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RESEARCH ARTICLE

# Use of agricultural waste material as an alternative substrate in cabbage seedling production and development

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## ABSTRACT

Considering the need to reduce costs in the production of seedlings, the use of agricultural wastes becomes essential. The objective of this study was to evaluate a substrate composed of agricultural residues replacing the commercial substrate. The experiment was carried out in two phases. For the first phase, seedling production, we used a completely randomized design with six treatments and eight replications, using commercial substrate (Bioplant®) and five treatments with increasing proportions of moinha/descending proportions of rice husk (0/40; 10/30; 20/20; 30/10 and 40/0%), and fixed proportions of coconut fiber (15%) and pine bark (45%). We evaluated plant height, stem diameter, number of leaves, root and shoot dry masses, and Dickson quality index at 33 days after sowing. In the second experiment, cabbage development under field conditions, the treatments were maintained with four replications, using the randomized block design. We evaluated cycle length, compactness, head and stem diameter, number of basal external leaves, mass of fresh matter of the head, and commercial yield. We recommend a substrate composed of 40% moinha, 15% coconut fiber, and 45% pine bark in the production of cabbage seedlings, replacing the commercial substrate.

**Keywords:** *Brassica oleracea* var. *capitate*; Field production; Substrate formulation; Vegetative development

## INTRODUCTION

Vegetable production is common on most farms of the Espírito Santo State, Brazil. Among the vegetables produced, cabbage (*Brassica oleracea* var. *capitata*), a plant of the Brassicaceae family, is widely cultivated and consumed. In 2017, the cabbage cultivation area was 5,448 hectares, with a production of 244,715 tons and an average yield of 44,918 kg/ha (Rocha and Galeano, 2018).

In the production of quality vegetables, the seedling stage is one of the most important stages, directly influencing the final performance of the plant, both from a nutritional and productive point of view; there is a direct relationship between healthy seedlings and plant production (Campanharo et al., 2006).

Cabbage growers, especially in Espírito Santo, use commercially available substrate to produce seedlings, with an increase in costs at the seedling stage. In this sense, the search for alternative materials is important, especially if, in addition to low acquisition costs, these materials are easily available and guarantee a high seedling quality.

According to Medeiros et al. (2010), the substrate should supply the nutrients and provide efficient germination and seedling emergence. Ideally, such substrate has good physical, chemical, biological, and sanitary characteristics (Mesquita et al., 2012).

Due to some attributes such as drainage capacity, easy handling, and absence of pathogens from charred rice husk (Saidelles et al., 2009), the good aeration and water retention provided by coconut fiber (Zorzeto et al., 2014), and improved drainage and a pH of about 3.7 provided by pine bark (Martin et al., 2006); (Nell et al., 1996), the use of such residues can be a valid alternative to commercially available substrate.

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Rice husks are not readily available in Espirito Santo and are regularly purchased from other states with a higher tradition of rice production, such as Paraná, Santa Catarina, and Mato Grosso, resulting in high costs. Thus, alternative materials need to be found, especially with a high availability in the region or on the farm, such as "coffee moinha". However, despite the potential fertilization ability of moinha, Meneghelli et al. (2016) have observed a high electrical conductivity in this residue. For this reason, adding moinha at concentrations higher than 10% resulted in unfavorable values of some parameters of Conilon coffee seedlings.

In this sense, when formulating an alternative substrate composed of these residues, it is essential to obtain the ideal proportion of each residue, especially in terms of coffee moinha and rice husk. In addition, it is hypothesized that increasing levels of moinha as a substitute for rice husk can improve seedling quality, consequently affecting the final harvest.

## MATERIAL AND METHODS

In 2017, the experiment was implemented and conducted in two stages: the seedling phase in the nursery and the development and production phase in the field. The seedling phase lasted from June to July of 2017, while the plant development phase took place from July to October, after transplantation of the seedlings into the field. The entire experiment was performed in the Instituto Federal do Espírito Santo, Santa Teresa *campus*, in the municipality of Santa Teresa, Espírito Santo, Brazil (18° 48' S, 40° 40' W, 130 altitude above sea level).

Temperature and relative humidity in the region during the experimental phase were 19.9 to 38.2ºC and 47.5to 69.5%, respectively. The nursery was screened with black nets, which provided a reduction of solar radiation by 50%.

The residues used in the alternative substrate for seedling production were pine bark, coconut fiber, charred rice husk, and "moinha" (residue from the drying of coffee beans). The charred rice husk and coconut fiber were donated by the Fibria Company, located in the municipality of Aracruz, ES, Brazil. The pine bark was donated by the Demunner Nursery in the municipality of São Roque do Canaã, ES, Brazil. The moinha was collected at the "Sítio da Saudade" farm, located in the municipality of Santa Teresa, ES, Brazil; prior to use, it was sieved through a 4-mm stainless steel sieve.

**Table 1: Physicochemical attributes of the commercial substrate and the different residues used in the composition of the substrates**

| Used materials | pH | CE | TN | TP | K |
|---|---|---|---|---|---|
| | | dS $m^{-1}$ | | dag $kg^{-1}$ | |
| Commercial substrate | 5.62 | 0.99000 | 0.62 | 1.550 | 0.440 |
| Coconut fiber | 7.15 | 0.09000 | 0.66 | 0.053 | 0.140 |
| Moinha | 5.6 | 6.49000 | 3.70 | 0.140 | 0.710 |
| Rice husk | 5.9 | 1.15000 | 0.59 | 0.082 | 0.033 |
| Pine bark | 5.5 | 0.00113 | 0.40 | 0.102 | 0.170 |

The chemical characterization of the residues used in the composition of the substrates for the production of cabbage seedlings was carried out at the Laboratory of Water Quality and Solid Residues of the Department of Agricultural Engineering of the Federal University of Viçosa, MG, Brazil. We analyzed pH, electrical conductivity (EC), total nitrogen (TN), total phosphorus (TP), and potassium (K), following the methodology described by Matos (2015).

The physical-chemical attributes of the commercial substrate and of each residue used in the composition of the substrates are described in Table 1.

### Seedling production

In the seedling production stage, the experimental design was completely randomized (CRD), with six treatments and eight replications. Each experimental unit consisted of 20 seedlings, totaling 960 seedlings in the experiment. Six plants were used from each experimental unit. The treatments applied consisted of increasing proportions of moinha/decreasing proportions of rice husk (0/40, 10/30, 20/20, 30/10, and 40/0%), and fixed proportions of coconut fiber (15%) and pine bark (45%).

The residues were mixed homogeneously in the proportions described in each of the treatments and arranged in the cells of the trays according to each replicate. The cabbage seeds used in the experiment were of the "Cabbage 60 days" variety, seeded in trays of expanded polystyrene (styrofoam) with 200 cells, using two seeds per cell.

Seedling production was performed in suspended trays on masonry benches; the tray were manually irrigated twice a day, in the morning and in the afternoon. At 16 days after sowing, thinning was done, leaving the most vigorous seedling per cell. Evaluations were performed at 33 days after sowing (DAS), consisting of the following parameters: leaf number per plant, plant height and diameter, aboveground dry mass, root dry mass, total dry mass, and Dickson Quality Index (DQI).

To measure plant height, we used a millimetric ruler, measuring from the stem base to the apical bud that gave rise to the last leaf. The stem diameter was measured via a precision digital caliper. To obtain the dry matter mass of the aboveground part and the root, the seedlings were cut close to the point of contact with the substrate, and the roots were carefully rinsed under running water on a sieve. Afterwards, the aboveground part and the roots were placed in paper bags, labelled, and placed in a stove with forced air circulation at 65°C for 72 hours. Subsequently, the materials were weighed on an electronic precision scale with an accuracy of 0.001 g.

The Dickson Quality Index (DQI) was determined as a function of plant height (H), stem diameter (DC), aboveground dry matter (APDM), and root dry matter mass (RDM), using Equation 1 (Dickson; Leaf; Hosner, 1960):

$$DQI = \frac{TDM(g)}{\left(H(cm)/SD(mm)\right) + (APDM\ (g)/RDM\ (g))}$$

where DQI = Dickson Quality Index; TDM = total dry matter mass (g); H = plant height (cm); SD = stem diameter (mm); APDM = aboveground part dry matter mass (g), and RDM = root dry matter mass (g).

**Cabbage development and productivity**

After determination and quantification of the growth variables in the first stage, the remaining seedlings were transplanted to the field at a spacing of 1.0 x 0.4 m. A complete randomized block design (CRD) was used, with six treatments and four replications in experimental units with 24 plants, totaling 576 plants.

Each block comprised four spaced lines of 1.0 m, with a length of 18 m, where the six experimental units were distributed. Within each block, treatments were randomly selected following the same distribution as in the seedling stage (T1-commercial substrate, T2-0:40, T3-10:30, T4-20:20, T5-30:10, and T6-40:0% coffee moinha and rice husk).

The cultivation area was located in the horticulture sector of the IFES - Santa Teresa campus, ES, Brazil. The soil was a Red Yellow Latosol with medium texture. Table 2 presents the results of the soil analysis.

The cultural treatments were carried out according to the agroecological production systems in transition. Prior to seedling transplantation, the soil was plowed and barred. Subsequently, mounds were built (a technique widely used by family-based farmers in Espírito Santo state) with a height of 20 cm, a length of 18 m, and a spacing of 1 m.

Into each well, we placed 1 kg of bovine manure and 86 g of the NPK formulation, prepared on the basis of a mixture of natural phosphate, potassium chloride, and ammonium sulfate, according to the results of the soil analysis and the crop requirement, following the recommendations of the Manual of Fertilization and Liming of the ES - 5ª approach (Prezotti et al., 2007).

Weeding was performed at 30 and 45 days after transplanting (DAT), followed by mulching with batatal grass remains at a height of about 2 cm, close to the plants. The cover fertilization consisted of the application of 500 g of matured compost, based on grass debris, cattle manure, and chopped castor bean (in pieces of about 5 cm), according to Oliveira et al. (2001).

For irrigation, were used microsprinklers, installed every 0.40 m, with a flow rate of 40 L $h^{-1}$, in 16-mm hoses, with a spacing of 1 m. Irrigation was performed daily in the morning for 25 minutes, providing a volume of 1 to 2 L of water per plant until the harvest phase.

For the determination of the harvest point, from each experimental unit, the compactness test was performed; compactness was characterized by the mechanical strength and the strength of the manual compression of the cabbage heads in their final maturing stage. The compactness test is commonly used by cabbage farmers, according to Oliveira et al. (2001), Moura et al. (2006), Moreira et al. (2011), and Silva et al. (2012). The harvest started at 65 days after planting (DAP) and lasted for 30 days. The plants were cut close to the ground, separating the aboveground part from the roots. Eight more centralized plants were harvested, excluding the borders of each experimental unit. The development and production variables evaluated were crop cycle, compactness, head diameter, number of external leaves per plant, fresh head matter mass, and commercial yield.

The diameter of the head was determined with a digital caliper, and the number of basal outer sheets was counted manually. The compactness of the heads was determined based on a scale, were 01 = low compactness, 02 = average compactness, and 03 = high compactness,

**Table 2: Result of soil analysis for cabbage cultivation "cv. 60 days" using seedlings produced on substrates with different residue ratios**

| pH em água | M.0. | P rem | P¹ | K | Ca | Mg | Al | H+Al | SB | T | t | m | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $ddm^{-3}$ | $mgL^{-1}$ | mg $dm^{-3}$ | | cmolc/dm³ | | | | cmolc/dm³ | | | % | |
| 6.8 | 17.5 | 38.0 | 615.1 | 756.0 | 8.4 | 2.4 | 0.0 | 2.4 | 12.7 | 15.1 | 12.7 | 0.0 | 84.1 |

Transcription of the results of analyzes done at the soil analysis laboratory of IFES-Itapina-ES on November 16, 2017 according to Oliveira et al. (2001). To quantify the mass of fresh matter of the head, the heads were cut, and a portion was placed in paper bags, where they were dried in a forced air circulation oven at 65°C until reaching constant weight. The commercial yield was obtained by adding the fresh matter masses of the heads harvested from each experimental unit, and based the area occupied by the harvested plants, the values were transformed to tons per hectare (t $ha^{-1}$).

To verify the normality of the data and the homoscedasticity of the variances, the data were submitted to normality tests (Lilliefors) and homoskedasticity (Barttlet) assumptions to perform analysis of variance. For the variables that met the assumptions, the treatments were compared one by one with the control, using the Dunnett test. To compare the levels of moinha (T2 to T6), the variables were submitted to regression analysis via the orthogonal polynomial method. The variables that did not meet the assumptions, not even after transformation, were evaluated via the Kruskal-Wallis non-parametric test, considering the evaluation of the effects of the treatments by stations. For all procedures, an "α" level equal to 0.05 was adopted.

All statistical analyses were performed through the software packages Assistat 7.7 (Silva; Azevedo, 2009) and Sisvar 5.6 (Ferreira, 2011).

## RESULTS AND DISCUSSION

### Seedling production

By means of analysis of variance, significant differences ($P < 0.05$) were observed for the effect of levels of moinha insertion on the substrate only for plant height (H) and stem diameter (SD). Thus, the estimated means of these variables by the Dunnett test, in response to treatments containing different levels of moinha and to the control, in cabbage seedlings at 33 days after sowing are presented in Table 3.

**Table 3: Plant height (H) and stem diameter (SD) of cabbage seedlings "cv. 60 days" produced on substrates with different ratios of various residues**

| Treatments | H (cm) | SD (mm) |
|---|---|---|
| T1 (0-0) Commercial substrate | 1.34 | 1.27 |
| T2 – (0-40) 0% moinha+40% rice husk+15% coconut fiber+45% pine bark | 1.30 | 0.91[a] |
| T3 – (10-30) 10% moinha+30% rice husk+15% coconut fiber+45% pine bark | 1.51 | 1.18 |
| T4 (20-20) 20% moinha+20% rice husk+15% coconut fiber o+ 45% pine bark | 1.48 | 1.40 |
| T5 (30-10) 30% moinha+10% rice husk+15% coconut fiber+45% pine bark | 1.59[a] | 1.61[a] |
| T6 (40-0) 40% moinha+0% rice husk+15% coconut fiber + 45% pine bark | 1.77[a] | 1.73[a] |

Averages, in the columns, followed by the symbol ([a]), differ from the control at the 5% probability level by the Dunnet Test

The treatments containing 30 and 40% of moinha in the substrate showed better results ($P < 0.05$) than the control in terms of H and SD, which might be related to the higher concentration of N-P-K macronutrients in moinha, mainly nitrogen (Table 1).

Vegetables, including cabbage, have a high demand for potassium (Aquino et al., 2005). Potassium favors the formation and translocation of carbohydrates and the efficient use of water by the plant, balances the application of nitrogen, and improves product quality (Filgueira, 2008). In terms of nitrogen, Taiz and Zaiger (2009) state that this element is considered one of the most relevant nutrients in plant production, influencing seedling emergence and leaf area expansion. Regarding the quantities of macronutrients exported, Aquino et al. (2005) obtained the following order: K > N > Ca > S > P > Mg. Thus, the highest concentrations of nutrients in moinha, especially in terms of N and K (Table 1), may have contributed to the higher values of plant height and stem diameter.

It should be noted that the treatment containing 0% of moinha resulted in statistically lower stem diameter values, most likely because of the lower nutrient availability, since coconut fiber, pine bark, and carbonized rice husk are residues with lower N-P-K concentrations (Table 1) when compared to the commercial substrate (control).

Evaluating different proportions (0 to 40%) of moinha in the production of cucumber seedlings, Almeida et al. (2018) verified that, in terms of plant height, the treatments presented no significant difference in relation to the commercial substrate. In terms of stem diameter, all treatments provided higher values than the commercial substrate, including the treatment with 0% of moinha. It is worth noting that the substrate with 0% of moinha contained 40% of the commercial substrate, which may explain the higher values, since the commercial substrate contains higher amounts of nutrients (Table 1).

Plant height (H) and stem diameter (SD) are shown in Figs. 1 (A) and 1 (B), respectively, as a function of the increasing proportions of moinha in the substrate. Both variables showed a linear behavior in the regression analysis as a function of the different percentages of moinha in the composition of the substrates for cabbage seedling production.

Increasing proportions of moinha in the substrate resulted in increased plant height Fig. 1 (A), with the highest values at 40% (1.73 cm).

The inclusion level of 40% also resulted in the highest SD value (1.78 mm), while the lowest value (0.91 mm) was obtained at an inclusion level of 0% (Fig. 1b). Values lower than those observed here have been found by Soares et al. (2009), who, when evaluating alternative substrates based on organic compost and rock powder in cabbage seedling production, obtained the best performance in the treatment with 100% of the compound, with SD values varying from 0.91 to 1.13 mm at 46 days after sowing (DAS).

Fig. 2 shows the comparisons of the average positions for the number of leaves per plant (NLP), aboveground part dry matter mass (APDM), root dry matter mass (RDM), and Dickson quality index (DQI), using the non-parametric Kruskal-Wallis test.

Based on Fig. 2 (A), in terms of NLP, the treatment containing 30% moinha showed the highest values, although the differences to the treatments with 10, 20, and 40% were not statistically significant. The quality and quantity of leaves are directly related to the dry matter mass of the aboveground part. Thus, this variable is of great importance, especially in cabbage seedlings, since photoassimilate production takes place in the leaves. Aragão et al. (2011), evaluating the number of leaves of sweet pepper plants fertilized with different nitrogen doses, verified increases of up to 274.61% with increasing doses, demonstrating the effect of nitrogen on the leaf number. The highest levels of N in moinha when compared to the other residues and to the commercial substrate (Table 1) explain the higher number of leaves per plant observed in the treatments with higher proportions of moinha (Fig. 2A).

Regarding the aboveground part dry matter mass, treatments with 20 and 30% of moinha resulted in higher levels, not differing from the treatments with 10 and 40% and from the commercial substrate (Fig. 3B). In relation to the root dry matter mass Fig. 3 (C), the treatments containing 30 and 40% of moinha plus the commercial substrate were statistically superior to the 0% treatment, not differing from the treatments with 10 and 20%. For APDM, Almeida et al. (2018) have found similar results for cucumber seedlings, while Meneghelli et al. (2016) have found that only up to the proportion of 30% of moinha

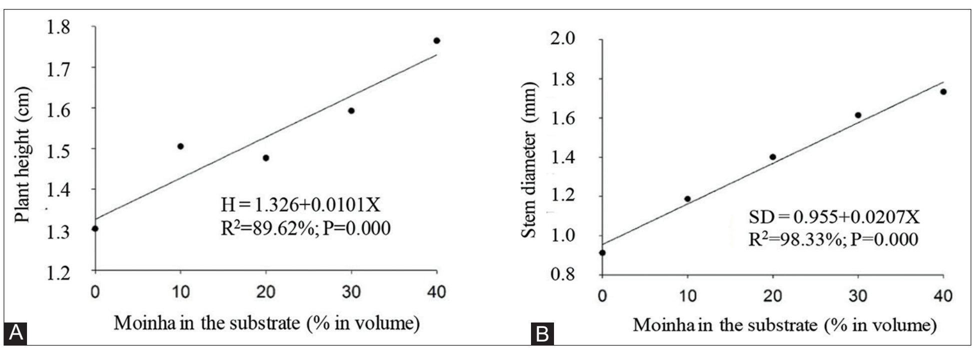


Fig 1. Plant height (A) and stem diameter (B) of cabbage seedlings as a function of the different moinha levels in the substrate.

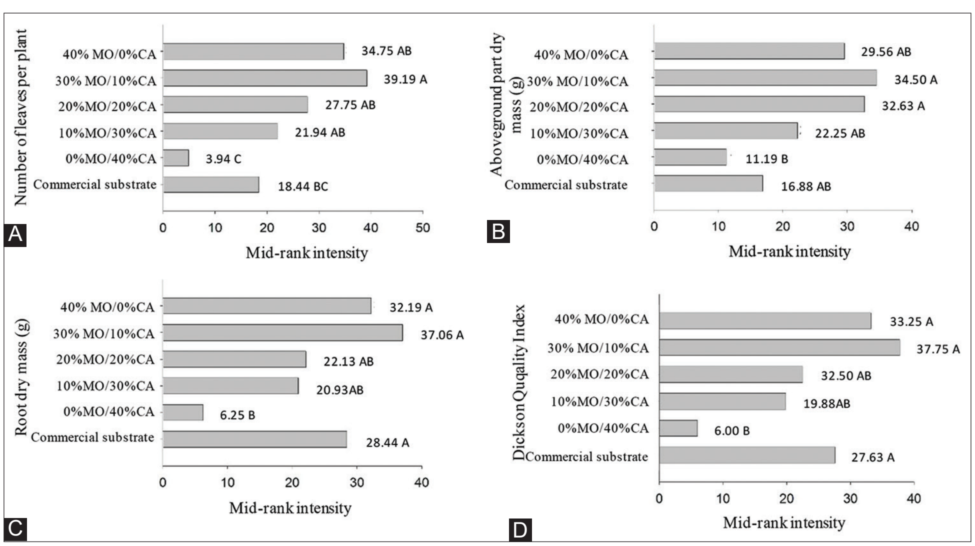


Fig 2. Number of leaves per plant (A), aboveground dry matter mass (B), root dry mass (C), and Dickson quality index (D) as a function of different proportions of agricultural residues used for cabbage seedling production.
Mid-rank intensities followed by the same letters do not differ from each other by the Kruskal-Wallis non-parametric test at the 5% probability level.

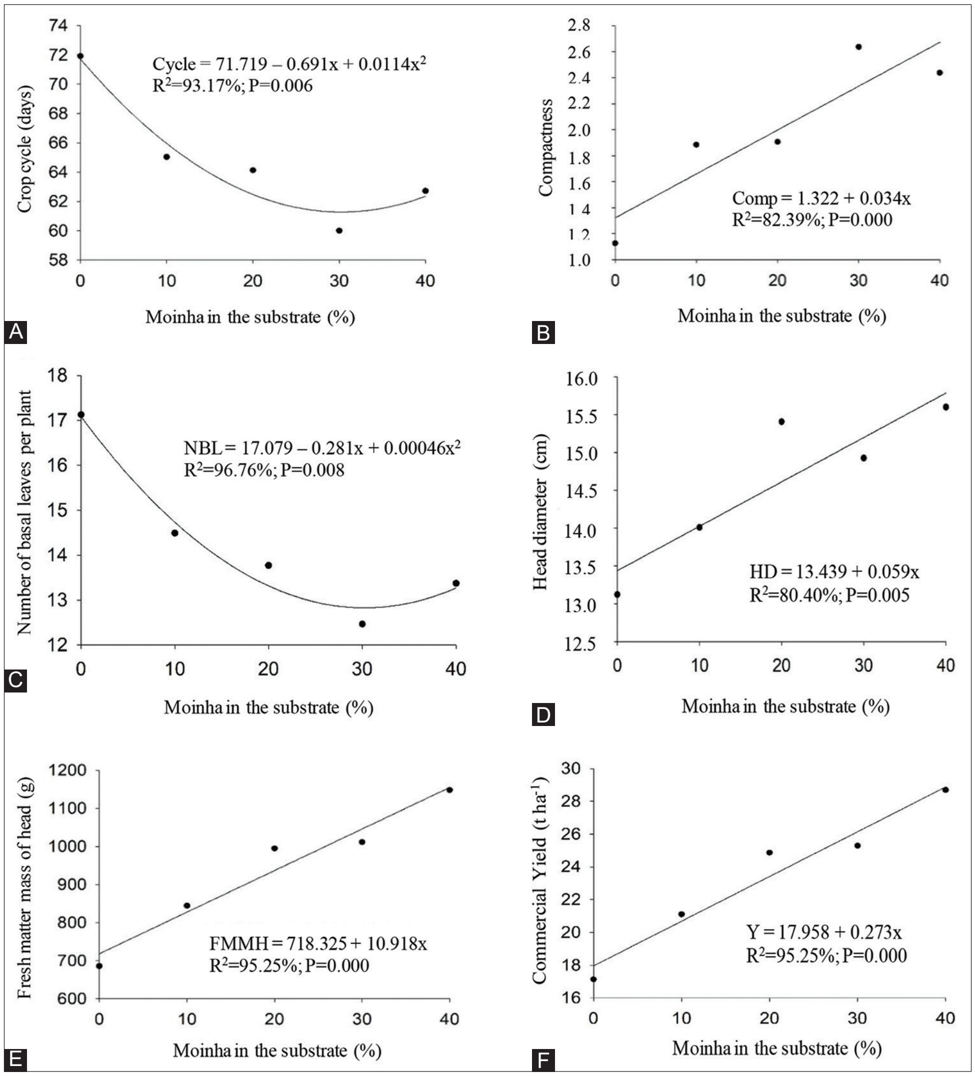


**Fig 3.** Crop cycle (A), head compactness (B), number of basal leaves per plant (C), head diameter (D), fresh matter mass of head (E), and commercial yield (F) of cabbage plants as a function of the use of substrate with different levels of moinha for seedling production.

in the substrate composition, there was no negative effect on the development of conilon coffee seedlings when compared to the use of commercial substrate.

Moreira et al. (2011), evaluating the effects of nitrogen doses applied on cabbage crop, verified that the masses of the dry matter of leaves and stems increased in a quadratic way with the crop cycle and in a linear way with increasing doses; Lobo et al. (2012) also verified increased root dry matter mass with increasing nitrogen doses.

Nitrogen is required in large quantities by plants. It is part of amino acids, nucleic acids, and proteins, and its deficiency rapidly inhibits plant growth (Kerbauy, 2008). Thus, in adequate amounts, it favors the vegetative development, increasing root dry matter mass and aboveground part dry matter mass, which could be observed for the treatments with higher moinha contents.

According to Marana et al. (2008), to avoid distortions from excess nitrogen, for example, or from leaf growth to the detriment of the root system, quality indices are used, representing the relationships between growth parameters. In this sense, the DQI stands out as one of the most used indices to evaluate the quality of seedlings, since it takes into account the dry matter mass of aboveground part, roots, and the entire plant, as well as plant height and stem diameter. In terms of root dry matter mass, regarding DQI Fig. 3 (D), the treatments containing 30 and 40% of moinha did not differ statistically from those with 10 and 20% of the commercial substrate; however, there as significant difference when compared to the treatment without moinha inclusion.

Evaluating the effects of nitrogen and potassium doses applied on guava seedlings in terms of DQI values, Dias et al. (2012) have observed higher values with increasing nitrogen doses, while potassium application had no such effect. Table 1 shows that the difference in terms of N contents between moinha and the other residues and commercial substrate is much higher than those observed for potassium, a fact that explains the higher DQI values.

### Cabbage development and productivity

The average values of the crop cycle, compactness, stem diameter, number of external leaves per plant, head diameter, fresh head matter mass, and commercial yield are presented in Table 4 as a function of the alternative substrates containing increasing proportions of moinha and decreasing rice husk proportions, compared to the commercial substrate.

In general, there was a significant difference ($P < 0.05$) among the treatments for all variables analyzed, except for stem diameter.

The treatment without moinha showed the longest cycle, the highest number of external leaves per plant, lower compactness, diameter, and mass of fresh matter of the head, as well as a lower commercial yield when compared to the control (commercial substrate). It is worth mentioning that the treatment with 10% of moinha also presented the smallest diameter of the head when compared to the control, and that the treatment in which the substrate was composed of 30% of moinha presented the shortest cycle of the plants when compared to the use of the commercial substrate.

In general, cabbage development and productivity were influenced by the seedling production stage. In the seedlings phase, the treatment containing 0% of moinha had the lowest values in the analyzed variables, which resulted in a lower final performance of the plant (Table 4). The increase in moinha (and the decrease in rice husk) in the substrate, especially in the highest proportion used (40%), did not result in significant differences when compared to the commercial substrate; moinha is therefore an interesting alternative substrate for cabbage producing.

According to Fig. 3, the cycle variables Fig. 3 (A) and the basal external leaves Fig. 3 (C) presented a quadratic behavior, whereas the variables compactness Fig. 3 (B), head diameter Fig. 3 (D), fresh matter mass of the head Fig. 3 (E), and commercial yield Fig. 3 (F) showed a linear behavior. For the variable stem diameter, there was no polynomial adjustment ($P < 0.05$).

Increasing moinha levels in the seedling production stage resulted in a shorter crop cycle and a lower number of external leaves per plant in the production phase, with optimal proportions (minimum values) of 30.7 and 30.54%, respectively, as can be seen in Figs. 3 (A) and 3 (C). Generally, family farmers try to reduce the crop cycle, thereby obtained a higher number of crop cycles, as observed by Gesteira et al. (2015). Likewise, the lower the number of basal leaves per plant, the more interesting it will be from the economic point of view, since the outer leaves are generally discarded to facilitate head formation. Regarding the compactness of the heads, with increasing moinha inclusion levels, the values increased (Fig. 3B). The reduction of the cycle length of the plants in the treatments with greater proportions of moinha is related to the compactness, because at the time of harvest, the heads were firmer. In the evaluation of the harvested heads, the maximum value of 3.0 was assigned, and the highest observed value was 2.68 with the application of 40% of moinha (Fig. 3B). Torres et al. (2015), point out that for the harvest, it is necessary that the heads have a certain compactness for market acceptance, hence the importance of this variable for cabbage farmers.

The variables diameter, fresh matter mass of head, and commercial yield presented a similar behavior. The best results were found using 40% of moinha in the substrate composition, obtaining maximum values of 15.80 mm Fig. 3 (D), 1,155.05 g Fig. 3 (E), and 28.88 t $ha^{-1}$ Fig. 3 (F), respectively. The low values obtained with the lowest moinha inclusion levels may be related to the high amount of rice husk in the substrate composition. Moreira et al. (2011), evaluating the effects of different nitrogen doses on the performance of the cabbage crop, verified that the

**Table 4: Mean values of the crop cycle length, compactness, stem diameter, number of external leaves per plant, head diameter, fresh head mass, and commercial yield as a function of substrates with increasing proportions of moinha and decreasing rice husk proportions, compared to the commercial substrate**

| Variables | Commercial substrate | Moinha inclusion level (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 10 | 20 | 30 | 40 | P-value |
| Cycle length (days) | 64.48 | 71.91* | 65,03 | 64.12 | 60.00* | 62.72 | 0.0004 |
| Compactness | 2.06 | 1.13* | 1,88 | 1.91 | 2.64 | 2.43 | 0.0090 |
| Stem diameter (mm) | 35.58 | 35.36 | 34,62 | 36.47 | 36.50 | 39.59 | 0.3565 |
| number of external leaves per plant (n) | 13.56 | 17.13* | 14,49 | 13.77 | 12.47 | 13.38 | 0.0008 |
| Head diameter (cm) | 17.56 | 13.12* | 14,01* | 15.41 | 14.93 | 15.60 | 0.0305 |
| Head fresh matter mass (g) | 1.034,8 | 685.5* | 844,1 | 994.6 | 1.011,5 | 1.147,7 | 0.0014 |
| Commercial yield (t $ha^{-1}$) | 25.87 | 17.13* | 21,10 | 24.86 | 25.29 | 28.69 | 0.0014 |

Averages followed by asterisks (*) differ from the commercial substrate (control) by the Dunnett test at the 5% probability level maximum value of fresh matter mass of head (1.13 kg) was obtained with the application of 277.8 kg N $ha^{-1}$, while for head diameter, the maximum value obtained was 16.9 cm with the application of 277.8 kg N $ha^{-1}$. Considering that the smallest N amount applied was 75 kg N $ha^{-1}$, N application had an impact on cabbage head formation; thus, seedlings produced on substrates with the highest availability of N (higher proportions of moinha) developed larger heads.

In general, the use of moinha in the substrate composition can be a sustainable alternative for small farmers in Espírito Santo, Brazil, since, in addition to reducing substrate costs, moinha is readily available in this region, making it an environmentally friendly alternative.

## CONCLUSIONS

The substrates containing different proportions of moinha (10 to 40%), replacing carbonized rice husk, resulted in similar or more favorable results when compared o the use of commercially available substrate. Increasing moinha inclusion levels (and decreasing rice husk levels) in the substrate during the production of seedlings favor the development of cabbage heads, similar to the results obtained with commercial substrate. For cabbage seedling production, we recommend a substrate with the following composition: 40% moinha, 15% coconut fiber, and 45% pine bark.

### Authors' contributions

This work was carried out in collaboration with all authors. Author Paola Alfonsa Vieira Lo Monaco designed the study and managed the writing of the manuscript. Author João Nacir Colombo designed the study and contributed to the writing. Author Josean de Castro Vieira and Karoline Matiello Almeida designed the study and conducted the field experiment. Author Marcelo Rodrigo Krause performed the statistical analysis and conducted the field experiment. The author Gustavo Haddad Souza Vieira translated the manuscript. All authors read and approved the final manuscript version.

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