MINISTÉRIO DA EDUCAÇÃO

INSTITUTO FEDERAL DO ESPÍRITO SANTO

CONSELHO SUPERIOR

RESOLUÇÃO DO CONSELHO SUPERIOR Nº 18/2019,
DE 1 DE JULHO DE 2019

ANEXO III – Relatório Individual de Trabalho

Nome: Euzileni Mantoanelli	Matrícula Siape: 1766664
Classe / Nível: D-III-01	
Lotação: *Campus* Montanha	
Período de avaliação: 2020/01	

Justificativa de cumprimento

1 - ATIVIDADE DE ENSINO

1.1 - Avaliação discente

1.2 - Disciplinas Ministradas

- Execução de aulas de Produção Vegetal I para a turma: I16 e I18
- Execução de aulas de Produção Vegetal II para a turma: I12 e I14
- Execução de aulas de Agroindústria para a turma: I08 e I10
- Planejamento de aulas para as turmas I08, I10, I12, I14 , I16 e I18
- Atendimento extraclasse.

2- ATIVIDADE DE APOIO AO ENSINO

2.1 - Participação em Comissões e Conselhos ligados ao ensino

- Membro da comissão responsável pelo projeto Ifes Portas Abertas do campus Montanha: PORTARIA Nº 65, DE 26 DE MARÇO DE 2020.
- Membro da comissão responsável em organizar a "VI Ifestival" do campus Montanha, que acontecerá em 2020: PORTARIA Nº 64, DE 26 DE MARÇO DE 2020.

2.2 - Cumprimento dos prazos estabelecidos para atividades didático-pedagógicas

[X] 75% a 100% [ ] 50 a 74% [ ] menor que 50%

2.3 - Atendimento e participação em reuniões de cunho pedagógico/administrativo -

[X] 75% a 100% [ ] 50 a 74% [ ] menor que 50%

3 - ATIVIDADES DE PESQUISA E INOVAÇÃO TECNOLÓGICA

3.1 - Artigo em periódico internacional

QUARTEZANI, W. Z.; LIMA, Julião Soares de Souza ; PLETSCH, T. A. ; OLIVEIRA, E. C. ; BERILLI, S. S. ; MANTOANELLI, E. ; POSSE, R. P. ; SUCI, L. M. . Multiple linear and spatial regressions to estimate the influence of Latosol properties on black pepper productivity. AUSTRALIAN JOURNAL OF CROP SCIENCE (ONLINE), v. 13, p. 857, 2019.

QUARTEZANI, W. Z.; SALES, R. A. ; PLETSCH, T. A. ; BERILLI, S. S. ; MANTOANELLI, E. ; HELL, L. R. ; OLIVEIRA, E. C. ; NEVES, F. L. ; NEVES, J. D. C. . Effect of different proportions of urban organic compost on Conilon coffee (Coffea canephora) propagation. AUSTRALIAN JOURNAL OF CROP SCIENCE (ONLINE), v. 13, p. 821, 2019

4 - ATIVIDADES DE EXTENSÃO

5- ATIVIDADES ADMINISTRATIVAS

6 – OUTROS

Data:

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Assinatura Docente

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Assinatura do Coordenador

MINISTÉRIO DA EDUCAÇÃO

INSTITUTO FEDERAL DO ESPÍRITO SANTO

CAMPUS MONTANHA

DECLARAÇÃO

Declaro, para os devidos fins, que **Euzileni Mantoanelli**, Matrícula Siape nº **1766664**, cumpriu em 2020/1 de 75% a 100% das atividades didático-pedagógicas.

Montanha – ES, 18 de novembro de 2020.

MAURICIO VALENTIN JUNIOR

Assinado de forma digital por MAURICIO VALENTIN JUNIOR
Dados: 2020.11.18 09:48:13 -03'00'

Maurício Valentin Júnior
Coordenadoria de Gestão Pedagógica
Ifes campus Montanha

MINISTÉRIO DA EDUCAÇÃO
INSTITUTO FEDERAL DO ESPÍRITO SANTO
CAMPUS MONTANHA

DECLARAÇÃO

Declaro, para os devidos fins, que **Euzileni Mantoanelli**, Matrícula Siape nº **1766664**, ministrou em 2020/1**,** para o Curso Técnico em Agropecuária Integrado ao Ensino Médio, as disciplinas conforme descrito abaixo:

Disciplina: Produção Vegetal
Carga Horária Semanal: 16 aulas

Disciplina: Produção Agroindustrial
Carga Horária Semanal: 04 aulas

Montanha – ES, 18 de novembro de 2020.

MAURICIO VALENTIN JUNIOR

Assinado de forma digital por MAURICIO VALENTIN JUNIOR
Dados: 2020.11.18 09:48:44 -03'00'

Maurício Valentin Júnior
Coordenadoria de Gestão Pedagógica
Ifes campus Montanha

MINISTÉRIO DA EDUCAÇÃO

INSTITUTO FEDERAL DO ESPÍRITO SANTO

CAMPUS MONTANHA

DECLARAÇÃO

Declaro para os devidos fins que **Euzileni Mantoanelli**, Matrícula Siape nº **1766664**, atendeu em 2020/1 de 75% a 100% aos chamados de reuniões de cunho pedagógico/administrativo.

Montanha – ES, 18 de novembro de 2020.

MAURICIO VALENTIN JUNIOR

Assinado de forma digital por MAURICIO VALENTIN JUNIOR
Dados: 2020.11.18 09:47:41 -03'00'

Maurício Valentin Júnior
Coordenadoria de Gestão Pedagógica
Ifes campus Montanha

PORTARIA Nº 64, DE 26 DE MARÇO DE 2020.

O DIRETOR GERAL DO CAMPUS MONTANHA DO INSTITUTO FEDERAL DE EDUCAÇÃO, CIÊNCIA E TECNOLOGIA DO ESPÍRITO SANTO, no uso das atribuições que lhe confere a Portaria nº 1.070, de 05 de junho de 2014, da Reitoria-Ifes,

RESOLVE:

Art. 1º Designar os servidores abaixo para, sob a presidência do primeiro, comporem a comissão responsável em organizar a "VI Ifestival" do campus Montanha, que acontecerá em 2020:

a) TAIELE PINHEIRO DA SILVA DE MIRANDA PEÇANHA, matrícula Siape 3282426;
b) CRISLAINE APARECIDA SELLES OLIVEIRA CÔRTES, matrícula Siape 3137258;
c) MAIKE DOS SANTOS SILVA, matrícula Siape 1334191;
d) EUZILENI MANTOANELLI, matrícula 1766664;
e) GESSICA GONÇALVES MARTINS, matrícula 3136795.

Art. 2º A comissão tem o prazo de 150 (cento e cinquenta) dias para conclusão dos trabalhos, e/ou até 01 (um) dia após o término do evento.

Art. 3º Definir 03 horas semanais a carga horária do Presidente da comissão e 02 horas semanais para os demais membros, até o término do evento.

Art. 4º Esta Portaria entra em vigor nesta data.

ANDRÉ DOS SANTOS SAMPAIO
Diretor-Geral

MINISTÉRIO DA EDUCAÇÃO
Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo
CAMPUS MONTANHA
Rodovia ES-130 (Montanha-Vinhático), Km 1, Bairro Palhinha – 29890-000 – Montanha – ES

PORTARIA Nº 65, DE 26 DE MARÇO DE 2020.

O DIRETOR GERAL DO CAMPUS MONTANHA DO INSTITUTO FEDERAL DE EDUCAÇÃO, CIÊNCIA E TECNOLOGIA DO ESPÍRITO SANTO, no uso das atribuições que lhe confere a Portaria nº 1.070, de 05 de junho de 2014, da Reitoria-Ifes,

RESOLVE:

Art. 1º Designar os servidores abaixo, para sob a presidência do primeiro, comporem a comissão responsável pelo projeto Ifes Portas Abertas do campus Montanha:

a) ANDRÉ TEIXEIRA OLIVEIRA, siape 2050111;
b) CARLOS AUGUSTO BALLA, siape 2734077;
c) CLAUDIA DA CUNHA MONTE OLIVEIRA, siape 1652723;
d) EUZILENI MANTOANELLI, siape 1766664;
e) FORTUNATO BRUNETTI LAMBERT, siape 2420939;
f) MAIKE DOS SANTOS SILVA, matrícula Siape 1334191;
g) BILIRRELLI DA CUNHA MONTE, matrícula Siape 2325057.

Art. 2º Definir 02 horas semanais a carga horária dos membros.

ANDRÉ DOS SANTOS SAMPAIO
Diretor-Geral

Australian Journal of Crop Science AJCS

AJCS 13(06):821-827 (2019) ISSN:1835-2707
doi: 10.21475/ajcs.19.13.06.p1313

Effect of different proportions of urban organic compost on Conilon coffee (*Coffea canephora*) propagation

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Abstract

Brazil is the largest producer of Conilon coffee (*Coffea canephora*) in the world. The use of organic matter in substrates for clonal plant propagation is essential to promote favorable conditions for the development of both shoots and roots. Therefore, it is important for production systems to test new sources of organic matter such as solid urban waste. The objective of this study was to evaluate the effect of different proportions of composted urban waste on the propagation of Conilon coffee plants. The experiment was arranged in a randomized block design, with five replications and seven treatments. The treatments consisted of different proportions of composted urban waste (0, 15, 30, 50, 70, 90 and 100%), and biometric and quality characteristics of the clonal plants were evaluated. The results showed that proportions of composted urban waste higher than 50% added to the soil substrate promoted the highest plant growth rates, and even the lowest proportion of organic matter (15%) showed better results for all characteristics than the treatment without organic matter.

Keywords: Conilon coffee, Solid urban waste, Compost, clonal plant production, biometric characteristics.

Introduction

The coffee industry constitutes a significant fraction of Brazil's economy due to its contribution to foreign exchange revenue and transfer of income to other sectors of the economy, thereby creating a large number of jobs (Serrano et al., 2011). These jobs are created by harvest-related activities encouraging agricultural workers to settle in to stay at the countryside.
According to Braun et al. (2007), the adoption of the clonal system in the production of *C. canephora* it is important because increases the productivity of the sector, and provides high quality and productive plants, which is desirable characteristic for the producer.
Besides the adoption of the clonal system, the addition of organic matter to the substrate must certainly be considered in the production of high quality clonal plants of coffee. Organic matter, along with providing additional nutrients and improving soil structure, it increases microbiota and cation exchange capacity (CEC) (Silva et al., 2014), which results in greater plant growth in the nursery and influences the establishment of the crop in the field.
Some the sources of organic fertilizers that can be added to the substrate, includes composted urban waste (Sales et al., 2016; Quartezani et al., 2018), cattle manure compost (Sales et al., 2017), tannery sludge (Berilli et al., 2015; Berilli et al., 2016; Berilli et al., 2018), poultry manure, dairy residue, goat manure. Additionally plant residues and earthworm humus can be incorporated into the soil and sand in different proportions (Araújo et al., 2010; Oliveira Filho et al., 2013; Sales et al., 2018).
Junkes (2002) points out that the utilization of solid urban waste brings benefits such as reduction in the amount of waste to be disposed which increases the lifespan of landfills. Utilization of different wastes can also deliver preservation of natural resources, by saving energy in the production of new products, reduction of environmental impacts, and creation of new businesses and jobs. Caramelo (2010) observes that among the urban waste discarded

daily, the organic waste constitutes a large part of the total waste production and, when discarded improperly, it loses its full potential, acting only as a contaminant of natural resources; however, when used properly, it can serve as an excellent source of nutrients and for the generation of energy.

The combination of organic and mineral fertilizers can provide the plants with a balance that promotes rapid growth and maintains the physical and chemical characteristics of the soil under favorable conditions. Since mineral fertilizers have a rapid availability effect and can accelerate plant growth (Wang and Konow, 2002).

The urban waste compost is a material derived from the decomposition of plant and animal residues using or not chemical processes (Sabonaro, 2006). This compost has the ability to increase the phyto-availability of P, K, Ca, and Mg, in addition to increasing the pH and CEC, which reduces the potential acidity of the soil (Oliveira et al., 2002). Therefore, the use of composted urban waste in the substrate is an alternative for replacing or reducing the amounts of mineral fertilizers and reducing production costs, as well as being another source of organic matter for the production of clonal plants.

The literature describes several formulations of organic and inorganic substrates used in the farming of clonal plants. However different species show a specific response pattern to each substrate since species have different demands for nutrients (Almeida et al., 2012). In this context, the objective of this work was to evaluate the effect of different proportions of urban waste compost on the growth and quality of *C. canephora* clonal plants.

Results and discussion

Non-destructive morphological variables

The analysis of variance showed significant influence ($p <0.01$) of the proportions of the urban waste compost on all variables studied. The proportions used in this study had an effect on the growth of Conilon coffee plants. The regression equations show a linear increase in the number of leaf pairs (Figure 1a) and increase in the stem diameter (Figure 1d) with the increase in the proportion of the urban waste compost in the substrate.

The regression function $y = 3.149 + 0.0318x$ shows that for each addition of 20% of urban compost to the substrate, there is a gain of 20% in number of leaves, which can be explained by the high content of nutrients that the increase in organic matter provided. For instance, the chemical analysis showed that the levels of potassium and phosphorus in the soil were low for the coffee crop, with 52.0 and 4.0 mg/dm^3, respectively (Prezotti et al., 2007). These nutrients have the capacity to influence the number and size of leaves (Hoffmann et al., 2001) and thus affect the leaf area, which is an important variable for the understanding of the physiological mechanisms involving photosynthesis, respiration, fruiting, and yield (Demirsoy, 2009).

The increase in the proportion of urban compost yielded a linear increase in the leaf area at 120 days after grafting, and the leaf area had the fifth largest coefficient of regression $R^2 = 0.94$. Leaf area is a fundamental morphological characteristic of the plant and an excellent response variable for studies on the influence of organic matter sources on propagation and development of plants, according to works of Pedó et al. (2015), Lima et al. (2007), and Silva et al. (2017). Medeiros et al. (2010) found linear increase in leaf area of *atropha curcas* L. with the increase of organic matter in the substrate. The authors tested organic matter from cattle manure, poultry litter, and biosolids and found a growing linear response at 40 days after sowing for the three sources used in different proportions.

The gain in leaf area is attributed to the characteristics that the organic matter from the urban waste compost provided such as the increased water retention capacity and aeration, which facilitated the distribution of the root system and consequently increased the leaf surface in these plants (Hafle et al., 2009).

The increase in the proportion of urban waste compost also provided a linear increase in crown diameter (Figure 1c) and plant height (Figure 1b) during the production of clonal plants. This may be linked to the increase in the concentrations of Ca, Mg, P, and OM, besides raising the pH and reducing the Al^{+3} concentration in the substrate, factors that favor plant growth (Malavolta, 1997). Nóbrega et al. (2008) also found increasing linear response to urban compost in seedlings of *Anadenanthera macrocarpa* (Benth.) Brenan.

Destructive morphological variables

The addition of the urban waste compost to the substrate had a significant positive linear effect on the fresh and dry shoot masses (Figure 2a, c), with determination coefficient R^2 of 0.96 and 0.95, respectively. The equation $y = 0.450 + 0.0313x$ estimated increases of 0.625 grams for each 20% increase of urban waste compost in the substrate (Figure 2a), that is, a gain of 138 % in shoot dry mass, and this gain is linked mainly to the nutrients that this compost provided.

The root fresh and dry masses (Figure 2b, d) of Conilon clonal plants increased linearly with the addition of the urban waste compost. This increase may be related, among other factors, to the reduction in micropores and organic colloids (humus), which, according to Souza (2013), are responsible for the greater storage and availability of water and nutrients (soil solution) and increase in CEC, respectively. Another factor that may have contributed to this gradual increase is the increase in the level of phosphorus in the substrate, while the soil was being replaced by increasing concentrations of the urban waste compost. Phosphorus has a structural function, as a constituent of cell membrane phospholipids and as a component of nucleic acids, nucleotides, and coenzymes (Soprano et al., 2016).

The root fresh and dry masses (Figure 2b, d) of Conilon clonal plants increased linearly with the addition of the urban waste compost, which may be related, among other factors, to the reduction in micropores and organic colloids (humus), which, according to Souza (2013), are responsible for the greater storage and availability of water and nutrients (soil solution) and increase in CEC, respectively. Other factors that may have contributed to this gradual increase can be related to the increase in the level of phosphorus in the substrate, as the soil has been replaced by increasing concentrations of the urban compost. Phosphorus is related to structural function, as constituent

Table 1. Chemical characteristics of the soil used in the substrate for the clonal plants.

pH	P	K	P-rem	Ca	Mg	Al	H+Al	MO	SB	T	T	m	V
	--mg/dm^3--		mg/ml	-------mmol$_c$/dm^3-------				g/dm^3	----mmol$_c$/dm^3----			----%----	
5.3	4.0	52.0	20.0	11.6	9.3	0.5	14.0	1.5	22.2	36.2	22.7	2.2	61.4

P-rem: remaining phosphorus; OM: organic matter; SB: sum of bases; t: effective cation exchange capacity; T: cation exchange capacity at pH 7; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; H+Al: potential acidity; Al: aluminum; m: aluminum saturation; V%: percent base saturation.

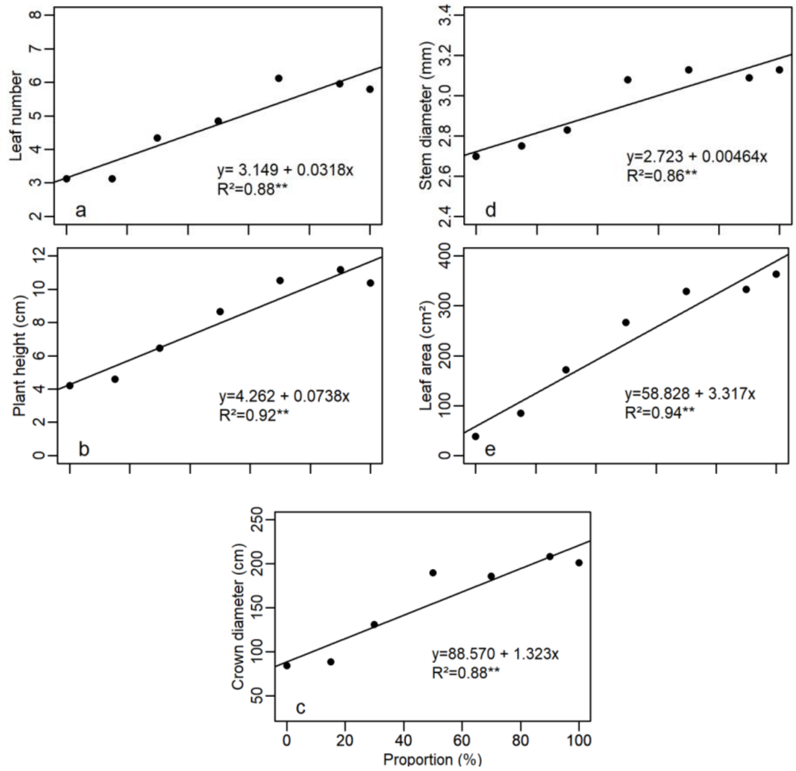

Fig 1. Regression analysis for leaf number (a), plant height (b), crown diameter (c), stem diameter (d), and leaf area (e) of Conilon coffee clonal plants as a function of urban waste compost concentrations.

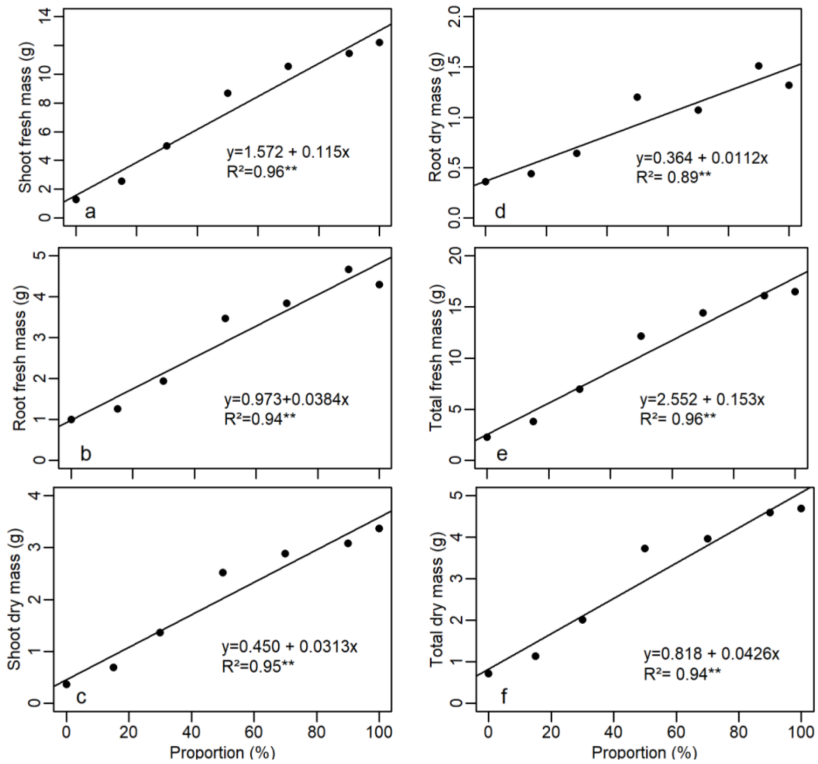

Fig 2. Regression analysis for fresh (a) and dry (c) mass of shoots, fresh (b) and dry mass (d) of roots, and total fresh (e) and dry (f) mass of Conilon coffee clonal plants as a function of urban waste compost concentrations.

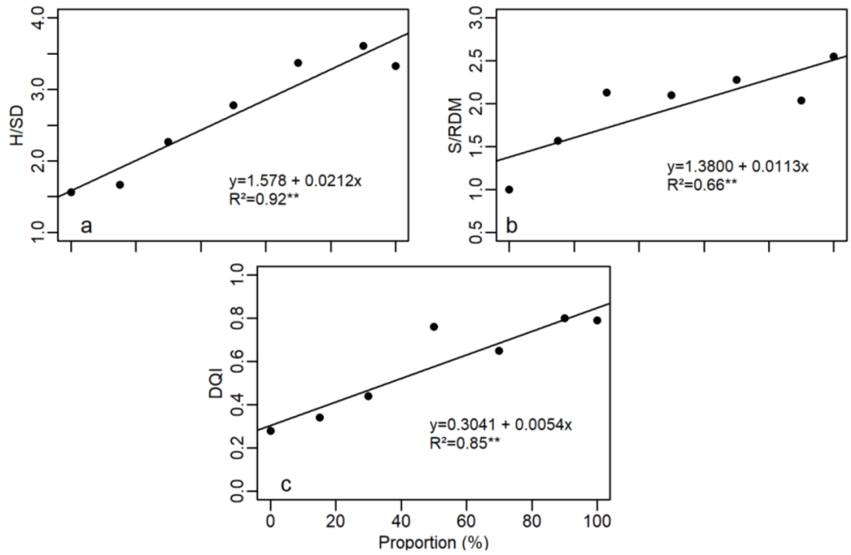

Fig 3. Regression analysis for the ratio between height and stem diameter (H/SD) (a), ratio between shoot dry mass and root dry mass (S/R DM) (b), and Dickson quality index (DQI) (c) of Conilon coffee clonal plants as a function of urban waste compost concentrations.

of cell membrane phospholipids, besides being a component of nucleic acids, nucleotides, and coenzymes (Soprano et al., 2016).

The total fresh and dry masses (Figure 2e, f) increased linearly with the increase in the concentration of urban waste compost in the substrate. Total dry mass (Figure 2e) increased 0.852 grams for each addition of 20% of compost to the substrate, corresponding to more than 100% gain for each addition of 20% of compost to the substrate. In general, organic matter confers important soil properties to plant growth such as increased microporosity and retention of water and nutrients, with consequent reduction in leaching and volatilization, increase in buffering capacity and cation exchange capacity, and reduction of soil density, which provide conditions favorable to plant development (Melo and Alleoni, 2009, Agne and Klein, 2014, Gomes et al., 2015, Soprano et al., 2016).

The quality of clonal plants is a very important factor for a good development in the field, thus, quality indexes have been extensively used as indicative of vigorous plants. In this study, the shoot/root dry mass ratio (Figure 3b) showed a linear increase in this quality index with the increase in the concentration of urban compost in the substrate, indicating that there was a greater allocation of photoassimilates for the production of shoots, which is essential to increase plant photosynthesis and achieve greater growth rates. The shoot/root dry mass ratios in this study ranged from 1.00 to 2.55 and were close to those found by Dardengo et al. (2013) for seedlings of Conilon coffee, which ranged from 1.10 to 1.48.

The ratio between height and collar diameter (Figure 3a) also showed a linear and positive increase, with $R^2 = 0.92$, which was the highest determination coefficient obtained among the quality characteristics, providing greater precision to the regression equation. The characteristic height/collar diameter ratio represents plant quality at any production stage (Gonçalves et al., 2014). The equation $y = 1.578 + 0.0212x$ estimated the gain obtained by the addition of 100% of urban waste compost at 2.12 for this characteristic; however, this result is below the range of 3.5 to 4 recommended by Marana et al. (2008).

Positive linear increase was also found for the variable Dickson quality index (DQI) for Conilon clonal plants with the increase of urban waste compost in the substrate. This is one of the most used indices in plant propagation as indicative of quality, since it comprises the variables stem diameter, shoot dry mass, root dry mass, total dry mass, and plant height.

The present work showed that the urban waste compost used in the substrate plays a fundamental role in the production of clonal plants of Conilon coffee. The addition of this organic compost to the substrate resulted in a increasing linear behavior of all characteristics evaluated, thus, it can be an alternative for replacing or reducing mineral fertilization at this stage of the crop implementation.

Treatments and composition of the materials used

The treatments were as follows: T-0: 100% pure soil; T-15: a mixture of 85% earth + 15% urban waste compost; T-30: 70% earth + 30% urban waste compost; T-50: 50% earth + 50% urban waste compost; T-70: 30% earth + 70% urban waste compost; T-90: 10% earth + 90% urban waste compost; T-100: 100% urban waste compost; All treatments received 10 grams of limestone and 10 grams of single superphosphate (FSS) per liter of substrate. The soil used for the substrate is classified as a Dystrophic Red Latosol (EMBRAPA, 2013), with the characteristics described in Table 1.

The urban waste compost comes from the municipal solid waste composting and sorting plant (SWP) of the Environment Agency of the city of Montanha-ES, which carries out waste sorting through selective collection and the final disposal.

Before the evaluation of the compost suitability for use in the propagation of clonal coffee plants, samples were analyzed for a complete characterization of the material and compliance with the Normative Instruction No. 27 (June 5

2006) (MAPA, 2006). This normative instruction regulates fertilizers, correctives, inoculants, and biofertilizers, and establishes limits on the maximum permitted values for microbiology, sanitation, plant health, and heavy metals for possible registration and commercialization. The compost composition was determined as follows: Moisture at 60-65 °C (%): 7.58; pH in CaCl2: 7.3; Total Organic Matter (%): 50.52; Compostable Organic Matter (%): 41.54; Organic carbon (%): 23.08; C/N ratio: 9/1; N (g/dm^3): 24.9; P (g/dm^3): 5.64; K (g/dm^3): 7.91; Ca (g/dm^3): 40.7; Mg (g/dm^3): 5.1; S (g/dm^3): 5.2; Fe (g/dm^3): 8.7; Na (g/dm^3): 6.3; Zn (mg/dm^3): 119.20; Cu (mg/dm^3): 32.50; Mn (mg/dm^3): 160.00; B (mg/dm^3): 39.50; Cr (mg/dm^3): 36.08.

The microbiological, sanitary, and phytosanitary characteristics were assessed and showed that the compost was free of thermotolerant coliforms (0 TTC/g), *Salmonella* ssp. (absence in TTC/10 g), viable helminth eggs (0 eggs/g TS), and soil fungi of the genus *Phytophtora*, *Pythium*, *Rhizoctonia,* and *Sclerotinia*. The maximum values found for the heavy metals cadmium (Cd: 6 mg kg^{-1}), lead (Pb: 31.50 mg kg^{-1}), chromium (Cr: 71 mg kg^{-1}), and nickel (Ni: 118.5 mg kg^{-1}) were below the maximum limits of contaminants allowed for use as soil conditioners, according to MAPA's Normative Instruction No. 27 (June 5 2006).

The plants were grown in 08x18x06cm plastic bags manually filled with the materials mixed in the treatment proportions, avoiding the compaction of the components, with soil density of 1.3 g/cm^3 and urban compost density of 0.6 g/cm^3.

The substrates were under continuous irrigation at the nursery until total humidification before the planting of the cuttings. Cloning was carried out 30 days after the filling of the plastic bags, using cuttings selected from shoots of clone nº 02, Var. Conilon "VITORIA INCAPER 8142". At the time of planting, the main stem of the shoot was cut about 3 cm below and 1 cm above the petiole. The secondary stems were cut 1 cm from the main stem, as well as 2/3 of the leaf area. All cuttings were treated by immersion in antifungal solution. Cultural treatments of seedlings over the experimental period were as recommended by Ferrão et al. (2012).

At 3 and 4 months after planting, foliar spraying of 20 grams of urea and 20 grams of potassium chloride dissolved in 10 liters of water was applied to the plants using a watering can. About 30 minutes after fertilization, the seedlings were hand-watered to wash the excess of fertilizer retained on the leaves.

At the end of the experiment, 120 days after planting the cuttings, the plants reached planting size and the following variables were determined: leaf number (LN); plant height (H), measured from the shoots at the base to the apex of the plant; crown diameter (measured from the furthest leaves on one side of the tree to the furthest leaves on the other side), stem diameter (measured with a pachymeter), leaf area, fresh and dry masses of shoots and roots, and total fresh and dry masses of the plant. The dry mass was obtained from an analytical balance after drying in a forced circulation oven at 72 °C for 72 hours.

Dickson Quality Index

Plant quality was assessed by the Dickson Quality Index - DQI (Dickson et al., 1960) as a function of the plant height (H), collar diameter (CD), shoot dry mass (SDM), root dry mass (RDM), and total dry mass (TDM), using Equation 1:

$$DQI = \frac{TDM(g)}{\frac{H(cm)}{CD(mm)} + \frac{SDM(g)}{RDM(g)}} \quad \text{Eq 1.}$$

Analysis of variance was performed using the open source program R (R *Core Team*, 2015), at 1% probability, followed by linear regression.

Conclusion

The addition of urban waste compost to the substrate promoted a linear increase in all evaluated characteristics. Gains were higher when using substrates with 50% or more of organic matter from urban waste. The utilization of urban waste as a substrate for the production of clonal plants of Conilon coffee may be an alternative for replacing or even reducing costs with mineral fertilizers.

Acknowledgements

The authors thank the Federal Institute of Espirito Santo - Ifes and CNPQ for the contributions to the accomplishment of this work and the financial support for the translation of this article.

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Australian Journal of Crop Science

AJCS

AJCS 13(06):857-862 (2019) ISSN:1835-2707
doi: 10.21475/ajcs.19.13.06.p1424

Multiple linear and spatial regressions to estimate the influence of Latosol properties on black pepper productivity

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Abstract

There is little knowledge available on the best techniques for transferring spatial information such as stochastic interpolation and multivariate analyses for black pepper. This study applies multiple linear and spatial regression to estimate black pepper productivity based on physical and chemical properties of the soil. A multiple linear regression including all properties of a Latosol was performed and followed by variance analysis to verify the validity of the model. The adjusted variograms and data interpolation by kriging allowed the use of spatial multiple regression with the properties that were significant in the multiple linear regression. The forward stepwise method was used and the model was validated by the F-test. The influence of the Latosol properties was greater than the residual on the prediction of productivity. The model was composed by the physical properties fine sand (FS), penetration resistance (PR), and Bulk density (BD), and by the chemical properties K, Ca, and Mg (except for Mg in the spatial regression). The physical properties were of greater relevance in determining productivity, and the maps estimated by ordinary kriging and predicted by the spatial multiple regression were very similar in shape.

Keywords: mapping, multivariate analysis, geostatistics.
Abbreviations: BD_Bulk density; CEC_Cation exchange capacity: CS_Coarse sand; ESP_Spherical model; EXP_Exponential model; Fcal_Test statistics; FS_Fine sand; LIN_Linear model; PNE_Pure nugget effect; PR_Penetration resistance; PRODUT_Producivity; R^2_Regression coefficient; SB_Sum of basis; SDI_Space dependence index; V%_Base saturation; Vp_Total volume of pores.

Introduction

According to Boari (2008), black pepper is an important spice for the international agricultural trade, and Brazil is one of the greatest producers of this commodity. In Brazil, plantations are concentrated in the states of Pará and Espírito Santo. In Espírito Santo, black pepper is usually cultivated in soil with low natural fertility. Because of the high nutritional requirements of the crop, the use of fertilizers is considered essential for rapid development and good productivity (Quartezani et al., 2013b). Quartezani et al. (2013a) studied the physical properties of soils of these areas and mapped soil particle-size fractions. This allowed for a visual diagnosis aiming at better managing black pepper plantations. Quartezani et al. (2013b), working with chemical properties, mapped the intensity of liming in black pepper plantations and confirmed the low fertility of the soils and the need to correct acidity to increase nutrient levels. This same study also enabled to identify priority areas for liming. The lack of knowledge on the preferential use and interaction of elements essential to achieve a more productive and profitable crop production demands the application of techniques of spatial information transfer. The main techniques for transfer are associated with deterministic or stochastic interpolation or with multiple regression analyses that consider spatially intervening parameters (Boni et al., 2008). The multiple regression analysis is a statistical method used to predict the values of one or more response variables (dependent) through a set of explanatory variables (independent) (Naghettini and Pinto, 2007). The more significant the weight of an isolated variable or a set of explanatory variables, the more we can be sure that certain factors affect the behavior of a specific response variable as opposed to others (Kasznar and Gonçalves, 2007). Lado et al. (2007) used multiple linear regression and ordinary kriging for modeling maximum, minimum, and average temperatures in the state of São Paulo. Gonçalves et al. (1990) found correlation between the solid volume of wood and the physical and chemical properties of the soil. The authors adjusted multiple regression models for sandy and medium texture soils of São Paulo. Gonçalves et al. (2008) sorted the environmental limitations to productivity in a descending order of importance: water deficit, nutrient deficiency, soil depth, and soil strength. Multiple and spatial regression techniques can be used to correlate predictive variables, such as soil properties with average crop productivity in large areas, thus providing equations or mathematical models to estimate the dependent variable at any point in those areas. Such analyses also provide the margin of error in the variable estimate as a quantitative unit. Therefore, the objective of this study was to apply multiple linear and spatial regression models to estimate black pepper productivity using chemical and physical properties of the soil as predictors.

Results and Discussion

Descriptive statistics and geostatistics

Table 1 presents the models and parameters of the variograms adjusted for soil properties and black pepper productivity. The Pearson's linear correlation analysis between chemical properties and productivity showed a low significant correlation of K with V% (0.28) but not with the other parameters. A high correlation between K and the properties related to soil fertility were expected, especially with SB, but this was not observed in the results. One explanation might be that the medium texture of the soil in the study area favors mobility, which is an intrinsic feature of this element. In fact, according to Werle et al. (2008), K tends to be scarcer in sandy soils due to its high mobility. Another explanation might be this crop high demand for K since sampling was conducted after harvest. The results suggest this kind of soil has no potassium supply capacity and that the exchangeable potassium is not enough to sustain crops for long periods. Therefore, the soil demands more frequent inputs of this nutrient. When the soil pH is high, a high and positive correlation of CEC with SB is expected, which did not occur in the analysis. Under high pH, the negative exchange sites on the soil colloids are freed up and basic cations are made available with the accompanying basic anion. At the same time, there is a moderate negative correlation between the pH value and the potential acidity (H + Al) as well as a high correlation with the amount of free Al. This is the case because when active acidity is reduced, more Al is precipitated and less hydrogen becomes available while the basic cations remain in the exchanging sites previously occupied by H and Al. However, in this study, the pH values were low, revealing an acidic soil with low Al precipitation and high hydrogen availability. The Pearson linear correlation between the physical properties and productivity showed a low negative correlation of BD with CS and a high correlation with Vp (-1.0). This was expected since Vp is calculated from the values of BD. PROD showed low positive and significant correlation with PR (0.43) and negative correlation with FS (-0.46).

The non-violation of the intrinsic hypothesis, a condition required for the use of geostatistics, was confirmed by the study of the stationarity of data using the trend analysis. The trend analysis showed that the soil properties in this study had little variation in all directions. It also allowed for spatial variability analysis by means of variograms standardized by variance. Due to the lack of stationarity of CS in the area as shown in Figure 1 (A), it was estimated using the parabolic trend surface as a function of the coordinates (x and y) and by working with the residuals from the model CSest = a + bx. As shown in Figure 1 (B), the variogram did not reach the sill expected in this analysis by failing to remove the linear trend between the semivariance and the sampling distance. In this circumstance, the original data was employed. Myers (1989) quoted by Lima et al. (2007) stated that working with residuals by fitting polynomials with the least squares method is reasonable, but not infallible.

It is worth noting that of the 20 properties studied, 16 fit the EXP model. The properties P and Mg showed no spatial dependence for distances larger than the shortest distance adopted in the sample and fit the PNE model. This implies the construction of a denser sampling grid with closer spacing to possibly define the spatial dependence distance. In this case, the mean value of the data is a good statistical measure to represent those properties. It is apparent from Table 1 that the chemical attributes Al, H+Al, and m% (aluminum saturation) display the same spatial distribution pattern. They reach sills close to 35.1, 38.7, and 33.9 m respectively and fit the same EXP model for the theoretical variogram, due to existing correlations in their determinations.

Multiple linear regression

In the multiple linear regression model, three physical properties (FS, PR, and BD) and three chemical properties (K, C, and Mg) were used to predict PRODUT and explained 55.1% of the total variance in productivity. This model can be accepted because the statistics (F_{cal}) indicates that these explanatory variables significantly reduce the variance of the dependent variable. In other words, the soil properties that entered the model have greater influence on the variation in productivity than the residuals at 5% probability level (Table 2). The results of the spatial multiple regression analysis in Table 3 shows, based on R^2, that the five dependent properties that entered the model explain 42.39% of the variability in productivity. However, as with the multiple linear regression, the analysis of variance of the spatial multiple regression statistically confirms, at 1% significance, the effect of soil properties on the productivity of black pepper.

Multiple linear regression and spatial multiple regression

The low R^2 of the spatial multiple regression (42.39%) compared with that obtained for the multiple linear regression (55.1%) is due to the fact that in the spatial multiple regression, we compare continuous surfaces created by interpolation using ordinary kriging and therefore, formed by a grid of interpolated values and not solely by "xyz" values . Moreover, the number of properties that entered the regression model to predict productivity is lower than that used in the multiple linear regression, and the adjustments to the variograms influence the accuracy of the kriging interpolation.

The results in this study confirmed the greater importance of the soil physical properties in comparison to the chemical properties for determining black pepper productivity. This

Table 1. Adjusted models and variogram parameters scaled to the soil properties and black pepper crop.

Property	Model	a (m)	C_0	C_0+C	SDI (%)	R^2 (%)	Cross-validation	
							R	p-value
pH	EXP	45.6	0.04	1.07	96.3	85.2	0.35	0.001
P	PNE	-	-	-	-	-	-	-
K	EXP	83.4	0.25	1.15	78.3	92.3	0.38	0.000
Ca	EXP	50.7	0.31	1.05	70.1	90.7	0.24	0.036
Mg	PNE	-	-	-	-	-	-	-
Al	EXP	35.1	0.13	1.07	88.4	87.0	0.35	0.006
H+Al	EXP	38.7	0.22	0.97	77.5	88.5	0.40	0.000
SB	ESP	24.4	0.16	1.03	84.2	97.4	0.30	0.007
CEC	EXP	97.8	0.47	1.12	57.8	72.5	0.25	0.021
V%	EXP	51.6	0.27	1.07	93.7	93.7	0.35	0.001
m%	EXP	33.9	0.23	1.09	79.3	75.9	0.30	0.005
U%	EXP	66.0	0.37	0.98	61.7	86.2	0.52	0.000
PR	EXP	51.0	0.00	1.11	99.9	81.3	0.46	0.000
CS	LIN	-	0.61	0.79	23.9	69.0	-	-
FS	EXP	25.8	0.27	1.03	73.9	78.0	0.24	0.025
Sil	EXP	25.8	0.25	0.89	72.0	87.6	0.32	0.030
CL	EXP	28.2	0.18	0.73	75.2	72.3	0.58	0.000
BD	EXP	27.6	0.26	0.84	69.4	88.7	0.42	0.000
Vp	EXP	25.8	0.26	0.85	69.5	87.6	0.41	0.000
PROD.	EXP	43.3	0.16	1.15	85.9	83.1	0.21	0.040

ESP: spherical model; EXP: exponential model; PNE: pure nugget effect; LIN: linear model; s: sill; C_0: nugget effect; C_0+C: range; SDI: space dependence index (C/C_0+C); R^2: adjusted coefficient of determination; r: cross validation correlation coefficient; e p-value: level of significance of the observed value estimated by the cross validation.

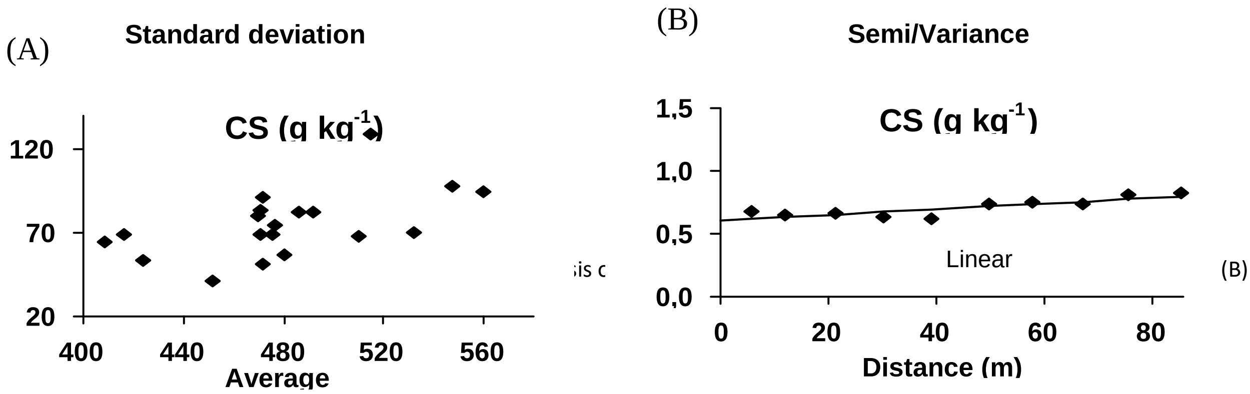

Fig 1. (A) Plot of standard deviation versus mean in the analysis of the proportional effect of the physical property Coarse Sand; (B) Scaled variogram of the physical property Coarse Sand.

Table 2. Stepwise multiple linear regression model of black pepper productivity and chemical and physical properties of the soil.

Input property	Model (Y = Productivity)	R^2 (%)	F_{cal}
FS	Y = 38.35 -0.21 * FS	24.0	11
K	Y = -0.17 * 38.07 FS-0.04 * K	34.2	8.8
PR	Y = -0.14 * AF-26.79 0.04 * K + 2.38 * PR	44.0	8.6
Ca	Y = 30.13 * FS-0.04 * K + 2.32 * PR-2.55 * Ca	49.7	7.9
BD	Y = -0.14 * 4.98 FS-0.04 * K + 2.55 * PR-2.48 * Ca + 14.9 * BD	52.9	7.0
Mg	Y = -5.13 -0.12 * FS-0.04 * K + 2.55 * PR-3.66 * Ca + 25.56 * BD + 2.99 * Mg	55.1	6.1

FS: Fine sand; K: Potassium; PR: Penetration Resistance; Ca: Calcium; BD: Bulk Density; Mg: Magnesium; R^2: Regression coefficient; F_{cal}: test statistics.

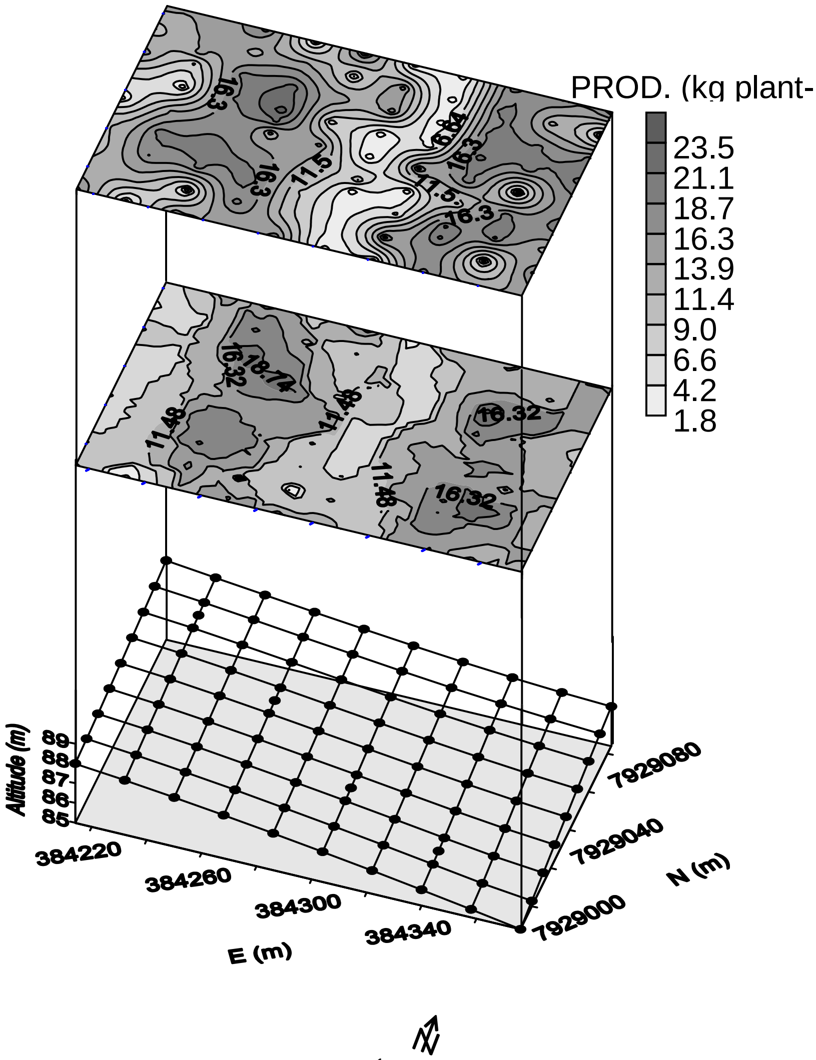

Fig 2. Maps of black pepper productivity (kg plant^{-1}) predicted by spatial multiple regression analysis (bottom layer) and estimated by ordinary kriging interpolation (top layer) over a 3D plane of the area.

Table 3. Spatial multiple regression model of black pepper productivity and chemical and physical properties of the soil.

Properties	Models (Y = Productivity)	R^2 (%)	F_{cal}
FS, K, PR, Ca and BD	Y = -0.25 * FS-0.10 0.04 * K + 0.68 * PR-0.05 * Ca + 0.11 * BD	42.39	395.86

FS: Fine sand; K: Potassium; PR: Penetration Resistance; Ca: Calcium; BD: Bulk density; R^2: Regression coefficient; F_{cal}: test statistics.

Table 4. Chemical and physical parameters of the studied soil.

pH	P[1/]	K[1/]	Ca[2/]	Mg[2/]	Al[2/]	H+Al[2/]	V[3/]	CS[4/]	FS[4/]	Sil[4/]	AR[4/]
4.8	83.2	75.7	1.5	1.1	0.4	4.5	39.5	476.1	108.6	131.1	286.1

[1/] mg dm^{-3}; [2/] cmol$_c$ dm^{-3}; [3/] %; [4/] g kg^{-1}; CS: Coarse sand; FS: Fine sand

finding is in accordance with those of other studies (Ortiz et al., 2006). According to Veloso and Carvalho (1999) quoted by Santos et al. (2012), studies undertaken in the top black pepper producing countries consistently show that the macronutrient requirement of the crop, in descending order, is as follows: N and K > Ca > Mg > P. The crop removes large amounts of nutrients, primarily N and K, from the soil. Interestingly,K is the first chemical property to enter the model and Ca is the second. Both variables have negative values, which indicates greater productivity in areas with low post-harvest levels of these elements due to crop intake. The low nutrient level and the minimal influence of chemical properties on productivity may be related to sampling during the harvest and to the great mobility of nutrients like K. On the other hand, it is clear that crop productivity is mainly influenced by physical properties such as PR, BD, and fine sand particle (FS). PR entered the model with a significant and positive value, thus revealing a direct contribution to productivity. In general, an inverse relationship between penetration resistance and crop productivity is found in publications since soil compaction tends to limit the crop root system (Lima et al., 2010). However, according to Embrapa (2006), this might not be the case for some tropical soils of the Latosol class, as those in the area of study, with high macroporosity and permeability.

Figure 2 presents and compares, in the same plane, the map of black pepper productivity (kg $plan^{-1}$) estimated by the ordinary kriging of values measured in the field with the map of productivity predicted by the spatial multiple regression analysis. The maps display similar behaviors with productivity varying in the same direction over the area and overlaying areas of low and high productivity. The map of the productivity predicted by spatial multiple regression was reclassified to match the scale of the map generated by kriging. With this, a difference can be seen between the maps regarding the range of each data series.

The data on productivity predicted by the regression had a lower range, or variability, than the data estimated by kriging. This was an expected result since productivity was determined by a multiple linear regression equation. As with Miranda et al. (2013), who estimated forest productivity using soil properties as predictors, we found a high degree of similarity between the two maps. Therefore, our findings confirm the feasibility of the model to predict black pepper productivity in areas with similar environments.

Materials and Methods

Plant material, location and designs

The study was conducted in a commercial black pepper plantation located in the municipality of São Mateus in the state of Espírito Santo, Brazil (18° 43' 37" south and 40° 05' 51" west and 87 m average altitude). The soils were classified, according to the Brazilian System of Soil Classification, as typical RED-YELLOW DYSTROPHIC LATOSOLS of sandy clay loam texture (Table 4). The soils have good physical characteristics, are well-drained with good infiltration rate and depth, but with low natural fertility. Four-year-old black pepper plants derived from the vegetative propagation of herbaceous cuttings of the high-yield variety Bragantina were used in the study. The plants were grown in the usual spacing of 3.0 x 2.0 m, in a single row system on ridges to avoid waterlogging. Data were collected in a selected plotof 15,500 m^2 (162 m long and 96 m wide), with 94 sample points spaced 18 m x 12 m apart forming a regular grid. Each sample point represented an area of 216 m^2.

Statistical analysis

Before running the spatial multiple regression, there are assumptions that have to be confirmed: that the dependent variable is normally distributed; that the number of observations is greater than the number of independent variables; and that there is no exact or close linear relationship between independent variables (no multicollinearity). When two independent variables showed a correlation coefficient greater than 0.80, one of them was excluded from the multiple linear regression model to avoid multicollinearity. Initially, a multiple linear regression analysis was performed with the chemical and physical data, which were considered mutually independent. Then, an analysis of variance was also performed to validate the model for prediction of productivity. The stepwise regression, which is often chosen for exploratory studies, was used. In this regression, the input sequence of parameters into the equation follows no theoretical model and is set statistically (Abbad and Torres, 2002). Productivity, the dependent variable (Y), was estimated based on the procedures described by Ortiz et al. (2006) and Diggle and Ribeiro Jr. (2007) by including the independent variables (X) into the model at each step (forward stepwise) to explain the Y behavior. In this case, the model required a multiple linear regression to verify the relationship between "xyz" data. It is possible, however, to perform this analysis with a spatial approach by examining the relationship between the resulting maps. To do this, the spatial multiple regression tests cumulative dependencies of a single dependent variable in relation to a number of independent variables based on their known geographical coordinates. Thus, for example, when three independent variables are used to explain one dependent variable, the equation of the spatial multiple regression becomes:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3$$

Where, Y is the dependent variable; x1, x2, and x3 are the independent variables; a is the intercept; and b1, b2, and b3 are the coefficients of the independent variables which define the increase (or decrease) of variable Y for a one-unit change in variable Xi.

Stationarity conditions must be fulfilled to build and interpret the variogram, which was tested by plotting means against standard deviations calculated for each row and column of the soil parameters. For stationarity to occur requires that the mean and variance are not correlated, given that the proportionality of the variance to the mean is determined by the significance of the linear regression analysis at 5 % probability. Since the data did not comply with stationarity, a second-degree parabolic trend surface was applied by working with the residuals towards an intrinsically stationary process. Once stationarity was assumed, the geostatistics analysis attested the spatial dependence of the soil properties with the equation:

$$\hat{\gamma}(h) = \frac{1}{2\,N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2$$

where N(h) is the number of pairs of the measured values Z (xi) and Z (xi + h) separated by a vector h; and Z (xi) is the random variable in the i-th position.

Gaussian, exponential, and spherical models were tested for adjusting the variograms with determination of the parameters nugget effect (C_0), sill (C_0 + C), and range (a) of spatial dependency.

Ordinary kriging was used to estimate soil properties in unsampled locations. This method of interpolation applies a linear unbiased estimator with minimal variance and takes into account the structure of the spatial variability found for each property. It is defined by the following equation:

$$Z(x_0) = \sum_{i=1}^{N} \lambda_i Z(x_i)$$

where $Z(x_0)$ is the value estimated for the x_0 unsampled location; $Z(x_i)$ is the value obtained by sampling in the field; and e λ_i is the weight associated with the measured value at x_i position.

The data interpolated by ordinary kriging allowed the creation of thematic maps for each of the soil properties and crop productivity, thus it was possible to run the spatial multiple regression using the properties that were significant for productivity in the multiple linear regression. A map of crop productivity was modeled by multiple regression aiming to decrease the number of properties in the analysis to simplify the process and reduce the effect of errors accumulated.

In order to determine the number of explanatory properties (predictors) in the adjustment of the spatial multiple linear regression model, a stepwise forward regression was performed with STATÍSTICA 8.0. The method begins with an empty equation in which the predictors are entered individually until the best predictors are identified. The validation of the results was tested by the F statistics and R^2 values. R^2 shows how much of the total variability of the dependent variable can be explained by the model. In other words, it shows how much of the variance of the dependent variable can be explained by this specific group of independent variables. For visual analysis, an isoline map was created and compared with both the productivity values predicted by the multiple regression model and with the values estimated by kriging.

Conclusions

1. Both the multiple linear regression and the multiple spatial regression resulted in models that are suitable to predict the productivity of black pepper.
2. The physical properties of the soil are more relevant to the productivity of black pepper than the chemical properties, with the multiple spatial regression having a lower coefficient of determination (R^2) than the multiple linear regression.
3. The maps estimated by kriging and predicted by spatial multiple regression were highly similar thus confirming the feasibility of regression models to predict black pepper productivity in areas with similar environments.

Acknowledgments

The authors thank the Instituto Federal do Espírito Santo (IFES) for the financial support for the translation of this article.

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