve with an opening of 5 mm. Subsequently, the materials were placed in paper bags and placed in an oven with forced air circulation at 65 °C for 72 hours. After that, the materials were weighed on an electronic balance with 0.01 g precision. To determine the DQI, the method proposed by Dickson *et al*.[11] was used, using Equation 1.

$$IQD = \frac{MST\,(\mathrm{g})}{(AP\,(\mathrm{cm}) / DC\,(\mathrm{mm})) + (MSF\,(\mathrm{g}) / MSR\,(\mathrm{g}))} \quad (1)$$

Where: DQI = Dickson Quality Index, TSS = Total dry matter mass (g), AP = Plant height (cm), CD = Collar diameter (mm), SFM = Leaf dry mass (g) and SRM = Root dry mass (g).

All variables evaluated were subjected to normality (Lilliefors) and homoscedasticity (Barttlet) tests, assumptions for the validation of their analysis of variance. In case of significant effects ($P < 0.05$), for comparisons between treatments T1, T2, T3, T4 and T5, related to the level of slag, their fits in regression models by the method of orthogonal polynomials were adopted. For all procedures an "á" equal to 0.05 was adopted.

Table 1. Chemical analysis of the substrates used in the different treatments for producing seedlings of "Dedo-de- moça" pepper plants

Treatment	pH in water	M.O.	P rem	P	K	Ca	Mg	H+Al	S.B.	V
		g dm^{-3}	mg L^{-1}		mg·dm^{-3}			mmol$_c$ ·dm^{-3}		%
T1 (0% Slag)	6.9	23.8	35	377	1,257	54.5	14.1	9	100.8	91.8
T2 (2.5% Slag)	7.1	22.8	34	328	1,330	53.8	21.1	7	108.9	94
T3 (5% Slag)	7.2	21.3	34	205	1,225	62.5	14.5	7.5	109.1	93.6
T4 (10% Slag)	7.4	24	34	81	1,198	65.1	12.9	8	108.6	93.1
T5 (20% Slag)	7.5	20.7	34	19	1,101	54.7	21.9	5.5	104.8	95

* Hydrogen Potential (pH) 1:2.5; Organic Matter (M.O.), oxidized by potassium dichromate and sulfuric acid; Remaining Phosphorus (P rem), present in the solution at equilibrium, obtained with $CaCl_2$; Phosphorus (P) and Potassium (K), extracted by Mehlich; Calcium (Ca) and Magnesium (Mg), extracted by KCl; Potential Acidity (H + Al), extracted by calcium acetate; Base Sum (S.B.) and Saturation by bases (V).

2. Results and discussion

Figures 1(a)–Figure 1(f) show the height of the aerial part, the number of leaves, the diameter of the collar, the root dry matter, the leaf dry matter, and the Dickson Quality Index, respectively, in response to the addition of increasing levels of steel slag in the composition of the substrates.

According to **Figure 1(a)**, plant height increased significantly with the increase of slag, up to a concentration of 9.62%, providing a maximum height of 15.14 cm. The variable number of leaves also increased with the increase of slag, up to a concentration of 14.23%, providing the maximum value of 9.07 units (**Figure 1(b)**). For the collar diameter, the increase of slag in the substrate, up to a concentration of 8.8%, provided the maximum value of 2.69 mm (**Figure 1(c)**). For the variables root dry matter (**Figure 1(d)**) and leaf dry matter (**Figure 1(e)**), there was an increase until concentrations of 10 and 9.2%, providing maximum values of 0.131 g and 0.426 g, respectively.

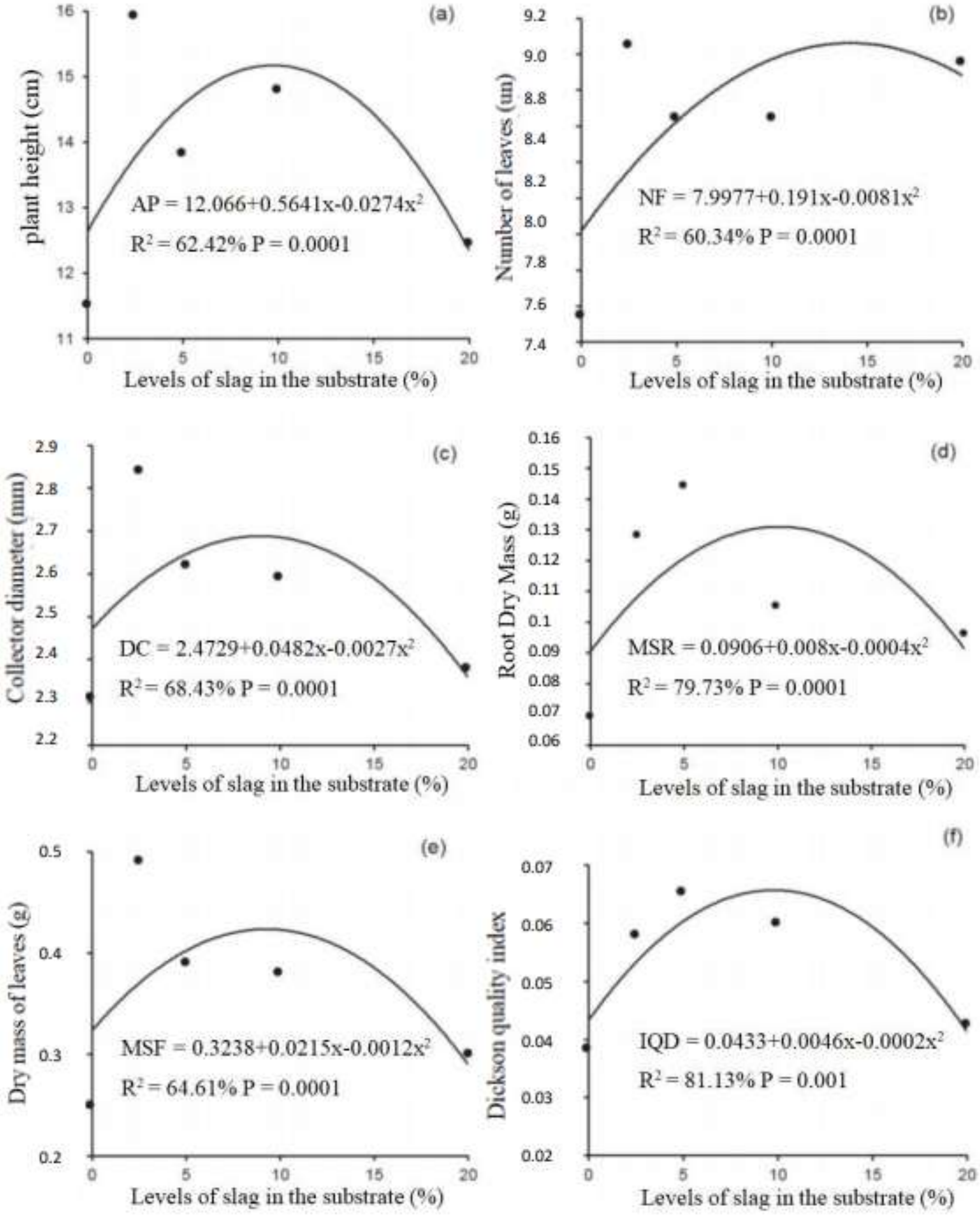

Figure 1. Plant height **(a)**, number of leaves **(b)**, neck diameter **(c)**, root dry mass **(d)**, leaf dry mass **(e)** and Dickson quality index **(f)**, as a function of substrates with different levels of steel slag, at 55 days after sowing.

According to Marana *et al.*[12], to avoid distortions arising from excess nitrogen, for example, or leaf growth to the detriment of the root system, quality indices, which are relationships between growth parameters. For this reason, the DQI stands out as one of the most used indices to evaluate the quality of seedlings, since it takes into account the production of dry matter of the aboveground part, roots and total, height and collar diameter of the plants[11]. According to **Figure 1(f)**, it is observed that the increment of slag in the substrate provided - increasing values of DQI in Dedo-de-moça pepper seedlings, reaching the maximum value (0.065) when 11.5% slag was used.

In general, it was observed that all variables increased with the increase of slag, up to concentrations around 10% (8.8 to 14.23%). This greater development of the seedlings in this range may be associated with the improvement of the root environment, with the neutralization of the acidity of the substrate and with the increase of Ca and Mg, as well as with the availability of adequate phosphorus, still present in this range (**Table 1**).

Even though the pH of the soil was close to neutral for the treatment that did not receive the addition of slag, the addition of this by-product increased the pH of the substrate to values higher than 7.0. Under these conditions, the reduction of soil acidity and the increase in Ca levels may have contributed to the greater development of the plants in terms of the variables evaluated. It is important to emphasize that, even though the pH range between 6.0 and 6.5 is commonly adopted as ideal, according to Raj[13] there is a great variability in the behavior of plant species in relation to soil pH and the effects of acidity and alkalinity, which makes it difficult to establish an adequate pH range for all crops. Furthermore, the availability of phosphorus, nitrogen, sulfur and boron remains high up to pH 7.3, while the availability of anionic micronutrients, especially molybdenum and chlorine, increases with increasing pH[14]. However, for cationic micronutrients, such as iron, copper, manganese, and zinc, availability to plants is reduced with increasing pH. For this reason, the increase in soil pH with the application of steel slag, even reaching values slightly above 7.0, may have contributed to the better development of the Dedo-de-moça pepper.

At higher concentrations of slag, there was a decreasing effect on the growth variables and on the quality of the seedlings of Dedo-de-moça chili pepper. This fact could be associated with the decrease in labile phosphorus in substrates whose treatments contained higher concentrations of steel slag (**Table 1**).

The importance of phosphorus for the development of seedlings has been highlighted by several authors[15–18]. According to Brasil & Nascimento[15], phosphorus is very important for the initial growth of plants because it acts in the process of storage and transfer of energy, being directly involved in the active absorption of nutrients. In a study of papaya seedlings, Saraiva *et al*.[17] showed that the positive effect of phosphorus increases the dry matter of the papaya roots, which should be reflected in a greater capacity for nutrient uptake, thanks to greater root development. David *et al*.[16] reported that higher doses of phosphorus provided conditions for the plant to absorb a greater amount of other nutrients, reflecting positively in greater height and dry matter production, of yellow passion fruit. Silva *et al*.[18] concluded that doses of 1.8, 2.70, 3.14 and 3.60 kg per container of the natural reactive phosphorus resulted in yellow passion fruit seedlings with greater development of aerial part length, root length, total plant length, stem diameter, aerial wet mass and root wet mass. Thus, it is believed that the decrease in labile phosphorus in the substrates with the higher concentrations of slag may have impaired the development of the Dandelion pepper seedlings.

According to **Table 1**, there was an increase in pH in response to the increasing doses of slag, indicating that steel slag acts as a soil acidity corrector, thus favoring, within certain pH limits, greater availability of macro- and micronutrients for the plants. However, in substrates with pH close to neutrality, as used in this work (**Table 1**), the addition of slag promoted pH elevation, causing the availability of P to be compromised.

The elevation of pH, above certain limits, can contribute to the reduction of P availability for plants. With the elevation of pH, there is an increase in the density of negative charges in the colloids, especially minerals, caused by the effect of acidity on the pH-dependent charges of the soil. With this, there is less density of positive charges in the colloids[19], which could mean less adsorption of phosphates and greater permanence of P in the soil solution, available to plants. However, when the reduction of the density of positive charges and the permanence of P in solution is accompanied by an increase in pH above 7.0 and, especially, with the presence of Ca in the soil solution, there may be a significant reduction in the availability of P to plants, because of the precipitation of phosphates. According to Sample *et al*.[20], this phenomenon occurs by the chemical bonding of P and Ca, forming tricalcium phosphate, in neutral or alkaline soils, giving rise to poorly soluble compounds, which is called "retrogradation" by Malavolta[21]. It is important to mention that, in this case, the unavailability of P remains, as long as the pH conditions are unfavorable. With soil acidification, these P-Ca compounds become more soluble and the P is available again, with some restrictions for the plants in the soil solution.

Thus, the use of steel mill slag can be an alternative for reducing seedling production costs, minimizing the impacts generated by the inadequate disposal of this waste by the steel industry.

4. Conclusion

The addition of around 10% slag to the substrate gave the best results in growth and quality in Dedo-de-moça pepper seedlings.

Conflict of interest

The authors declare that they have no conflict of interest.

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