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Agricultural wastes incorporated to the substrate in the production of scarlet eggplant seedlings

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Abstract

The use of agricultural residues for seedling production stands out as an effective sustainable alternative in the production of vegetables. The aim of this research was evaluate concentrations of wastes from the coffee bean drying process (moinha) in substrates composed of coconut fiber, eggshell and commercial substrate on the emergence and quality of scarlet eggplant (*Solanum gilo*) seedlings. An experiment was conducted in a completely randomized design with five treatments and ten repetitions. Thus, the following treatments were evaluated: T0 – commercial substrate Bioplant®; T1- 15% of moinha (MO) + 15% of coconut fiber (CF) + 5% of eggshells (ES) + 65% of commercial substrate (CS); T2 - 30% MO + 15% CF + 5% ES+ 50% CS; T3 - 45% MO + 15% CF + 5% ES + 35% CS; and T4 - 60% MO + 15% CF + 5% ES + 20% CS. The emergence speed index, seed emergence, number of leaves, seedling height, stem diameter, shoot, root and total dry mass, Dickson's Quality Index and the electrical conductivity of the substrates were evaluated. The addition of moinha concentrations above 15% promotes an increase in electrical conductivity compared to the control and negatively affects seedling emergence. Among all treatments, 38% of moinha promotes an increase in the number of leaves, and 15% of moinha results in higher plant height, stem diameter, and the highest dry mass accumulation. The alternative substrate containing 15% MO + 15% CF + 5% ES + 65% CS promotes a better development for scarlet eggplant seedlings, being an alternative to the exclusive use of the commercial substrate.

Keywords: *Solanum gilo*, alternative substrate, seedling growth

Introduction

Large amounts of agricultural wastes are generated and their management on farms is a major difficulty. The economic and environmental issues associated with wastes are correlated with activities carried out, and waste generated in one agricultural activity can be used as a resource in another (Gontard et al., 2018).

In Espírito Santo state, southeast of Brazil, large quantities of coffee moinha, coconut fiber and eggshell are generated (Meneghelli et al., 2017) and several studies are being carried out with the use of these residues (Krause et al., 2017; Guisolfi et al., 2018; Lo Monaco et al., 2018). These studies report that those residues have attributes that can be used as substrate in the production of seedlings with high-quality.

The substrate must have satisfactory water retention for adequate germination and to be able to meet the water needs of the seedlings during their growth (Carmona et al., 2012). It should also have good structure, adequate aeration, levels of nutrients, pH and cation exchange capacity. Also, the substrate should be free of phytopathogens, easy to handle, low cost and of high availability (Silva Júnior et al., 2014).

Coconut fiber has attributes such as high porosity and the presence of micropores responsible for good aeration and water retention in the environment (Zorzeto et al., 2014). Eggshell has a high amount of calcium (Naves et al., 2007). The calcium present in the eggshell will play an important role in the initial growth of the seedlings when it becomes available, since it constitutes a structural function of the cell walls. Coffee moinha has fertilizing potential, especially regarding nitrogen (Meneghelli et al., 2016). Nitrogen is involved in the formation of plants, leaf expansion and accumulation of biomass, and large amounts of this nutrient are required

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by plants, especially in the early stage of development (Belapart et al., 2013). Despite the fertilizing potential, high concentrations in the substrate reduced the growth of *Coffea canephora* plants due to the high electrical conductivity in the moinha (Meneghelli et al., 2016). In this context, different concentrations of moinha in the composition of the substrate and different crops should be investigated.

Commercial substrates are widely used for the production of scarlet eggplant (*Solanum gilo*) seedlings. However, many farmers report that the amount of nutrients in these substrates is enough only for the first growth stage of the seedlings. Thus, it becomes necessary to add fertilizers to the seedling to complete its cycle in the nursery. Besides, they constitute an additional cost in the production stage of seedling formation. Therefore, producers seek a substrate with better quality and low cost for seedlings.

Considering that agricultural residues, which are widely available on farms, are low cost (Kalaruban et al., 2016), that it is necessary to use the available regional residues and that there are few studies evaluating the production of quality seedlings of scarlet eggplant, this study becomes important. The aim of this study was to evaluate concentrations of moinha in substrates composed of coconut fiber, eggshell and commercial substrate, on the emergence and quality of scarlet eggplant seedlings.

Material and Methods

The experiment was conducted in the seedlings nursery at the Federal Institute of Espírito Santo, Santa Teresa campus, Santa Teresa, Espírito Santo, Brazil. The temperature and relative air humidity in the experimental period ranged from 18.5 to 39.2 °C and 54.9 to 90.2%, respectively. The nursery where the experiment was conducted was covered with a polypropylene net, which reduced solar radiation by 50%.

The residues used in the alternative substrate for the production of scarlet eggplant seedlings consisted of the residue from the coffee bean drying process, called "moinha", eggshell and coconut fiber. The eggshell was crushed in a mortar until it became bran in the form of powder. The coconut fiber was washed and dried for three days and then processed in a disintegrator, followed by sieving until particle size within the range from 1 to 10 mm was obtained. The moinha was used as it was collected, i.e., without any grinding or sieving treatment.

The residues used in the composition of the substrates for the production of scarlet eggplant seedlings were chemically and physical-chemically characterized in the Soil and Solid Waste Laboratory of the Department of Agricultural Engineering of the Federal University of Viçosa (Table 1). The physical-chemical analysis consisted of the determination of the electrical conductivity (EC), using a benchtop conductivity meter. The chemical analysis were pH determination, using a benchtop pH meter, and the quantification of the concentrations of easily oxidizable organic carbon (EOOC), total organic carbon (TOC), total nitrogen (N_T), phosphorus (P) and potassium (K) (Matos 2015). The chemical characteristics of the commercial substrate Bioplant® were 0.62, 1.55, 0.44, 1.84, 21.0 and 52.21 dag kg^{-1} for nitrogen, phosphorus, potassium, calcium, total organic carbon, and organic matter, respectively, and pH of 5.62 (Paixão et al., 2012).

Table 1. Chemical and physical-chemical (EC) characteristics of the eggshell (ES), coconut fiber (CF) and moinha (MO) used in the experiment.

Residues	pH	EC	EOOC	TOC	N_T	P	K	Ca+ Mg
		dS m^{-1}	--------------------------------dag kg^{-1}-----------------------------					
ES	9.37	0.37	2.8	3.6	0.87	0.084	0.06	31.9
CF	7.15	0.09	57.1	74.1	0.66	0.053	0.14	-
MO	5.60	6.49	45.3	58.9	3.7	0.14	0.71	-

EC: electrical conductivity; EOOC: easily oxidized organic carbon; TOC - total organic carbon; N_T - total nitrogen; P: phosphorus; K: potassium; Ca + Mg: calcium + magnesium.

The experimental design was completely randomized, with five treatments and ten replicates. Each experimental unit consisted of 20 seedlings, totaling 1,000 seedlings in the experiment. Five plants were evaluated for each experimental unit. Thus, the following treatments were evaluated: T0 - Bioplant® commercial substrate (control); T1 - 15% of moinha + 15% of coconut fiber + 5% of eggshell + 65% of commercial substrate; T2 - 30% of moinha + 15% of coconut fiber + 5% of eggshell + 50% of commercial substrate; T3 - 45% of moinha + 15% of coconut fiber + 5% of eggshell + 35% of commercial substrate; T4 - 60% of moinha + 15% of coconut fiber + 5% of eggshell + 20% of commercial substrate. The amount of waste added to the treatments was calculated based on the volume.

Seeds of scarlet eggplant 'Comprido Grande Rio' were sown in trays of expanded polystyrene (Styrofoam®) with 200 cells, placing two seeds per cell. The seedling production system used was in suspended trays, placed on masonry benches, hand irrigated twice a day, in the morning and in the afternoon. No fertilization was carried out with fertilizers. Thinning was carried out at 21 days after sowing (DAS), leaving only the most vigorous seedling.

Evaluations were performed from 6 to 21 and 40 (DAS). In the period from 6 to 21 DAS, the emergence speed index (ESI) and seedling emergence (SE) were evaluated. The number of leaves (NL), seedling height (SH), stem diameter (SD), shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM), Dickson's quality index (DQI) and the electrical conductivity (EC) of the substrates were evaluated at 40 DAS.

A millimeter ruler was used to measure seedling height, measuring from the base of the collar to the apical bud that gave rise to the last leaf. Stem diameter was measured using a precision digital caliper. To determine shoot dry mass, root dry mass and total dry mass, the seedlings were washed in order to remove the substrate from the roots. Subsequently, the materials were packed in paper bags and dried in an oven with forced air circulation at 65 °C for 72 hours.

After drying, the material was weighed on an electronic precision scale with a precision of 0.01 g. The EC of the substrates was determined using a portable conductivity meter (Matos, 2015).

The emerged seedlings were counted daily from the appearance of the first seedling (6 DAS) to the last seedling (21 DAS) for the determination of SE and ESI. ESI was calculated using the following Equation: ESI= (E1/D1) + (E2/D2) + (En/Dn), where ESI: emergence speed index; E1, E2, En: number of normal seedlings emerged in the first, second and last count; D1, D2, Dn: number of days of sowing until the first, second and last count (Maguire, 1962). DQI was calculated as a function of seedling height (SH); stem diameter (SD); shoot dry mass (SDM), root dry mass (RDM) and total dry mass (TDM), using the following Equation: DQI = TDM / (SH/SD+SDM/RDM) (Dickson et al., 1960).

All the evaluated variables were submitted to the tests of normality (Shapiro-Wilk) and homoscedasticity (Levene), which are assumptions for the validation of analysis of variance. For variables that did not meet the assumptions, the data were subjected to the non-parametric Kruskal-Wallis test, comparing the scores using the Nemenyi test. Due to the qualitative difference between the commercial substrate treatment (T0) and the others (T1 to T4), the data were compared using contrasts between T0 and the other treatments (T1 to T4). Also, in the case of significant effects for the comparisons between the treatments T1, T2, T3 and T4, related to the moinha levels, regression models were fitted to their values by the orthogonal polynomial method. All analyses were performed with R software, version 3.6.2, adopting an "α" of up to 0.05 (R Core Team, 2019).

Results and discussion

According to the results, it is observed that the group of treatments where the moinha was present was superior to the one with exclusive use of the commercial substrate, for all variables evaluated, since the estimators of the contrasts for each variable were negative and significant, except for emergence speed index (Table 2).

Table 2. Coefficients, significance levels and estimators of the contrasts between conventional substrate treatment and those with different levels of moinha addition to the substrate.

		Moinha levels					
	Conv.	15%	30%	45%	60%	Estimators	Error α
Coefficients of the contrasts	4	-1	-1	-1	-1	-	-
		Emergence speed index					
Mean of treatments	2.99	2.67	1.61	1.04	0.53	6.098	<0.0001
		Number of leaves					
Mean of treatments	5.06	5.59	5.94	5.96	5.34	-2.587	0.0039
		Seedling height (cm)					
Mean of treatments	2.43	4.79	3.93	3.03	2.36	-4.385	0.0011
		Stem diameter (mm)					
Mean of treatments	1.45	2.21	1.90	1.44	1.12	-0.871	0.0525
		Root dry mass (mg)					
Mean of treatments	9.95	51.06	38.93	22.61	11.74	-84.544	<0.0001
		Shoot dry mass (mg)					
Mean of treatments	53.62	146.88	125.02	85.67	44.38	-187.473	<0.0001
		Total dry mass (mg)					
Mean of treatments	46.35	196.72	166.65	103.14	56.12	-37.247	0.0001

These positive results in the development of seedlings may be related to the higher concentration of some nutrients present in the moinha, especially nitrogen (Table 1) when compared to the commercial substrate. Nitrogen is one of the nutrients that most limit the development, accumulation of biomass in seedlings and directly affects the success of planting (Villar-Salvador et al., 2013). An adequate supply of this nutrient promotes adequate levels of chlorophyll, vigorous growth, high photosynthetic activity and adequate carbohydrate synthesis (Luna et al., 2014).

The use of eggshell and coconut fiber in the proportions used in this research probably contributed to the development of the seedlings. However, it is important to note that the total organic carbon content of the eggshell was lower than that of coconut fiber (Table 1). Then, coconut fiber may have contributed not only to the chemical quality of the substrate, due to the total organic carbon content (Table 1), but also to the physical quality of the substrate, providing adequate aeration and water retention.

The lower values of the emergence speed index presented in the treatments with moinha addition in the substrate may be related to the presence of some toxic compounds to seed germination. One of these components is chlorogenic acid, which is present in several residues generated in coffee processing (Janissen & Huynh, 2018). The application of this compound on *Artemisia herba-alba* caused the inhibition of germination (AL-Charchafchi & AL-Quadan, 2006). However, for scarlet eggplant, a reduction in emergence speed was observed only with the addition of moinha doses above 15% (Table 2).

According to the regression analysis, emergence speed index, seedling height, stem diameter, root dry mass, shoot dry mass, and total dry mass showed a linear polynomial behavior (Figure 1(A), (C), (D), (E), (F), (G)), while the number of leaves showed a quadratic behavior (Figure 1).

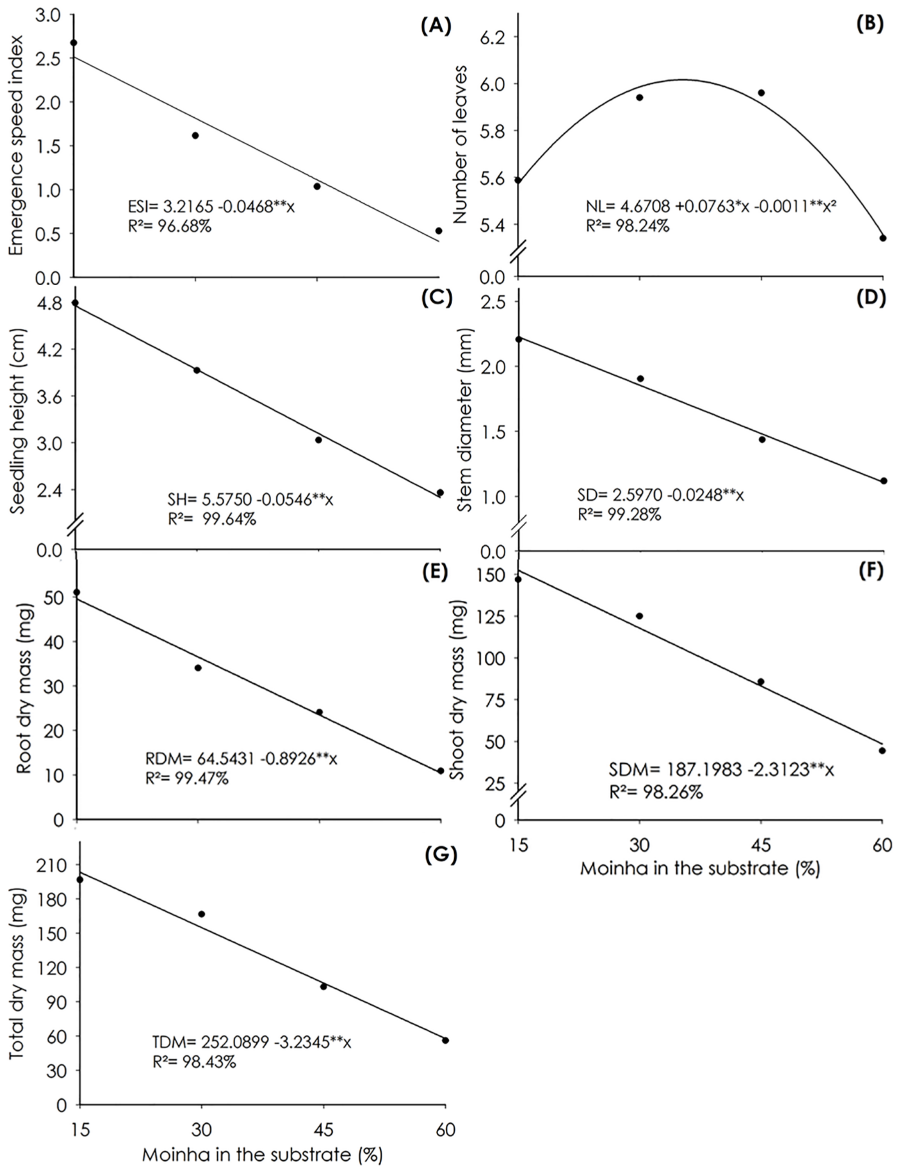

Figure 1. Emergence speed index (A), number of leaves (B), seedling height (C), stem diameter (D), root dry mass (E), shoot dry mass (F), total dry mass (G) as a function of the substrates with different percentages of moinha.

Reducing the time for seedling production in the greenhouse is advantageous. The addition of 15% of moinha to the commercial substrate promoted emergence speed indexes (2.67) close to those found with the use of commercial substrate alone (2.99) and the best results among the substrates with addition of moinha (Figure 1(A) and Table 2). This late emergence of the seedlings did not lead to negative results in the development of the seedlings when compared to the control, where it is possible to observe that the addition of up to 45% of moinha results in values higher than those found with the exclusive use of commercial substrate for most of the evaluated characteristics (Table 2). In the production of seedlings of yellow pepper (*Capsicum chinense*), chili pepper (*Capsicum frutescens*) and sweet pepper (*Capsicum annuum* L.), alternative substrates based on sand, carbonized rice husk, earthworm humus, and cattle manure also resulted in lower values of emergence speed index (Silva et al., 2019). However, these authors did not find satisfactory results of seedling development with the use of commercial substrate.

The percentage of 34.68% of moinha in the substrate composition promoted the highest number of leaves (6.04 units), among the treatments (Figure 1 (B)), with a decrease above this concentration. The number of leaves is the most favored parameter with the addition of moinha, while for the other variables the residue can be added up to 15% (Figure 1). For the number of leaves, it is possible to add 34.68% of moinha. As the leaves are the main photosynthetic organs (Schock et al., 2014), the increase in the number of leaves becomes a desirable characteristic in seedlings. These results are probably associated with the benefits of the alternative substrate, which promoted the most vigorous growth of the seedlings and resulted in an increase in the number of leaves. That said, the obtained result in this work can be considered satisfactory when compared to those found with other substrates used in the production of scarlet eggplant seedlings. The use of sisal residue added to the commercial substrate in the formation of scarlet eggplant seedlings promoted much lower values (2.06 to 2.38 units/plant) when compared to the alternative substrates of this research, including the lowest value, due to the higher concentration of moinha (Silva et al., 2015). Similarly, the effect of the charcoal sludge (biochar) previously treated with water and acids, associated with different substrates in the formation of scarlet eggplant seedlings, did not result in number of leaves superior to 4.2 units (Marimon Júnior et al., 2012).

Seedling height and stem diameter are fundamental characteristics to decide the moment of planting and are indicative of vigorous plants (Santos et al., 2010; Krause et al., 2017). For these variables, the addition of 15% of moinha to the commercial substrate promoted the best results, 4.76 cm and 2.23 mm, respectively (Figure 1(C) and 1(D)). These results probably occurred because the addition of 15% of moinha in the commercial substrate promoted nutrient contents higher than those of the commercial substrates and lower electrical conductivity when compared to the addition of higher doses of moinha. The use charcoal sludge (biochar) associated with different substrates in the formation of scarlet eggplant seedlings resulted in seedling height values between 1.4 and 3.3 cm, at 55 DAS (Marimon Júnior et al., 2012), results that are lower than those found in the present study.

Regarding the root, shoot and total dry mass the best results were achieved with the addition of 15% of moinha in the composition of the substrate, with values of 51.16, 152.51 and 203.72 mg, respectively, with a linear decrease occurring above this percentage (Figure 1 (E), (F) and (G)). The best results found with the use of this substrate may be related to the adequate nutrition and physical characteristics favorable to seedling development. Moinha contributes especially to the nitrogen supply, the eggshell to the calcium supply and coconut fiber is essential in the proper aeration and water retention of the substrate (Krause et al., 2017). Consequently, seedlings produced with 15% of moinha would be more nourished throughout the seedling production cycle, reducing the need for complementary fertilization as it would be necessary with the exclusive use of the commercial substrate.

The incorporation of doses greater than 15% of moinha to the substrate does not promote satisfactory results in the biomass accumulation of scarlet eggplant seedlings. As already mentioned, moinha may have toxic components that, in large quantities, hamper the plants development. Also, the high amount of salts evidenced by the electrical conductivity of the substrate can harm biomass accumulation (Figure 2 (C)). However, moinha has a high potential for use to produce quality seedlings of scarlet eggplant. The addition of sisal residues in the production of scarlet eggplant seedlings did not result in a greater accumulation of root and shoot dry mass, with values varying from 6.0 to 9.0 mg and from 1.4 to 2.3 mg, respectively (Silva et al., 2015). In the present study, significantly higher values were found, ranging between 9.95 and 51.06 mg for root dry mass and between 44.38 and 146.88 mg for shoot dry mass.

The commercial substrate and the one with addition of 15% of moinha showed better emergence than the substrates with the highest doses of moinha in their composition (Figure 2(A)). For Dickson's Quality Index, the addition of 15 and 30% of moinha promoted the best results compared to the control and to the addition of 60% of moinha (Figure 2(B)). Concentrations above 30% of moinha in the substrate resulted in higher values of electrical conductivity compared to the exclusive use of the commercial substrate, while the addition of 15% of moinha led to results similar to those found with the commercial substrate (Figure 2(C)).

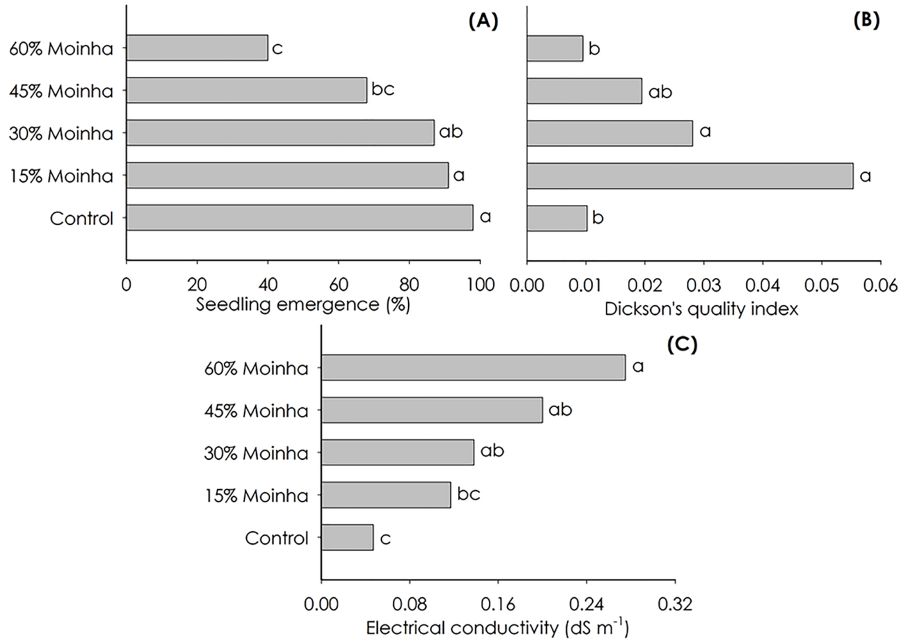

Figure 2. Seedling emergence (A), Dickson's Quality Index (B) and electrical conductivity (C) as a function of the substrates with different percentages of moinha. Means followed by the same letters do not differ from each other, by the Nemenyi test at 5% probability level.

Seedling emergence is an important characteristic that can be seen in the production of scarlet eggplant seedlings. Substrates that promote better emergence are desirable to reduce seed loss and expenses when compared with substrates that result in low emergence of seedlings. The difference between the seedling emergence values observed in this study probably occurred due to the higher salinity, evidenced by the EC found in the substrates with addition of 15% of moinha (Figure 2(C)). The high salt content may inhibit germination due to a decrease in the osmotic potential (Lima et al., 2005) because, when the substrate has a higher salinity level, the water is osmotically retained in the substrate and becomes less available for the imbibition by seeds. The addition of 15% of moinha in the substrate did not cause these negative results because in this treatment the EC was similar to that of the commercial substrate.

To avoid distortions from the excess of nitrogen, for example, or from leaf growth to the detriment of the root system, quality indexes are used, which are relationships between growth parameters (Marana et al., 2008). In this context, the DQI stands out as one of the most used indexes to evaluate the quality of seedlings, since it takes into account the root, shoot and total dry mass, the height and the stem diameter of the seedlings (Dickson et al., 1960). According to Figure 2(B), the addition of 15 and 30% of moinha contributes to increasing the DQI, in comparison with the exclusive use of the commercial substrate. In these treatments, the nutritional effect of moinha and the porosity of the substrate likely contributed to the better development of the seedlings (Lo Monaco et al., 2020), while at higher concentrations this effect was inhibited by the high salinity, evidenced by the high EC of the substrate (Figure 2 (C)).

The higher EC found with the addition of more than 30, 45 and 60% of moinha probably directly influenced the lower development of the scarlet eggplant seedlings (Figure 1(A-G)). The high concentration of salts is a stress factor for plants because it reduces the osmotic potential and promotes the action of the ions on the protoplasm (Harter et al., 2014). The water was osmotically retained in the saline solution, being less available to plants. As the addition of 15% of moinha did not promote an increase in EC when compared to the use of the isolated commercial substrate, the addition of moinha promoted benefits because the alternative substrate provides better nutritional characteristics than the commercial substrate.

Although the higher doses of moinha in the composition of the substrate promoted higher values of EC of the substrate, reducing the emergence rate and the emergence speed, the addition of moinha in the substrate led to satisfactory results. Among all treatments, 38% of moinha promotes an increase in the number of leaves, 15% of moinha results in higher plant height, stem diameter, and greater dry mass accumulation. Because of these results, the use of 15% of moinha in the composition of the substrate is indicated for leading to similar values of germination and EC of the substrate to those found with the exclusive use of commercial substrate for better development of scarlet eggplant seedlings. In this treatment, the effect of salinity and toxic compounds did not overcome the beneficial effect of the nutrients present in the moinha, notably nitrogen.

Conclusions

Doses greater than 15% of moinha in the composition of the substrate increase the electrical conductivity of the substrate and negatively affects seedling emergence.

The alternative substrate containing 15% of moinha + 15% of coconut fiber + 5% of eggshell + 65% of commercial substrate promotes the best development of scarlet eggplant seedlings, being an alternative to the exclusive use of the commercial substrate.

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References

Al-Charchafchi, F., Al-Quadan, F. 2006. Effect of chlorogenic acid on germination and seedling growth, and on the enzymes activity extracted from *Artemisia herba alba* ASSO. Part I: Germination and Seedling Growth. *Dirasat, Pure Sciences* 33: 168-175.

Belapart, D., Leite, S.M.M., Girotto, M.D., Pedrone, L.P. 2017. Efeito de diferentes doses de nitrogênio e cálcio no desenvolvimento inicial do guanandi. *Revista Unimar Ciências* 22: 71-77.

Carmona, E., Moreno, M.T., Avilés, M., Ordovás, J. 2012. Use of grape marc compost as substrate for vegetable seedlings. *Scientia Horticulturae* 137: 69-74.

Dickson, A., Leaf, A.L., Hosner, J.F. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *The Forestry Chronicle* 36: 10-13.

Gontard, N., Sonesson, U., Birkved, M., Majone, M., Bolzonella, D., Celli, A., Schaer, B. 2018. A research challenge vision regarding management of agricultural waste in a circular bio-based economy. *Critical reviews in environmental science and technology* 48: 614-654.

Guisolfi, L.P., Lo Monaco, P.A.V., Haddade, I.R., Krause, M.R., Meneghelli, L.A.M., Almeida, K.M. 2018. Production of cucumber seedlings in alternative substrates with different compositions of agricultural residues. *Revista Caatinga* 31: 791-797.

Harter, L.D.S.H., Harter, F.S., Deuner, C., Meneghello, G.E., Villela, F.A. 2014. Salinidade e desempenho fisiológico de sementes e plântulas de morango. *Horticultura Brasileira* 32: 80-85.

Janissen, B., Huynh, T. 2018. Chemical composition and value-adding applications of coffee industry by-products: A review. *Resources, Conservation and Recycling* 128: 110-117.

Kalaruban, M., Loganathan, P., Shim, W.G., Kandasamy, J., Ngo, H.H., Vigneswaran, S. 2016. Enhanced removal of nitrate from water using amine-grafted agricultural wastes. *Science of the Total Environment* 565: 503-510.

Krause, M.R., Lo Monaco, P.A.V., Haddade, I.R., Meneghelli, L.A.M., Souza, T.D. 2017. Aproveitamento de resíduos agrícolas na composição de substratos para produção de mudas de tomateiro. *Horticultura Brasileira* 35: 305-310.

Lima, M.G.S., Lopes, N.F., Moraes, D.M., Abreu, C.M. 2005. Qualidade fisiológica de sementes de arroz submetidas a estresse salino. *Revista Brasileira de Sementes* 27: 54-61.

Lo Monaco, P.A.V., Oliveira, D.L.S., Haddade, I.R., Krause, M.R., Almeida, K.M., Meneghelli, L.A.M., Vieira, G.H. 2018. Optimum substitution of commercial substrate with moinha as an alternative biodegradable agricultural waste substrate in the production of beet seedlings. *Journal of Experimental Agriculture International* 24: 1-9.

Lo Monaco, P.A.V., Roldi Junior, G., Haddade, I.R., Krause, M.R., Guisolfi, L.P., Almeida, K.M. 2020. Reuse of residues as substrate for production of Eucalyptus (*Eucalyptus urograndis*) Seedlings. *Floresta e Ambiente* 27: e20180140.

Luna, A.M., García, E.R., Servín, J.L.C., Herrera, A.L., Arellano, J.S. 2014. Evaluation of different concentrations of nitrogen for tomato seedling production (*Lycopersicon esculentum* Mill.). *Universal Journal of Agricultural Research* 2: 305-312.

Maguire, J.D. 1962. Speed of germination: Aid in selection and evaluation for seedling emergence and vigor. *Crop Science* 2: 176-177.

Marana, J.P., Miglioranza, É., Fonseca, É.D.P., Kainuma, R.H. 2008. Índices de qualidade e crescimento de mudas de café produzidas em tubetes. *Ciência Rural* 31: 39-45.

Marimon Júnior, B.H., Petter, F.A., Andrade, F.R., Madari, B.E., Marimon, B.S., Schossle, T.R., Gonçalves, L.G., Belém, R. 2012. Produção de mudas de jiló em substrato condicionado com Biochar. Comunicata Scientiae 3: 108-114.

Matos, A.T. 2015. Manual de análise de resíduos sólidos e águas residuárias. 1ª ed. Viçosa, Brazil. 149 p.

Meneghelli, C.M., Lo Monaco, P.A.V., Haddade, I.R., Meneghelli, L.A.M., Krause, M.R. 2016. Resíduo da secagem dos grãos de café como substrato alternativo em mudas de café Conilon. *Coffee Science* 11: 330-335.

Meneghelli, L.A.M., Lo Monaco, P.A.V., Haddade, I.R., Meneghelli, C.M., Almeida, K.M. 2017. Agricultural residues as a substrate in the production of eggplant seedlings. *Horticultura Brasileira* 35: 527-533.

Naves, M.M.V., Prado, C.M.M., Fernandes, D.C., Serafini, A.B. 2007. Avaliação microbiológica do pó da casca de ovo e otimização da técnica de elaboração do produto. *Pesquisa Agropecuária Tropical* 37: 113-118.

Paixão, M.V.S., Schmildt, E.R., Matiello, H.N., Ferreguetti, G.A., Alexandre, R.S. 2012. Frações orgânicas e mineral na produção de mudas de mamoeiro. *Revista Brasileira de Fruticultura* 34: 1105-1112.

R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2019.

Santos, M.R., Sediyama, M.A.N., Salgado, L.T., Vidigal, S.M., Reigado, F.R. 2010. Produção de mudas de pimentão em substratos à base de vermicomposto. *Bioscience Journal* 26: 572-578.

Schock, A.A., Ramm, A., Martinazzo, E.G., Silva, D.M., Bacarin, M.A. 2014. Crescimento e fotossíntese de plantas de pinhão-manso cultivadas em diferentes condições de luminosidade. *Revista Brasileira de Engenharia Agrícola e Ambiental* 18: 3-9.

Silva Júnior, J.A.S., Gheyi, H.R., Dias, N.S., Araújo, D.A., Guedes Filho, D.H. 2014. Substratos e diferentes concentrações da solução nutritiva preparada em água residuária no crescimento do girassol. *Revista Ciência Agronômica* 45: 696-707.

Silva, L.P., Oliveira, A.C., Alves, N.F., Silva, V.L., Silva, T.I. 2019. Uso de substratos alternativos na produção de mudas de pimenta e pimentão. *Colloquium Agrariae* 15: 104-115.

Silva, M.J.R., Santos, N.T., Rios, E.S., Oliveira, A.C., Souza, D.A. 2015. Resíduo de sisal incorporado à substrato comercial na formação de mudas de jiló e brócolis. *Revista Verde de Agroecologia e Desenvolvimento Sustentável* 10: 12-16.

Villar-Salvador, P., Peñuelas, J.L., Nicolás-Peragón, J.L., Benito, L.F., Domínguez-Lerena, S. 2013. Is nitrogen fertilization in the nursery a suitable tool for enhancing the performance of Mediterranean oak plantations?. *New forests* 44: 733-751.

Zorzeto, T.Q., Dechen, S.C.F., Abreu, M.D. Fernandes Júnior, F. 2014. Caracterização física de substratos para plantas. *Bragantia* 73: 300-311.

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