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Multivariate analysis in the evaluation of sustrate quality and containers in the production of Arabica coffee seedlings

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Coffee growing is recognized as an activity of great economic and social importance for Brazil. Obtaining good quality coffee seedlings is a major factor in the implantation of a productive and lasting crop. In view of the aforementioned, the objective of this study was to evaluate the quality of Arabica coffee seedlings produced with different substrates in different containers with multivariate analysis techniques. The experimental design used was in randomized blocks, in a 3 x 4 subdivided plot scheme, with 3 replications. The plot levels were: Tube of 120 cm³, Tube of 280 cm³ and Polyethylene bag with volume of 615 cm³. In the subplots the different levels of substrate were randomized: Conventional (S1), leguminous compound (S2), composed of grass + cured bovine manure (S3) and Vermicompost (S4). Treatments 10; 1; 4; 7 evaluated presented potential for diffusion of technology in the process of seedling formation.

Key words: *Coffea arabica*, composting, agroecology.

INTRODUCTION

Coffee growing is recognized as an activity of great economic and social importance for Brazil. Obtaining good quality coffee seedlings is a major factor in the implantation of a productive and lasting crop. Sustrate quality influences the soil bulk density/porosity and decomposion thus enhances the nutrient cycling in the soil and finally the production/productivity (Upadhyay et al., 1989; Bargali et al., 1993, 2015; Bargali, 1996;

Pandey et al., 2006). Due to this importance, several studies have been carried out in order to seek the production of seedlings with superior quality and low costs (Vallone et al., 2010). According to Morgado et al. (2000), containers and their different volumetric capacities may influence the quality of the seedlings and also on the cost of production, because using containers larger than the recommended volume results in additional expenditure for the viveirista.

The viveirista should be attentive in the production of the substrate so that the final product reaches physical and chemical characteristics required by the plant. According to Silva et al. (2010), the substrate should have good aeration, good porosity, water retention capacity, ability to exchange cations and be free of pests and inoculates as a source of disease propagation. According to Vallone et al. (2010), the substrate is responsible for 38% of the total cost of the project. Currently, the replacement of industrialized materials with organics enriched with macro and micronutrients has become frequent for substrate production. And the production of substrate within the property is common in the sector, with expenses reaching up to 38% of the total cost of the seedling (Vallone et al., 2010).

Considering these factors, coffee is a perennial crop, and for its implementation it is necessary to plan all phases, from seedling formation to crop management. Any limitation in this period can severely compromise exploration, resulting in a decline in productivity and lower crop durability. Thus, the planting of vigorous coffee seedlings ensures a good "catch", decreases spending on the replanting operation and contributes with rapid initial growth of plants in the field, constituting a fundamental factor for a successful cultivation (Alves and Guimarães, 2010).

According to Henrique et al. (2011), vigorous seedlings have bright green leaves, thick stem and root system with abundant absorbent roots. However, the diameter of the stem is one of the most relevant parameters to estimate the seedling quality and the setting rate after transplantation in the field.

The objective of this study was to evaluate the quality of Arabica coffee seedlings produced with different substrates in different containers.

MATERIALS AND METHODS

The experiment was carried out at the Federal Institute of Espírito Santo (IFES) - Campus de Alegre, located in the municipality of Alegre-ES, in a seedling nursery with sombrite coverage 50%. The geographical coordinates of the nursery are 20º45'44" south latitude and 41º27'43"longitude West, with altitude of 134 m. According to Köppen classification, the climate of the region is of the type "Aw", dry winter and rainy summer with average annual temperature of 23ºC and precipitation annual period around 1,200 mm. The rainy season in the region is concentrated from November to March.

The experimental design used was in randomized blocks, in a 3 x 4 subdivided plot scheme, with 3 replications. The plot levels were: Tube of 120 cm³, Tube of 280 cm³ and Polyethylene bag with volume of 615 cm³. In the subplots, the different levels of substrate were randomized: Conventional (S1), leguminous compound (S2), composed of grass + cured bovine manure (S3) and Vermicompost (S4). The containers used present as a primordial characteristic the non-release of toxins in the cultivation substrate.

The substrates used were: S1 - conventional - made from ravine land with bovine manure, in the proportion of 3:1 (volume/volume) plus the complementation of fertilization with NPK recommended for culture (Prezotti et al., 2013); S2 - organic leguminous compound, consisting of the basis of legumes (guandu beans) with bovine manure in the proportion of 1:1 (volume/volume), after the maturation process of the material reaching 90 days; S3 - organic grass compound, derived from the process of composting bovine manure and snapping of grasses of gardens in the proportion of 1:1, as described by Souza et al. (2013) and; S4 - vermicompost, resulting from the organic compound grasses.

After the composting process, the compound was taken to a vermicomposteira (3 m long by 0.80 m wide and 0.50 m) for the formation of the vermicoposto. The compound was covered by a layer of 10 cm of dry straw of mowed grass to maintain moisture and darkness, essential to the creation of earthworms, which cannot receive sunlight. The internal temperature of the construction site was maintained between 16 and 22ºC and humidity of 60%, through regas on alternate days. The species used was red worm of California (*Eisenia foetida*) and the process of vermicomposting lasted approximately 40 days. The chemical characterization of the substrates was performed at the Soil Fertility Laboratory of the Soil Department of the Federal Rural University of Rio de Janeiro (Table 1).

The cultivar "Catuai IAC 44 - Arabica" was evaluated. Two seeds per container were used, sowing at 1.0 cm deep. Thinning was carried out shortly after the appearance of the first pair of true leaves, eliminating the less vigorous plants (Matiello et al., 2005). The irrigations were carried out twice a day (morning and afternoon), by microaspersion, until the end of the experimental phase.

At 165 days after sowing, the characteristics evaluated were: shoot and root dry mass (g plant^{-1}), number of leaves, shoot height (cm plant^{-1}), leaf area (cm² plant^{-1}), Dickson quality index, shoot/root ratio, root length (cm plant^{-1}), total nitrogen (plant^{-1}%) and total crude protein (% plant^{-1}). The dry mass of shoot and root were obtained in a digital scale after drying in a greenhouse forced circulation at 75°C until constant weight. Height was measured with millimeter rule, considering the region between the collection and the apical yolk.

Leaf area (PA) was measured by the mathematical model AF=0.667 from Barros et al. (1973), where CNC is the length of the central rib of the sheet. Dickson's quality index was obtained by the formula: IQD = [total dry mass / (height/diameter ratio + shoot/root ratio)) recommended by Dickson et al. (1960).

Total nitrogen was obtained by the Kjeldahl method, which is based on the decomposition of organic matter through the digestion of the sample at 400ºC with concentrated sulfuric acid, in the presence of copper sulfate as a catalyst that accelerates the oxidation of the matter organic. Nitrogen present in the resulting acid solution was determined by steam drag distillation, followed by

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Table 1. Chemical characterization of substrates used in the production of coffee seedlings.

Substrates	N	P_2O_5	K_2O	Mg	Ca	C	pH
	g kg^{-1}	mg dm^{-3}		$Cmol_c.dm^{-3}$		g kg^{-1}	H_2O
S1	18.0	38.0	18.07	5.0	26.0	40.7	6.2
S2	33.0	28.1	15.36	5.7	2.9	158.0	8.8
S3	15.0	16.0	30.6	5.3	27.9	62.0	7.4
S4	15.0	36.3	36.72	7.9	5.3	113.0	6.7

S1 - conventional; S2 - composed of legumes + cured bovinemanure; S3 - grass compound + cured bovine manure; S4 - vermicomposto.

titration with diluted acid (Nogueira and Souza, 2005).

The expression (PBT = NT x FN) was used to determine the total crude protein (PBT), where NT is the total nitrogen and FN is the factor of 6.25 (Nogueira and Souza, 2005). The protein content of a food is measured from the nitrogen content present in the sample analyzed. The analysis is performed by the Kjeldahl Method, where the percentage of nitrogen obtained is multiplied 6.25 and then expressed as Crude Protein (CP). This analysis is based on the fact that all proteins have 16% nitrogen, and that all nitrogen of the food is in the protein form (Nogueira and Souza, 2005).

In the next stage, the computational application R Core Team (2017) was used to determine the generalized Euclidean distance in order to obtain the matrix of dissimilarities between the treatments where the combinations between qualitative and quantitative factors were made, depending on the distance between individuals and the grouping was grouped by the hierarchical method of medium group connection (UPGMA).

The previous characterization of the treatments was performed with the combinations between the containers and substrates used soon after using the principal component analysis (PCA), which is an exploratory multivariate technique. It was processed with the covariance matrix of the original variables, obtaining from it the self-values that built the auto-vectors. These are linear combinations of the original variables and are called main components. The discriminatory power of each variable in a component was measured by the formula:

$$r_{xj}(cp_h) = \frac{a_{jh}\sqrt{\lambda_h}}{S_j}$$

Where, sj =standard deviation of variable j, ajh = coefficient of variable j in the h-thésimo main component, and λh = h-ésima root characteristic (autovalue) of the covariance matrix (Hair et al., 2009). All analyses were processed in the computational program R Core Team (2017) after standardization of variables (null mean and unit variance).

RESULTS AND DISCUSSION

From the dendrogram obtained by the hierarchical method of distance means (Figure 1), considering the cut by the method Mojena (1977) to 45% of the maximum fusion level, it was possible to verify that the 12 treatments were separated into two dissimilar groups: Group I: T10; T1; T4 and T7. Group II: T11; T2; T12; T6; T3; T9; T5; T8.

In the evaluation of the treatments studied, treatment 10 (bag 615 ml + vermicompound) and 8 (tube 280 ml + Grass compound + cured bovine manure) were the most discrepant among them, while the lowest divergence was presented by T10 treatments and T1 (bag 615 mL + conventional substrate). These divergences can be noted using the mean distance between groups method in order to detect more divergent groups, as well as Dardengo et al. (2013). The highest quality indices were observed in T10; T1; T2, T7, and T4, and these treatments can be used for seedling production, such as T10, or even submitted for local selection, with an increase in the quality index.

Main component 1 (CP1) and main component 2 (CP2) contributed 64.13 and 17.03%, respectively, of the remaining variance. Thus, these agronomic variables of coffee seedlings highlighted in the first two main components CP1 and CP2 are considered important for the selection of treatment between container and substrates for the Alegre-ES region.

Figure 2 shows that negative correlations are responsible for the discrimination of treatments located on the left of CP1 (T11, T10, T1, T4 and T7) and positive correlations by treatment discrimination on the right of CP1 (T2, T3, T5, T6, T8, T9) while positive correlations by treatment discrimination was on the right of CP1 (T2, T3, T5, T6, T8, T9 and T12). The variables with positive correlation are responsible for the discrimination of treatments located at the top and bottom of CP2 while the variables with negative correlation are responsible for the discrimination of treatments located in the upper and lower part of CP2 (T10, T11, T7, T2 and T6).

You can note that the variables associated with seedling production are left-facing in CP1. When observing in Figure 1 the association between the groups of variables and the treatments formed between substrates and containers, it was seen that treatments 10, 11, 7, 4 have potentials to have higher total fresh mass values (FTM), nitrogen of the aerial part (NTPA), shoot length (CPA), number of leaves (NF), total length (CT), height and diameter ratio (ALT/DC), ratio of dry mass shoot sand root (MSPA/MSR) and Dickson quality index (IQD).

Regarding CP2, treatments 10, 11, 7, 4 present potentials, although weak, to have higher values of shoot dry mass (FTM), leaf area (PA), root length (CR), root nitrogen (NTR), crude aerial protein (PBPA) and crude root protein (PBR). In T1 occurs the reverse in which they

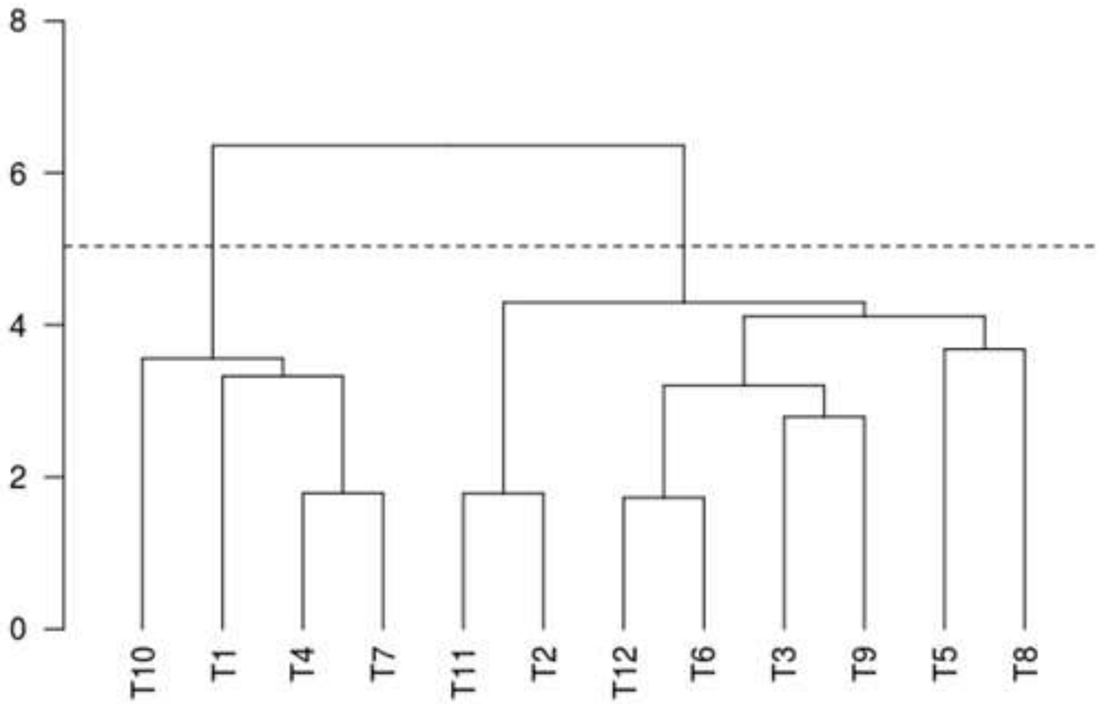

Figure 1. Representationof the dissimilarities between 12 treatments formed between substrates and coffee containers through theEuclidiana generalized distance.

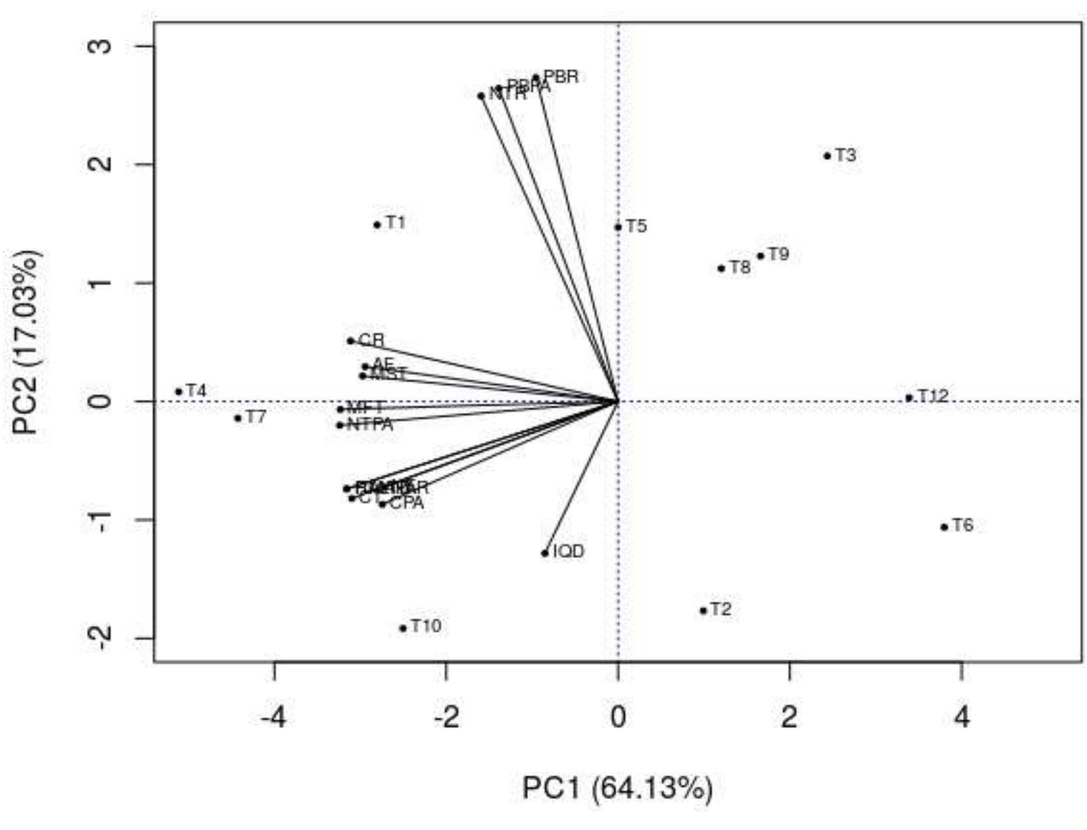

Figure 2. Analysis of main components in the evaluation of the quality of Arabica coffee seedlings produced with different substrates and containers.

Table 2. Analysis of correlations related to the characteristics evaluated in response to the types of substrates and containers.

Variable	CT	MFT	CR	CPA	RALT/D	MSA/R	IQD	AF	MST	NTPA	NTR	PBPA	PBR
NF	0.712	0.799	0.653	0.553	0.717	0.717	0.521	0.593	0.544	0.728	0.199	0.149	0.084
CT		0.818	0.873	0.873	0.941	0.941	0.318	0.630	0.716	0.847	0.278	0.195	0.038
MFT			0.903	0.573	0.868	0.868	0.241	0.839	0.837	0.961	0.311	0.343	0.089
CR				0.455	0.733	0.733	0.090	0.766	0.807	0.837	0.385	0.423	0.216
CPA					0.658	0.658	0.295	0.462	0.501	0.603	0.301	0.110	0.174
ALT/D						1.000	0.287	0.654	0.760	0.892	0.221	0.225	-0.061
MSA/R							0.287	0.654	0.760	0.892	0.221	0.225	-0.061
IQD								-0.186	-0.224	0.105	0.033	-0.101	-0.011
AF									0.947	0.905	0.251	0.311	0.151
MST										0.926	0.270	0.338	0.109
NTPA											0.275	0.324	0.060
NTR												0.472	0.876
PBPA													0.404
PBR													

present potentials to have higher values of dry mass shoot (MST), leaf area (PA), root length (CR), root nitrogen (NTR), crude shoot protein (PBPA), crude root protein (PBR), weak for the variables total fresh mass (FTM), nitrogen of the aerial part (NTPA), shoot length (CPA), number of leaves (NF), total length (CT), height and diameter ratio (ALT/DC), ratio dry mass shoot sand root (MSPA/MSR) and Dickson quality index (IQD).

The other treatments, although located on the right side, tend to have samples with less expressive characters, differentiating from treatments 10, 11, 7, 4 and 1. The main component technique has been used for the characterization of vegetable germplasm benches, such as coriander, onion and beans (Rodrigues et al., 2002; Leite et al., 2005; Magalhães et al., 2010) and has led to identification of important characteristics to be evaluated through previous studies of its contribution to variability (Pereira, 1989). This has enabled discarding of low-contribution characters for genotype discrimination or even evaluated treatments and, thus, it is possible to reduce labor, time and costs (Cruz et al., 2004).

Table 2 presents the correlation analysis according to the model developed by Wright (1934) to better understand the associations between different variables. According to Silva et al. (2010), characters with high positive correlations indicate the presence of an influence on another causing dependence. Thus, the total length obtained dependence on the number of leaves with 0.712 and total fresh matter obtained dependence on number of leaves and total length with 0.799 and 0.818, respectively.

In root length (CR), dependence was observed between CT and MFT with 0.873 and 0.903. For shoot length, the only dependence generated was with the variable total length (CT) with 0.873. For the correlations between, the ALT/D ratio were significant for NF, CT, MFT and CR with values of 0.717, 0,941, 0.868 and 0.733, respectively. Importance should be given to the root system of seedlings, in addition to morphological parameter studies to ensure better field performance. The roots are closely linked to seedling survival since every physiological process started in this soil water and plant environment system (Carneiro, 1995).

The height of the shoot is easy to measure and, therefore, has always been used efficiently to estimate the quality pattern of seedlings in nurseries (Gomes, 2013), and is also considered as one of the most important parameters to estimate growth in the field (Eloy et al., 2013), in addition to the fact that their measurement does not lead to destruction, being technically accepted as a good measure of the performance potential of the seedlings (Mexal and Lands, 1990).

In other research papers, the highest heights corresponded, in the field, to the highest survival rate and the highest initial growth for Pinus Radiata Pawsey and Pseudotsuga Menziesii (Richter, 1971; Pawsey, 1972). For the ratio dry mass shoot and root (MSA/R), there was cause and effect for variables: NF, CT, MFT, CR and ALT/D in which the effects were highly positive with 0.717, 0,941, 0,868, 0.733 and 1,000 showing high dependence among these evaluated character sets. The ratio of dry matter weight of the shoot/dry matter weight of the roots, despite being considered as an efficient and safe index to assess the quality of seedlings. Parviainen (1981) may be contradictory to express growth in the field (Burnett, 1979).

In the evaluation of Dickson's quality index (IQD), no cause and effect were observed between the correlations in which the values were low for variables; NF, CT, MFT, CR, CPA, ALT/D and MAS/R. The values obtained in the correlations in the present study are in accordance with those cited by Dardengo et al. (2013). In the evaluation in the leaf area correlation (PA) between the other variables, it was observed that only two characteristics presented dependence that were MFT (0.839) and CR (0.766).

Positive effect of CT characters were observed to evaluate the total dry mass (FTM), MFT, CR, ALT/D, MAS/R and AF with 0.716, 0,837, 0,807, 0,760, 0.760 and 0.947, respectively, but the same did not occur with Dickson's quality index (IQD) that obtained negative effect with -0.224 showing that when higher, the lower FTM values will be those of IQD. According to Ribeiro Júnior and Melo (2009), when the coefficient is negative, high values of one variable will be associated with low values of the other.

In the NTPA feature it was observed that it causes highly positive effect of NF characters; CT, MFT, CR, ALT/D, MAS/R, AF and MST with values of 0.72, 0,84, 0,96, 0,83, 0,89, 0,89, 0.90 and 0.92, respectively. In the bromatological character it is evident that the effect generated between NTPA in IQD and very low with 0.10 showed null effect. For the NTR and PTBA characters, no high-effect correlation scans were expressed and null effect may be considered. The same does not occur with the PBR character that correlates with values of 0.87 NTR. For the characteristics of IQD importance, MAS/R and ALT/D correlation are negative with -0.011, -0.061 and -0.061 showing that this characteristic has its null expression.

Conclusions

The analysis of main components, as an exploratory tool, allowed to identify the important variables in the characterization of treatments for seedling formation. Thus, it was possible to identify treatments 10, 1, 4, 7 as promising and with potential for the diffusion of technology in the process of seedling formation.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interest.

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