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Tannery Sludge Added in Commercial Substrate for *Capsicum baccatum* Pepper Seedlings Production

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Abstract

Among the most used inputs in the seedling production stage, substrate has a higher cost when compared to fertilizers, trays and fungicides. The use of residues in addition to commercial substrates, reduces production costs and promotes greater sustainability in the agricultural and industrial production process. The objective of this study was to evaluate the tannery sludge added to commercial substrate in *Capsicum baccatum* pepper seedlings production, as well as to identify better proportions of the substrate composition integrated with tannery sludge for this seedling. Pepper seedlings were evaluated growing in substrates with eight different compositions of tannery sludge (0%, 10%, 20%, 30%, 40%, 50%, 60% and 80%) in commercial substrates. A randomized block design with four replications was used. Plant height, stem diameter, crown diameter, dry matter of shoot and roots were evaluated, and Dickson quality index was obtained. The linear models were predominantly the most significant to explain the developmental response of the seedlings when the tannery sludge was added in the substrate. It was found that alternative substrate can be used in a proportion of 80% of tannery sludge and 20% of commercial substrate and contribute in *Capsicum baccatum* pepper seedlings production with greater vigor, besides decreasing the cost of these substrates.

Keywords: residues, olericulture, "*dedo-de-moça*", sustainable agriculture

1. Introduction

Pepper belongs to the genus *Capsicum* and is considered a vegetable widely appreciated as the seasoning and it has as a characteristic some species, fruits with high pungency, resulting in capsaicin production (Kehie et al., 2016). Like other vegetables, the cultivation of peppers is one of the activities with the potential to generate income between small and medium farmers, and can be marketed *in natura*, in the jelly form, as conserves and sauces, and in the form of paprika (Signorini et al., 2013).

Also, just like any other olericulture crop, the most important production stage is the seedling stage that ensures quality and successful production in the field (Oliveira et al., 2015). Therefore, the use of quality inputs, such as seeds, substrate, greenhouse structure, adequate irrigation, among others is of utmost importance to obtain seedlings with high vigor, to be grown in the field.

While investment in quality inputs reduce the risk of production losses, may be you could say excessive expenditure on the inputs reduces profitability. The most used input at the seedling stage is the commercial substrate due to its high nutrient content and sufficient organic matter levels that promotes its usage by olericulture producers (Sediyama et al., 2014). Therefore, the acquisition of these substrates is one of the factors that most increase the production cost.

Since there is a high cost involved in the use of the commercial substrates, there is need to explore other alternatives like agricultural residues that can be processed to substitute the commercial substrates or used as a complement. (Almeida al., 2017; Berrili et al., 2015; Berilli et al., 2018a; Mota et al., 2018; Chagas et al., 2019). This alternative reduces the seedling production costs, and also generates greater sustainability of agricultural and industrial activities that generate waste, which are often discarded in landfills or improper areas, causing degradation to the environment (Alves & Barbosa, 2013).

Among the industrial activities that generate income in Brazil, the tanning processing is one of the worrisome activities, due to generating waste. Although this activity generates significant profits, contributing to the economic and social development of the country, it has been a concern mainly for the significant production of residues/effluents that are produced during the bovine leather tanning process (Sales et al., 2018a). For this material to be discarded, it is often necessary for the company to rent spaces in landfills, making the production process even more costly.

Hence, searching alternative ways to use residues from animal leather processing, as well as the possibility of its use in substrates for seedlings production can reduce the production costs in vegetable seedlings and leather processing (Silva Júnior et al., 2014). Therefore, it is expected that tannery sludge added in substrates for seedling production will favor the development of the seedlings and thus reduce the production cost.

The objective of this study was to evaluate the using tannery sludge in commercial substrate in *Capsicum baccatum* pepper seedlings production and to identify the best proportions of substrate composition for this production.

2. Material and Methods

The study was carried out at the seedling green house in Federal Institute of Education, Science and Technology of Espírito Santo-IFES, *Campus Itapina* (IFES-*Campus Itapina*), located at Rod. BR 259, Zona Rural de Colatina, Espírito Santo, Brazil. The experiment was conducted from March to May 2014, being used a sombrite with 50% of block of luminosity, endowed with the system of irrigation by automatic micro sprinkler keeping the seedlings always near the field capacity. We evaluated the development of UENF 1417 pepper seedlings from seeds. That genotype belongs to the species *Capsicum baccatum* var. *pendulum*, being popularly known as "*dedo-de-moça*".

A randomized block design with four replications and eight treatments were used, and the experimental unit had 10 seedlings. The seedlings were grown in polypropylene trays containing 128 cells. For each plot, three cell rows were prepared, and the seedlings of the central row were evaluated. Between the plots was left a cell row to avoid contamination of the substrates during the cultivation of the seedlings. The treatments differered as to the proportions of tannery sludge added to commercial Bioplant® substrate (Table 1).

The analyses of the agrometeorological favorability of mildew and *B. cinerea* occurrence were simulated through the already established models that use the temperature in the wet period and the leaf wetness duration (LWD) as input variables. The meteorological data used covers a period of 10 years (from 2007 to 2016) obtained through the automatic meteorological station of the National Institute of Meteorology located in Santa Teresa, state of Espírito Santo, Brazil and the mean of the climatic variables used can be seen in Table 1.

Table 1. Different substrates composition (treatments) used in *Capsicum baccatum* pepper seedling production

Treatment	Substrate Composition
0	100% Commercial Substrate
10	90% Commercial Substrate + 10% Tannery Sludge
20	80% Commercial Substrate + 20% Tannery Sludge
30	70% Commercial Substrate + 30% Tannery Sludge
40	60% Commercial Substrate + 40% Tannery Sludge
50	50% Commercial Substrate + 50% Tannery Sludge
60	40% Commercial Substrate + 60% Tannery Sludge
80	20% Commercial Substrate + 80% Tannery Sludge

The description of the tannery slurry and the commercial substrate used in the preparation of the substrates are described in Table 2 and 3, respectively.

Table 2. Chemical characteristics of tannery sludge used in the preparation of substrates for *Capsicum baccatum* pepper seedling production

TOM¹	COM²	OC	N	P	K	Ca
------------	------------	------------	g dm^{-3}	------------	------------	------------
293.1	110.2	61.2	17.3	7.6	0. 6	230.2
Mg	S	IC	Cr	Na	B	
------------	------------	------------	g dm^{-3}	------------	------------	
21.3	13.2	61.2	40.0	8.0	0.28	

Note. TOM[1] = total organic matter; COM[2] = compostable organic matter; OC = organic carbon; N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; IC = inorganic carbon; Cr = chromium; Na = sodium; and B = boron.

Table 3. Chemical characteristics of the commercial Bioplant® substrate used in the preparation of substrates for *Capsicum baccatum* pepper seedling production

pH*	N	P	K	Ca	TOC	OM	C/N
	------------	------------	------------	g dm^{-3}	------------	------------	------------
5.62	6.2	15.5	4.4	18.4	210	522.1	33.9

Note. * Hydrogenation potential (pH) in $CaCl_2$ ($CaCl_2$ pH).

N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; TOC = total organic carbon; OM = organic matter; C/N = carbon/nitrogen ratio.

Two seeds were sown per cell and the seedlings were thinned 20 days after sowing in order to produce only one seed per cell. At 64 days after sowing, the seedlings were evaluated, and data were obtained from the following variables: plant height (PH), in cm; stem diameter (SD), in mm; crown diameter (CD), in mm; leaf area (LA), in cm²; dry shoot mass (DSM), in grams (g); and dry root mass (DRM), in grams (g). For the evaluation of DSM and DRM, after measuring the other variables, the seedlings were deposited in paper bags which were placed in a forced ventilation oven at 105 °C for 24 hours for subsequent measurement.

After the data was collected, the quality index of the seedlings was calculated by the Dickson quality index (DQI), adapted according to the methodology proposed by Dickson et al. (1960), respecting the equation:

$$DQI = \frac{TDM}{\left(\frac{PH}{SD}\right) + \left(\frac{DSM}{DRM}\right)} \tag{1}$$

where, TDM = total dry mass (DSM+DRM); PH = plant height (cm); SD = stem diameter (mm); DSM = shoot dry mass (g), and; DRM = dry root mass (g).

To identify a significant response from the seedlings to the tannery sludge added in the substrate, since they are quantitative effect, the Shapiro-Wilk normality test was performed at 5% probability ($p < 0.05$). Subsequently the data were submitted the analysis of regression variance for the linear and quadratic models. After the responses were significant, the coefficients of response equations already adjusted were obtained and the average values for each treatment were plotted in the dispersion graphs. Statistical analysis was performed using the open source software R (R Core Team, 2014).

3. Results and Discussion

Data from chemical analysis of tannery sludge indicated the presence of total organic matter (293.1 g dm^{-3}) and calcium (230.2 g dm^{-3}) in a higher percentage which is important for the formation of substrates for quality seedling production (Table 2). The analysis of variance of the models indicated that mainly the linear models, with the exception of the leaf area, were significant to explain the response to the tannery sludge in the substrate (Table 4).

Table 4. Analysis of variance and regression model variance for the pepper seedlings response to commercial substrates with different proportions of tannery sludge

Variable	$QM_{Treatment}$	Model	QM_{Model}
PH	167.502 *	Linear	1056.4790 *
SD	0.11543 *	Linear	0.7291 *
CD	250.753 *	Linear	1595.8930 *
LA	3.55160 *	Quadratic	18.6000 *
DSM	0.00157 *	Linear	0.0099 *
RDM	0.00050 *	Linear	0.0028 *
DQI	0.28474^{ns}	-	-

Note. *significant at the significance level of 5% according to the F test ($p < 0.05$); ns = not significant. PH-Plant height, SD-stem diameter, CD-crown diameter, LA-leaf area, DSM-dry shoot mass, DRM-dry root mass and DQI-Dickson quality index.

This findings are in agreement with Almeida et al. (2017) that addition of tannery sludge to a commercial substrate in *Capsicum chinense* seedlings, gave significant plant responses. In addition, the responses observed can be explained by the linear regression model, with the exception of the leaf area. The dispersion graphs of the averages show that there was a positive and direct response of the plants in to tannery sludge in the substrate, for the variables of stem diameter, plant height and crown diameter (Figures 1B, 1C and 1D).

By the estimation equation, it was possible to observe that the highest proportion of sludge used in this experiment (80%) provided gains of 18.21 cm for plant height, 0.47 mm for stem diameter and 22.77 cm for crown diameter. Tannery sludge is rich in several important nutrients for plants, notably for the amount of nitrogen, which is an essential element needed in greater quantity, capable of directly interfering with the plant growth (Sales et al., 2018a; Berilli et al., 2019), participating directly in the formation of proteins and enzymes, chlorophyll etc. Similarly, Sales et al. (2018b) identified gains for the same characteristics evaluated in this work for passion fruit seedlings with the addition of up to 50% of tannery sludge in the substrate.

In relation to the leaf area (Figure 1A), the estimated value obtained with the addition of 80% of tannery sludge in the substrate was 2.5 cm². The leaf area is a fundamental component for plants, since the larger is the leaf area, the greater the light uptake by the plant and the greater the production of metabolic energy, which will be responsible for the maintenance of plant metabolism and growth, as well as in determining the productivity of the plant (Koester et al., 2014; Sales et al., 2017).

Sales et al. (2018c) studying chlorophyll content in *Schinus terebinthifolius* Raddi seedlings cultivated in different substrates, showed that the addition of tannery sludge in the substrate positively favors chlorophyll content, as well as other organic materials added in other compounds. The higher organic matter content and nutrients of these substrates may result in higher chlorophyll production and cellular structures, resulting in a larger leaf area (Sales et al., 2017).

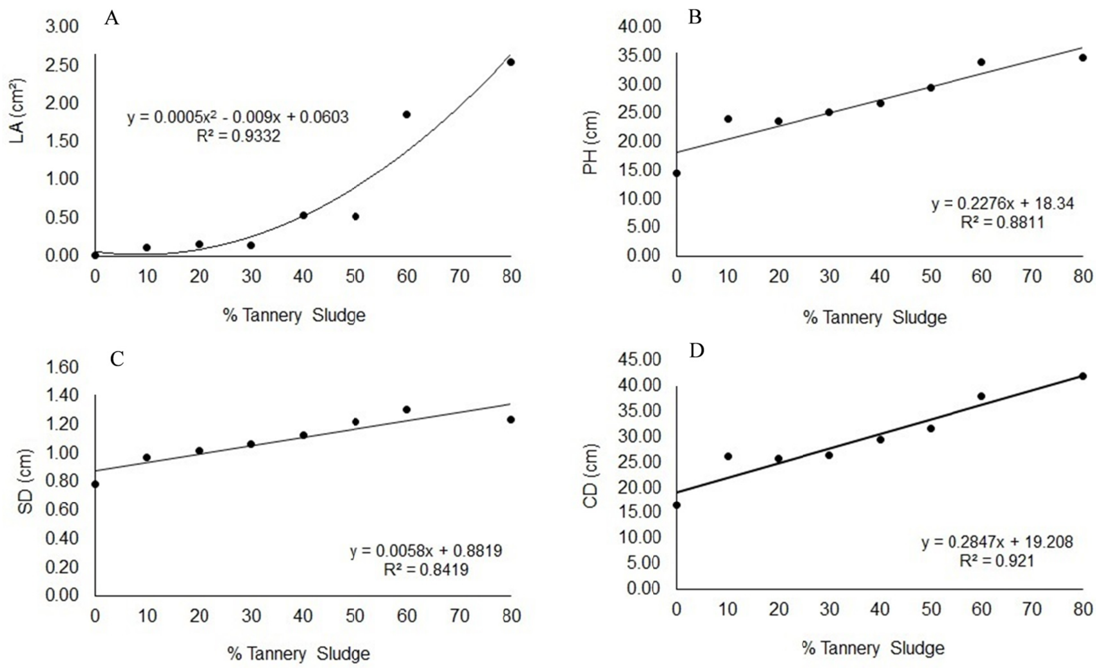

Figure 1. Dispersion graphs between agronomic characters: A = leaf area (LA), B = plant height (PH), C = stem diameter (SD) and D = crown diameter (CD) of *Capsicum baccatum* pepper seedlings, due to different proportions of tannery sludge added to the commercial substrate

The values of root and shoot dry mass (Figures 2A and 2B) show that the addition of tannery sludge in the substrate favors the incorporation of carbon. Once the leaf area gain was favored (Figure 1D), the plant presented a greater gain of photoassimilates, and consequently, a greater gain of root and shoot dry mass. With contrasting results, Berilli et al. (2014) studying tannery sludge in substrates for coffee seedlings production, identified that higher values of dry mass could be obtained in substrates with 20 to 30% of tannery sludge, however, according to the authors, resulted in seedling death. This may have occurred because they are different species, in addition, each batch of the residue contains a different composition, in which the levels of chromium and sodium, which are normally raised in the tannery, will vary.

The same fact that was not observed in this study, with good seedling growth for all the doses of sludge. It is worth emphasizing that this residue should be carefully used, since the characteristics of each lot or the different tanneries distributed throughout the country may vary and influence concentrations of existing beneficial or toxic elements in the process of tanning, thus affecting its use as fertilizer (Berilli et al., 2018b). Therefore, it is extremely important to know the concentrations of the elements through chemical analysis, since these elements present in the sludge can alter the characteristics of the development and the physiological characteristics, since there may be an accumulation of chromium in their tissues and also deleterious effects from the sodium (Berilli et al., 2015; Quartezani et al., 2018a, 2018b).

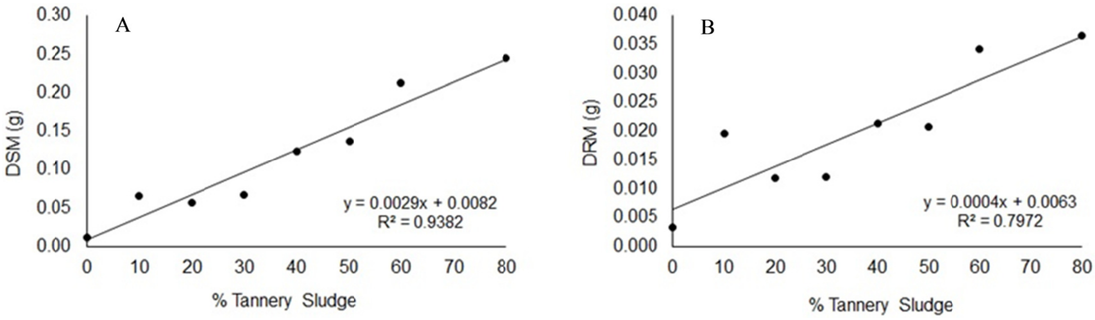

Figure 2. Dispersion graphs between agronomic characters: A = dry shoot mass (DSM) and B = dry root mass (DRM) of *Capsicum baccatum* pepper seedlings, due to different proportions of tannery sludge added to the commercial substrate

Considering the variables in general, the results indicate that doses from 10% guarantee increasing gains. The limit dose (80%) of tannery sludge added to the substrate favored the development of pepper seedlings. These results differ from Almeida et al. (2017), in which doses above 70% showed a decrease in the development of *Capsicum chinense* seedlings.

Such differences in the optimal doses for peppers, can be related to the genetic nature of the material used, since different genotypes may have different responses to environmental stimuli. Another factor, can be the difference in the nutrient content of different lots of residue used, considering that the interaction of the substrate can occur in different ways with the elements present in the tannery sludge, as a function of its composition (Quadro et al., 2018).

The R^2 values obtained indicate that there is a satisfactory representation of the equations to predict plant growth in relation to the addition of sludge in the substrate. The lowest value of representation ($R^2 = 0.79$), although still satisfactory was observed for dry root mass (Figure 2A).

By the estimation equation, it was possible to observe that the tannery sludge in the commercial substrate in the proportion of 80% of sludge and 20% of substrate resulted in an increase of 99% in plant height; >1000% in leaf area; 52% for stem diameter; 118% for crown diameter; 507% for dry root mass; >1000% dry shoot mass; in relation to the pure commercial substrate.

Finally, besides quality studies, due to food safety concerns, studies may also be carried out on chrome content in fruits, although it is already known that there is a tendency of accumulation in a smaller quantity in fruits. Nunes et al. (2018) studied the of chromium contents absorbed by sweet pepper fruits (*Capsicum annuum* L.) cultivated in substrate based on tannery sludge, identified that although there was presence of chromium in the fruits, these contents remained constant and did not reach values risk to health and food safety. It is also worth mentioning that the consumption of foods with certain levels of chromium is stimulated, mainly in the diet of athletes (Silva, 2014).

4. Conclusion

The addition of tannery sludge to commercial substrate promotes better development of *Capsicum baccatum* pepper seedlings, making it a good alternative to reduce production costs and possibly increase productivity.

The use of 80% of tannery sludge to 20% of commercial substrate presented significant gains and can be used in *Capsicum baccatum* pepper seedlings production.

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