

Reuse of agricultural waste as an alternative substrate in the production of eggplant (*Solanum melongena* L.) seedlings

Reutilización de residuos agrícolas como sustrato alternativo en la producción de plántulas de berenjena (*Solanum melongena* L.)

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ABSTRACT

Seedling formation is one of the most important phases for the eggplant crop cycle. One of the decisive factors for obtaining quality seedlings and the consequent increase in productivity is the type of substrate used. The objective of this research was to evaluate the growth of eggplant seedlings grown in alternative substrates with increasing levels of “moinha” (residue from the coffee dry milling process) replacing the commercial substrate. The experiment was carried out in a completely randomized design, with six treatments and ten replicates. The treatments were: T1: commercial substrate (control); T2: 0% moinha (MO) + 40% burnt rice husk (BRH) + 15% coconut fiber (CF) + 5% eggshell (ES) + 40% commercial substrate (CS); T3: 10% MO + 40% BRH + 15% CF + 5% ES + 30% CS; T4: 20% MO + 40% BRH + 15% CF + 5% ES + 20% CS; T5: 30% MO + 40% BRH + 15% CF + 5% ES + 10% CS; T6: 40% MO + 40% BRH + 15% CF + 5% ES + 0% CS. The electrical conductivity of the substrates and the seedling total dry mass, plant height and stem diameter were evaluated. It is recommended to use the substrate containing 20% MO + 40% BRH + 15% CF + 5% ES + 20% CS.

Key words: growth, moinha, *Solanum melongena*, seedling quality, horticulture.

RESUMEN

La formación de plántulas es una de las fases más importantes para el ciclo de cultivo de la berenjena. El tipo de sustrato utilizado es uno de los factores decisivos para obtener plántulas de calidad y el consiguiente aumento de la productividad. El objetivo de este estudio fue evaluar el crecimiento de las plántulas de berenjena cultivadas en sustratos alternativos con niveles crecientes de “moinha” (residuo del proceso de molienda en seco de café), en sustitución del sustrato comercial. El experimento se realizó en un diseño completamente al azar, con seis tratamientos y diez repeticiones. Los tratamientos fueron: T1: sustrato comercial (control); T2: 0% de moinha (MO) + 40% de cáscara de arroz quemada (CAQ) + 15% de fibra de coco (FC) + 5% de cáscara de huevo (CH) + 40% de sustrato comercial (SC); T3: 10% MO + 40% CAQ + 15% FC + 5% CH + 30% SC; T4: 20% MO + 40% CAQ + 15% FC + 5% CH + 20% SC; T5: 30% MO + 40% CAQ + 15% FC + 5% CH + 10% SC; T6: 40% MO + 40% CAQ + 15% FC + 5% CH + 0% SC. Se evaluó la conductividad eléctrica de los sustratos y la masa seca total de las plántulas, la altura de la planta y el diámetro del tallo. Se recomienda utilizar el sustrato que contiene 20% de MO + 40% de CAQ + 15% de FC + 5% de CH + 20% de SC.

Palabras clave: crecimiento, moinha, *Solanum melongena*, plántulas de calidad, horticultura.

Introduction

In the production of quality vegetables, seedling formation is one of the most important phases for the crop cycle (Zaccheo *et al.*, 2013), and the type of substrate used for growing them is one of the crucial factors for obtaining high-quality seedlings and, therefore, high-yield plants.

The substrate should provide an adequate supply of air and water to the root system, besides physically supporting plant growth (Júnior *et al.*, 2014). In addition, growth

media or substrates must be free of plant pathogens, easy to handle, long-lasting, highly available and of low cost (Fernandes *et al.*, 2006; Mesquita *et al.*, 2012).

Several studies have been developed to reuse agricultural and agro-industrial residues in the composition of substrates to minimize the environmental impact that would be caused by inadequate disposal, and reduce production costs by replacing commercial substrates (Krause *et al.*, 2017; Almeida *et al.*, 2018; Guisolfi *et al.*, 2018; Meneghelli *et al.*, 2018). The reuse of residues to compose substrates

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in eggplant seedling production has been investigated by several authors (Costa *et al.*, 2012; Bardivieso *et al.*, 2014; Ferreira *et al.*, 2014).

Agricultural wastes, such as coir (or coconut fiber), burnt rice husk, eggshell, and the dry residue of coffee beans, also known as “moinha”, are highly available and potential alternative materials to compose substrates for the production of eggplant seedlings.

Coconut coir dust has a predominance of medium and fine particle size fractions, which makes it an adequate substrate when looking for high porosity and presence of micropores. These are important factors to obtain good aeration and water-holding capacity (Zorzeto *et al.*, 2014). Coconut fiber is a renewable and highly biodegradable substrate with improved mechanical properties and low cost (Machado *et al.*, 2014). Therefore, its high availability, low cost, and physical-chemical properties make coconut fiber an adequate alternative material for the composition of substrates.

Burnt rice husk has a high water-holding capacity and fast and efficient drainage. These characteristics provide good oxygenation to the roots, well-aerated conditions, resistance to decomposition, relative structure stability, low density, and pH close to neutrality (Soares *et al.*, 2012). Due to the aforementioned properties, rice husk has become intensively used as a substrate for plant growth.

Eggshells are composed of organic and inorganic substances. Calcium carbonate (CaCO₃) is the main component in the inorganic phase of hen eggshells (Medeiros and Alves, 2014) and they can be used as one of the nutritional materials for the formulation of a substrate.

Moinha is a residue generated during the processing of coffee beans. It is composed of plant residues, such as leaves, branches, inflorescences, and poorly formed coffee beans, which, when dried together with the coffee beans, are burned and released from the dryer. When chemically analyzed, this material was found to contain a high content of organic matter as well as phosphorus, potassium, and nitrogen (Meneghelli *et al.*, 2016). In addition to its potential use as a fertilizer, the authors found a high electrical conductivity in this residue, which is why they verified that concentrations greater than 10% of moinha in the substrate provided lower values in the analyzed variables in Conilon coffee seedlings. In this sense, different concentrations of moinha in the composition of substrates for different crops should be investigated, considering the hypothesis

that this residue is an important substrate material, but in an adequate proportion that requires experimentation.

It is believed that partial or even total replacement of commercial substrates by the combination of different agricultural residues may be a sustainable alternative for the production of eggplant seedlings since all of them have appropriate characteristics to seedling germination and development. In addition, it reduces costs when compared to commercial growing media (Mesquita *et al.*, 2012; Ferreira *et al.*, 2014). However, it is necessary to know the exact proportions of moinha and commercial substrate in the composition of the alternative substrate, which will provide high-quality eggplant seedlings.

The objective of this research was to evaluate the growth of eggplant seedlings grown in alternative substrates with increasing levels of moinha, replacing the commercial substrate.

Material and methods

The experiment was carried out at the plant nursery of the Federal Institute of Espirito Santo, Campus Santa Teresa, located in the municipality of Santa Teresa, Espirito Santo State (18°48' S, 40°40' W, 130 m a.s.l.), in Brazil. According to Köppen and Geiger (1928), the climate of the region, is Cwa (subtropical dry-winter climate), with an average annual temperature of 24.6°C and average annual precipitation ranging from 700 to 1200 mm. The temperature and relative humidity of the air during the experimental period ranged from 19.9 to 38.2°C and 47.5 to 69.5%, respectively. The plant nursery was covered with a shading screen, which provided a reduction of solar radiation by 50%.

The residues used in the alternative substrate composition for the production of eggplant seedlings were: residues from the coffee dry milling process (moinha), eggshells, dry coconut fiber (coir), and burnt rice husk. Eggshells were collected from local restaurants and dried in the sun for 3 d. Subsequently, they were crushed and ground into a fine powder. Burnt rice husk and coir were donated by the company Fibria, located in Aracruz-ES, Brazil. Moinha was collected from a private property (Sítio da Saudade), located near the experimental area in Santa Teresa, Espirito Santo, Brazil. Before being used, moinha was sieved in a stainless-steel sieve with a 4 mm mesh.

The chemical and physical-chemical characterization of the residues used in the composition of the substrates was carried out at the Soil and Solid Waste Laboratory of the

Agricultural Engineering Department of the Federal University of Viçosa. The physical-chemical analysis consisted of the determination of the electrical conductivity (EC), through a laboratory conductivity meter (model P613, Shanghai Yoke Instrument Co. Ltd., Shanghai, China). The chemical analysis consisted in the determination of the pH, using a bench pH meter (model HMCDB-150, Highmed Solutions in Measurement Technology Ltd- ME Tatuape, São Paulo, Brazil) and the quantification of organic matter (OM), total nitrogen (TN), phosphorus (P) and potassium (K), according to the methodology described by de Matos (2015).

The chemical and physical-chemical attributes (EC) of coconut fiber, moinha, eggshells and burnt rice husk used in the experiment are shown in Table 1.

TABLE 1. Chemical and physical chemical attributes (EC) of eggshells (ES), coconut fiber (CF), moinha (MO) and burnt rice husk (BRH) used in the experiment.

Residues	pH ^(a)	EC	OC _{ro}	OC _T	OM	N _T	P	K	Ca
		dS m ⁻¹	g kg ⁻¹						
ES	9.37	0.37	2.8	3.6	6.2	0.87	0.08	0.06	31.9
CF	7.15	0.09	57.1	74.1	127.7	0.66	0.05	0.14	0.0
MO	5.60	6.49	45.3	58.9	101.5	3.7	0.14	0.71	0.0
BRH	5.9	1.15	31.5	40.9	70.5	0.59	0.08	0.03	0.0

pH^(a): potential of hydrogen in water; EC: electrical conductivity; OC_{ro}: readily oxidizable organic carbon; OC_T: total organic carbon; OM: organic matter; N_T: total nitrogen; P: phosphorus; K: potassium; Ca: calcium.

A completely randomized experimental design (CRD) was used, with six treatments and ten replicates. Each experimental unit consisted of 20 seedlings, totaling 1,200 seedlings used in the experiment. Six plants were considered useful for each experimental unit.

The treatments: T1: commercial substrate (control); T2: 0% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshells + 40% commercial substrate; T3: 10% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell + 30% commercial substrate; T4: 20% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell + 20% commercial substrate; T5: 30% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell + 10% commercial substrate; T6: 40% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell + 0% commercial substrate were evaluated.

Chemical attributes of the commercial Bioplant[®] substrate, obtained by Paixão *et al.* (2012) are shown in Table 2.

TABLE 2. Chemical analysis of the commercial substrate Bioplant[®].

pH ^(a)	N _T	P	K	Ca	OC _T	OM
	g kg ⁻¹					
5.62	0.62	1.55	0.44	1.84	21.00	52.21

pH^(a) in CaCl₂(CaCl₂ pH); N_T: total nitrogen; P: phosphorus; K: potassium; Ca: calcium; OC_T: total organic carbon; OM: organic matter.

Seeds of eggplant (*Solanum melongena* L.) cultivar Embu were sown in a 200-cell Styrofoam propagation tray, placing two seeds per cell. The seedling production system was arranged in suspended trays, placed in masonry raised beds. Seedlings were manually irrigated twice a day, once in the morning and once in the afternoon without fertilizer application. Fifteen days after sowing (DAS) thinning was performed leaving only one seedling per cell, the most vigorous one.

The variables plant height, stem diameter and total dry mass were evaluated at 31 DAS. Plant height was obtained using a millimeter ruler, measuring from the stem base to the apical bud that originated the last leaf. The stem diameter was measured using a precision digital caliper (Zaas Precision). To obtain the total dry mass, the roots were carefully washed in running water, over a sieve. Afterward, the seedlings were packed in paper bags and placed in a forced air circulation drying oven (model WGL-30B, Westtune, Suzhou Beiyin medical equipment Co., Ltd., Zhejiang, China). The seedlings were maintained at 65°C until a constant weight was achieved. Subsequently, the materials were weighed in an electronic precision scale (1 g) (reference LS5, Scientific Mars, São Paulo, Brazil). In addition to the biometric and gravimetric analysis, the electrical conductivity of the substrates was determined using a conductivity meter (model P613, Shanghai Yoke Instrument Co., Ltd, Shanghai, China) following the methodology proposed by de Matos (2015).

All the evaluated variables were submitted to the tests of normality (Lilliefors) and homoscedasticity (Bartlett), to validate and assess their variance. Due to the qualitative difference between the commercial substrate treatment (T1) and the other substrates (T2 to T6), the analysis of variance for qualitative treatments was performed only considering the contrast between T1 and the other treatments in the decomposition of the sums of squares of the treatments. In addition, for the comparisons between treatments T2, T3, T4, T5, and T6, related to the moinha level, their adjustments were adopted in regression models using the orthogonal polynomial method. For all procedures, an “α” equal to 0.05 was adopted. All the statistical analyzes were performed through the SAEG 9.1 software (2007).

Results and discussion

For the variables stem diameter (SD), plant height (PH), and total dry mass (TDM), superiority ($P < 0.05$) was observed for the group of treatments containing 0, 10, 20, 30 and 40% of moinha, in comparison to the commercial substrate treatment (Tab. 3). This result may be associated with the greater amount of nutrients contained in this residue, especially nitrogen. Nitrogen can favor leaf expansion and provide greater plant growth (Eichler *et al.*, 2008). Increases in shoot dry mass are expected due to the application of nitrogen doses, mainly because this nutrient contributes to vegetative growth, leaf expansion, and stem growth rate (Aleman and Chaves, 2016). Thus, the higher content of nitrogen in the treatment group containing moinha may have provided greater vegetative growth in the seedlings.

The use of eggshells and coconut fiber may have positively contributed to seedling development, even because no moinha was added (0% moinha) in T1. The eggshell mineralized in a short period of time could have contributed to the availability of nutrients. Studying the use of eggshell as a soil acidity corrective, Lo Monaco *et al.* (2015) concluded that in a period of 2 weeks, the residue added to the soil in the form of powder was mineralized and favored the increase of pH in the soil. Likewise, Niezer and Silveira (2014), using eggshell to recompose the pH of the soil, found a decrease in acidity after 3 weeks of incubation of the soil with the residue. Although it has the lowest organic matter content compared to the other residues used, eggshells provide nutrients, especially calcium (Tab. 1), in greater amounts than the commercial substrate (Paixão *et al.*, 2012). Calcium is extremely important in the primary growth phase of plants, since it is involved in

the construction of cell walls, in addition to other essential processes such as photosynthesis, cell division, cytoplasmic movements, and increased cell volume (Malavolta *et al.*, 1997). Moreover, calcium plays an important role in ion absorption and when in deficit it affects root growth points (Vitti *et al.*, 2006). Coconut fiber may have contributed to the physical quality of the substrate, providing adequate aeration and water retention. Granulated coconut fiber shows a predominance of intermediate and fine fractions, which may be appropriate when seeking high porosity and presence of micropores, which are responsible for good aeration and water retention in the environment (Zorzeto *et al.*, 2014).

In highly weathered tropical and subtropical soils, organic matter is of great importance for crop nutrient supply, cation retention, toxic and micronutrient complexation, structure stability, infiltration and retention, aeration, and microbial activity, constituting a fundamental component of its productive capacity (Bayer and Mielniczuk, 1999). Organic matter added to soil favors numerous microbiological processes related to mineralization and nutrient release to plants, nitrogen fixation (symbiotic to non-symbiotic), and decomposition of organic waste. It also improves the physical qualities of the soil such as structure development and aggregate stability, which are beneficial for plant growth and development (Bento, 1997). In addition to physical factors, the increase in organic matter content promotes improvements in chemical attributes such as increased pH and base saturation, as well as aluminum complexation and soil solution precipitation (Mello and Vitti, 2002).

Regarding the variable electrical conductivity (EC), there was no difference ($P < 0.05$) between the two groups of contrasted treatments.

TABLE 3. Significance levels, contrast estimators and P value between the conventional substrate treatment and those with different levels of moinha in the composition.

	Treatments						Estimator	P value
	Conventional	0%	10%	20%	30%	40%		
Contrast coefficients	5	-1	-1	-1	-1	-1	-	-
	Moinha level							
Means of the treatment	Stem diameter (mm)							
	1.67	1.57	1.88	1.99	2.05	1.87	-1.00	0.0189
Means of the treatment	Plant height (cm)							
	4.00	4.00	5.09	6.04	5.78	4.48	-5.38	0.0082
Means of the treatment	Total dry mass (mg)							
	213.75	298.63	270.25	492.0	454.63	376.63	-823.38	0.0034
Means of the treatment	Electrical conductivity ($\mu\text{S cm}^{-1}$)							
	48.75	45.00	55.00	55.00	31.25	83.75	-26.25	0.4986

When the different moinha levels were evaluated (polynomial regression), second-degree effects ($P < 0.05$) were observed for the variables electrical conductivity (EC), stem diameter (SD) and plant height (PH). For the total dry mass (TDM), no adjustment was observed in regression models ($P < 0.05$).

It was observed that, in general, increasing percentages of moinha in the substrate composition led to an increase of the salinity level in the substrate (greater electrical conductivity) (Fig. 1). This result was already expected since moinha showed higher electrical conductivity than the other residues (Tab. 1). The high concentration of salts is a stress factor for plants, because it reduces the osmotic potential and causes the action of ions on the protoplasm (Harter *et al.*, 2014). Water is osmotically retained in the saline solution, so that the increased concentration of salts makes it less and less available to plants (Ribeiro *et al.*, 2001).

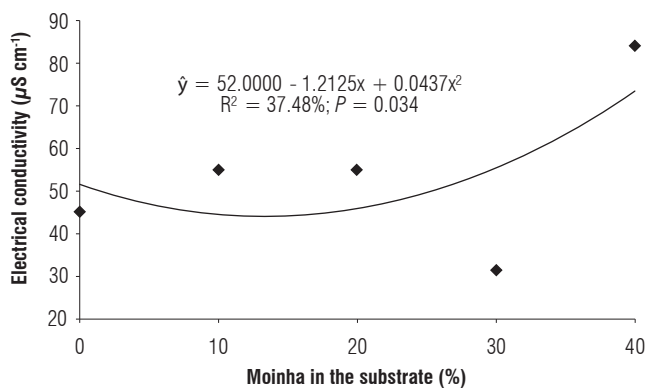


FIGURE 1. Electrical conductivity as a function of increasing percentages of moinha in the composition of the substrates.

The stem diameter is a key variable to evaluate the survival potential and growth of seedlings (Souza *et al.*, 2006). These authors emphasize that within the same species, plants with large stem diameters have higher survival rates because they have the capacity to generate and develop roots. In this sense, it can be observed that the substrate containing 26.3% moinha provided the highest stem diameter (2.05 mm), with a decrease in the variable above this percentage (Fig. 2). However, the stem diameter values obtained at doses higher than 26.3% were still greater when compared to the treatment without the addition of moinha in the substrate (0% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell + 40% commercial substrate), demonstrating the beneficial effect of this residue on substrate composition.

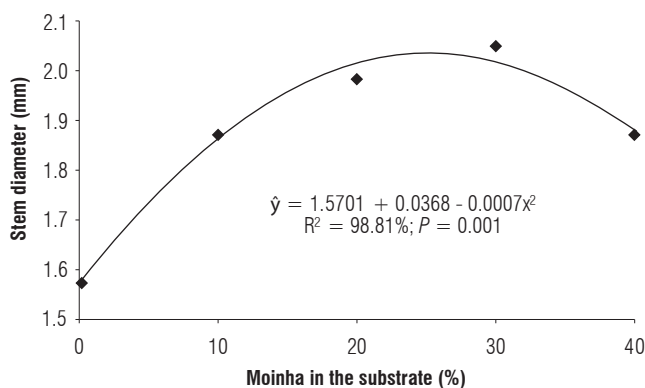


FIGURE 2. Stem diameter of eggplant seedlings as a function of increasing percentages of moinha in the composition of substrates.

The smaller amount of nutrients present in the substrate, due to the absence of moinha, may have been the reason for having a smaller stem diameter in T2. In the highest concentrations of moinha, the decrease in this variable can be attributed to the higher salinity of this residue, which impairs plant growth and development, as mentioned earlier. A similar result was obtained by Almeida *et al.* (2018), who verified a decrease in the stem diameter of cucumber seedlings with the increase of the residue in the alternative substrate.

The plant height increased significantly with the gradual replacement of the commercial substrate by moinha up to the percentage of 21.80%, providing a maximum height of 5.94 cm (Fig. 3). Above this percentage, there is a decrease in the plant height values. However, similarly to what occurred for the stem diameter, the plant height values obtained at higher moinha concentrations were still greater than those registered for the treatment in which no moinha was added (T2).

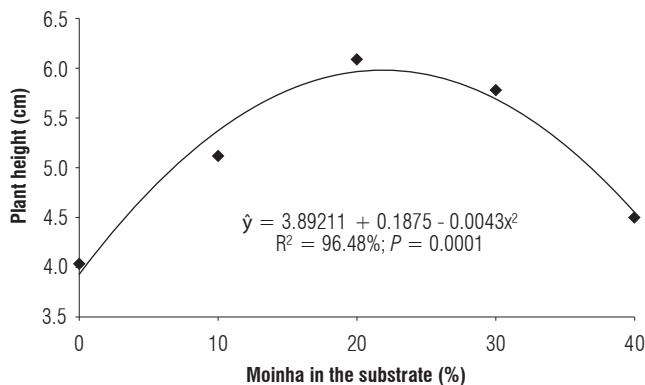


FIGURE 3. Plant height of eggplant seedlings as a function of increasing percentages of moinha in the composition of the substrates.

In general, it was verified that the highest values obtained for the assessed variables were those in which around 20% moinha was added in the composition of the substrates. When moinha proportion increased above this percentage, all variables showed decreasing values. It is believed that this result could be associated with the higher salinity levels achieved with increasing moinha percentages in the substrate, evidenced by the greater electrical conductivities (Fig. 1). The high concentration of salts is a stress factor for plants, as it reduces the osmotic potential and provides the action of ions on the protoplasm (Harter *et al.*, 2014). The water is osmotically retained in the saline solution, making it less and less available to the plants, and, consequently, interfering negatively in the growth and productivity of the crop.

Studying the use of agricultural residues in the composition of substrates for the production of tomato seedlings, Krause *et al.* (2017) found that the highest values obtained from the analyzed variables were those in which around 15 to 32% of moinha was used in the composition substrates. With the increase in this proportion, all variables showed decreasing values. The authors also believe that this fact may be associated with higher salinity in the substrate, evidenced by the greater electrical conductivity in the residue. Likewise, Meneghelli *et al.* (2016), studied moinha as an alternative substrate in conilon coffee seedlings and also found a decrease in the analyzed growth variables and concluded that the high salinity of the residue may have favored this result.

The use of about 20% of moinha in the substrate composition promoted the best development of eggplant seedlings, probably because at this proportion the negative effects of salinity did not overcome the beneficial effects of the nutrients, especially nitrogen, present in higher amounts (Tab. 1).

Conclusion

The moinha can be used to partially replace the commercial substrate for eggplant seedling production. We recommend using the substrate containing 20% moinha + 40% burnt rice husk + 15% coconut fiber + 5% eggshell and 20% commercial substrate.

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