Physicochemical characteristics of substrate obtained through composting of residues from cotton and poultry industries

Características físico-químicas do substrato obtido através da compostagem de resíduos da indústria do algodão e da avicultura

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ABSTRACT
Although it is widely used, peat is a material from geologic origin, with high environmental impact in its extraction and scariness in the market, factors that lead to the increase of its cost. Based on these aspects, searching new alternatives for the development of inoculant carriers is necessary as the use of industrial and agricultural waste is environmentally very important. The objective of this study was to physicochemically produce and characterize an inoculant substrate obtained through composting of residues from the cotton and poultry industry. Initially, residues of cotton seed hull (CH) and laying hen manure (HM) were analyzed so as to know the macro and micronutrients content and the ratio between C and N. The experimental design was completely randomized with six treatments and four replications. The treatments were elaborated based on the raw material of HM and CH, resulting in different named formulated: SUB-A0, SUB-A1, SUB-A2, SUB-A3, SUB-A4 and SUB-A5. The following physicochemical parameters were analyzed: current moisture, wet density, dry density, water retention capacity, pH, electrical conductivity, organic carbon content, total nitrogen, C/N ratio, ammonium and nitrate. The analytical results demonstrate that compared to peat, formulated substrates have similar physicochemical characteristics and potential use as inoculant carrier.

Keywords: organic compounds, biological fixation, inoculant carrier, gossypium hirsutum, peat.

RESUMO
Embora muito utilizada, a turfa é um material de origem geológica, com alto impacto ambiental na sua extração e escasse no mercado, fatores que levam ao aumento de seu custo. Com base nesses aspectos, a busca de novas alternativas para o desenvolvimento de carreadores de inoculantes se faz necessária, pois o aproveitamento de resíduos industriais e agrícolas é ambientalmente muito importante. O objetivo deste trabalho foi produzir e caracterizar físico-quimicamente um substrato inoculante obtido por meio da compostagem de resíduos da indústria do algodão e da avicultura. Inicialmente, foram analisados residuos de casca de caroço de algodão (CH) e esterco de galinha poedeira (HM) para conhecer os teores de macro e micronutrientes e a relação entre C e N. O delineamento experimental foi inteiramente casualizado com seis tratamentos e quatro repetições. Os tratamentos foram elaborados base nas matérias-primas de HM e CH, resultando em diferentes denominações formuladas: SUB-A0, SUB-A1, SUB-A2, SUB-A3, SUB-A4 e SUB-A5. Os seguintes parâmetros físico-químicos foram analisados: umidade atual, densidade úmida, densidade seca, capacidade de retenção de água, pH, condutividade elétrica, teor de carbono orgânico, nitrogênio total, relação C/N, amônia e nitrito. Os resultados analíticos demonstram que, em comparação com a turfa, os substratos formulados apresentam características físico-químicas semelhantes e potencial de uso como transportador de inoculante.
1 INTRODUCTION

The production and usage of inoculants in Brazil started in 1956 and since then, the inoculant trade had followed the price fluctuations and soybeans planted area as well as international companies that began to dispute the national market, especially the ones coming from the Mercosul. In Brazil, the majority of the commercial inoculants are produced as peat-based, which is a geologic material with elevated organic matter content, high in nutrients, low chloride content, free from sand, and needed of a long period to form, of which its exploitation is extractive. Consequently, the renewal is difficult, the availability is small and restrict to a few countries, it is often imported, the exploitation requires careful environmental licenses, and it is subject to being scarce.

The low quality of the national peat and the high costs of the imported peat create a demand for a substratum that would be easy to extract/produce, low cost and adequate to guarantee the survival, in large amounts, of the inoculated microorganisms until the moment of its use. The search for substrata and the addition of compounds as a new option for diastrophic bacteria inoculation are reported by several papers, among them, the ones cited by Ferreira et al. (2003) and Lorda et al. (2007).

There are several types of waste that even though they cause environmental problems, they have high potential use as organic fertilizer, soil conditioner, plants substrates or inoculant. Agroindustry as well as agriculture produces large amounts of waste, which has high value because of its organic quality that can be treated and used, avoiding environmental problems due to the improper disposal.

The process of cotton industrialization produces a residue composed of hull (pericarp) of the green or dry boll, and small fiber fragments that had not been used by the machines. This residue, which is popularly known in some regions as cotton seed hull, that if not adequately managed becomes a huge environmental pollutant, especially by particles with reduced size and containing fibers in it.

According to the National Solid Residues Policy – Política Nacional de Resíduos Sólidos -, the management of waste produced in diverse producing sectors is the responsibility of companies and industries (Brasil, 2010). Therefore, the management programs must choose alternatives for recycling and using of these residues. Composting is a viable alternative for converting the residue from the cotton industry into inoculant carrier for microorganism.
Barbosa (2009) reported that composting is a process of converting organic residues into humified organic fertilizers. In other words, it consists of using the raw materials that contain a carbon/nitrogen ratio favorable to the growth of microorganisms that will perform the digestion in case they happen to be inoculated.

The usage of agricultural waste becomes important so as to decrease the pressure on the exploitation of natural resources used for making fertilizers and the costs from agricultural inputs in the productive system (Marques et al., 2007). However, scientific studies have proven the efficacy of these residues applied to the soil under different crops, mainly as source of organic matter and enhancing its chemical and physical properties (Trannin et al., 2007), thus encouraging even more use of it.

In order for the bacteria with high potential for biological nitrogen fixation, or other microorganisms with vegetal growth promoting effect, to reach the farmer in a viable condition, it is necessary inoculant carriers capable of maintaining them biologically active (Guiramães et al., 2013). According to the Normative Instruction n°13 of 24/03/2011 from the Brazilian legislation (Brasil, 2011), it is required that the inoculants should be capable of maintaining a minimum concentration of $10^8$ viable cells per gram of the product for at least 180 days. Some materials with low cost, described as residues and with potential of use as inoculant carrier, such as sugarcane bagasse, rice husk, wheat bran, charcoal, wood shavings, mining waste, and others, have raised interest of some researchers (Schlemper & Sturmer, 2014; Czerniak & Sturmer, 2014; Silveira et al., 2013; Canellas et al., 2013). However, there are no studies of the usage of cottonseed hull and reports about the physicochemical characterization of composted substrate for inoculation purposes either.

Considering the large local availability of residue in the cotton industry and its possible usefulness as an inoculant carrier, this paper aimed to evaluate the physicochemical characteristics of an inoculant substrate obtained through the composting of residues from the cotton industry and laying hen, compared with the characteristics of peat.

2 MATERIAL AND METHODS

The experiment was conducted at Guanambi municipality, southwest region of the state of Bahia, situated at 528m of altitude, coordinates 14°13’S; 42°46’W, from July 2013 to July 2014. According to the Koppen climate classification, the climate is in transition between Aw and BSw”h”, hot and dry semi-arid.
The temperature and relative humidity, inside the shed where the experiment was conducted, were obtained with the thermo-hygrometer, model 7663.02.0.00 of the Incoterm® brand. The temperature and average relative humidity occurred over the period of this study were 30.2 °C and 51.2 %, respectively, in which the measurements were taken always at 13:00h.

Initially, analysis of the physicochemical characteristics of the utilized residues was conducted. The moisture in the raw residues, which was determined by oven-drying at 105 °C, was 7.5% in the cotton hulls and 13.9% in the bird manure. The macro and micronutrients contents in the used waste were determined through nitric-perchloric digestion. Then, the extracts were used to determine S and P by colorimetry, Ca, Mg, Cu, Fe, Zn, and Mn were quantified in an equipment of atomic absorption, Na and K in a flame photometer and the total of T through the Kjeldahl method.

The experimental design was completely randomized with six treatments and four replications. The treatments were elaborated based on the raw material of laying hen manure (HM) and cottonseed hulls (CH), resulting in different named formulated: A0, SUB-A1, SUB-A2, SUB-A3, SUB-A4 and SUB-A5. These compositions were formulated by IFBAIANO Campus Guanambi Soils Laboratory and are in prior art search process for patent registration.

By being a widespread inoculant carrier, a national peat was used so as to make comparisons between treatments. The peat, coming from Embrapa Agrobiologia, went through an improvement process composed of sifting, milling and pH adjustment with the addition of CaCO₃.

The process for obtaining formulated was through compost piles arranged in conical shape and randomly distributed in the shed making each experimental unit. Every three days, samples were collected to determine the water content, and the temperature of each compost pile was measured with portable digital thermometer model TH-075 from the Instrutherm® brand. The moisture content in the compost pile was always maintained around 45% of moisture with addition of water, calculated based on its content previously collected, and then they were homogenized for controlling the temperature and aeration for maintenance of the microbial activity. To obtain the water content, the collected samples were weighed on an analytical digital balance, oven dried at 105°C for 24 hours and weighed over again.

In the end of the composting period formulated substrates were obtained (SUB-A0, SUB-A1, SUB-A2, SUB-A3, SUB-A4 e SUB-A5) was weighed, sifted and determined the water content and the percentage of reduction by the difference between the initial and final masses.

Samples from the different treatments were collected and crushed by Wiley knife mill, and then taken to conduct the physicochemical analysis. The current moisture (CM), the dry density (DD), the water retention capacity (WRC₁₀), the potential hydrogen (pH), and the electric
conductivity (EC) were determined according to specific methodologies described in the Normative Instruction n°17, of the May 21\textsuperscript{th} of 2007, of the Ministério da Agricultura, Pecuária e Abastecimento – Ministry of Agriculture and Supply – (Brasil, 2007) that approves the official analytical methods for analyzing the substrates and conditioners of the soil.

The current water moisture was determined by taking an aliquot of 100 g of the sample to an oven (65 °C ± 5.0 °C) until the constant mass was reached. The wet density was obtained through the auto compaction method by using a clear plastic graduated cylinder with 500 mL, so that the cylinder was filled with substrate with the current moisture up to 300 mL and then letting it drop from a height of 10 cm on its own mass for 10 consecutive times.

The water retention capacity was quantified after saturation and ceasing the drainage, when a pressure of 10 cm of water column (0.98 kPa) was applied. The pH was determined in extract suspension 1:5 (v/v) obtained through an agitator, Wagner type, after an hour of stirring at 40 rpm. Afterwards, this suspension was passed through a quantitative filter paper (white ribbon), disposing the first 10 mL. After an hour of extraction of the filtrate, the electric conductivity (EC) was measured.

To determine the organic carbon (%OC), a sample was oven dried at 105°C and thereafter it was calcined with muffle furnaces at 450°C ±10°C during 8 hours, wherein it was obtained the organic matter content (%OM), from the formula: \( \%\text{OC} = \%\text{OM}/2 \) (Zucconi & de Bertoldi, 1987). The total nitrogen content was determined by Kjeldahl method, and using the microdistillery method and the inorganic nitrogen (\( \text{NH}_4^+ + \text{NO}_3^- \)), it was determined by steam distillation, both described by Silva (2009).

The obtained data were tested by variance analysis and when the means are significantly different from each other, they were subjected to the Scott-Knott (P<0.05) test, using the statistical program SISVAR (Ferreira, 2011).

3 RESULTS AND DISCUSSION

The results of the chemical analysis for determination of macro and micronutrients in the solid wastes used to compose the formulated are shown in Table 1. As expected, it turns out that the nutrient content in laying hen manure is higher than in cottonseed hulls, except only for carbon, as also observed by Seoudi (2013) evaluating the two types of residues. It is known that the chemical composition of the manure of laying hens can vary depending on the genetic characteristic and feeding of the birds, however, Oustani et al. (2015) found similar values in the composition of macro
and micronutrients in the residue, which was used by these authors to increase the potato yield under saline conditions in arid regions.

The microbial activity on the organic matter of the compost results in marked losses of organic C unattached to the atmosphere as CO$_2$ form, thus reducing the volume of the final compost up to 1/3 of the initial volume (Inácio & Miller, 2009). Table 2 shows that the SUB-A4 and SUB-A5 formulated underwent minor reduction of 44% and 38%, respectively, between the initial and final mass when compared to the others. The reason for this lower reduction is the higher proportion of cottonseed hulls in the compost, which increases the C/N ratio and hinders the decomposition of microorganism. Seoudi (2013), in a study to accelerate the composting of cotton residue, found reduction of the initial dry mass ranging between 37% and 49%, in a way that the lowest percentage of reduction there was no addition of external microorganisms and the higher reduction percentage was achieved with the addition of *Phanerochaete chrysosporium* and *Azotobacter chroococcum*.

Silva et al. (2011) studying the characterization of organic waste compost, observed reductions of 49% of the initial wet mass and 34% of the initial dry mass, these results were lower than those observed in this study. Contrastingly, this volume loss is responsible for concentration of the other elements, resulting in higher levels of nutrients, including nitrogen, a factor of interest for maintenance and viability of microorganisms. At the end of the composting process, the moisture content of the substrates varied between 19% and 29%, with the highest values observed in treatments with high proportion of cottonseed hulls.

In the Table 3 are arranged the results of physicochemical characteristics, made after obtaining the substrates. The average percentage of current moisture was 2.43%, and the highest observed value was in the SUB-A5 formulated, corresponding to 3.36%. The formulated SUB-A0, SUB-A1 and SUB-A4 were not different, but they differed between the other formulated, showing the lowest percentage of moisture, 2.24%, 1.79% and 2.13%, respectively. Possibly, the reason for the increased moisture content is related to a higher proportion of cottonseed hulls, resulting in a greater presence of negatively charged organic compounds and a higher water retention.

The bulk density comes from the ratio between the mass and the total volume of a sample (Fermino & Kampf 2012). The determination of this parameter becomes important in the interpretation of other characteristics such as porosity, air space, water availability, plus the salinity and nutrient content. The wet and dry densities showed a tendency of reduction in the extent to which increased the proportion of cottonseed hulls and reduced laying hen manure proportion. The
SUB-A0 formulated showed the highest density (1337.2 kg m$^{-3}$) and SUB-A5 the lower density (561.4 kg m$^{-3}$), whereas the average is 773.3 kg m$^{-3}$.

The water retention capacity (WTC$_{10}$) refers to the maximum amount of water retained in the produced substrate after being subjected to a 10 cm water column pressure (0.98 kPa). This parameter has a close relationship between the density and particle size, and the reduction in the value of these parameters increased the WTC$_{10}$. It is observed that the SUB-A0 and SUB-A1 formulated had the lowest WTC$_{10}$ values, 45.1% and 46.6%, respectively, statistically differing from the others, however not among themselves. The SUB-A5 formulated showed higher WTC$_{10}$, corresponding to 56%, statistically differing from the others.

Among the chemical properties of organic materials, substrates and conditioners applied to soil, the pH value is very important, since very low or high values can promote the unavailability of nutrients or cause toxicity by micronutrients in some plants (Bailey et al. 2013). Therefore, pH values between 6.0 and 7.0 occur suitable nutrient availability (Schmitz et al., 2002) and provide ideal conditions for the growth of microorganisms. Given the above, it can be seen in Table 3 that the analyzed treatments show average value of pH 7.58 while the peat used as a reference has a pH = 6.22. In this case, it would be unnecessary to correct the pH of the substrate, unlike the raw peat that becomes necessary to raise the pH with addition of CaCO$_3$. It was observed that there was a decreasing variation in the pH value from 7.91 to 7.18 between formulated due to the reduction of the amount of laying hen manure in the proportion of the substrate.

Besides the availability of nutrients, pH and exchangeable cation levels can influence the growth of microorganisms in the substrate. According to Brady & Weil (2013), high concentrations of calcium and almost neutral pH provide to the soil greater amount and diversity in the bacterial population. Otherwise, in low pH conditions fungi become dominant in the microbial population. Ferreira et al. (2010) selecting peat-based inoculants containing diazotrophic bacteria, had to raise the pH of peat up to 6.0 by addition of CaCO$_3$ so as to provide the conditions required to maintain viability and survival of *Herbaspirillum Seropédica*, *Burkholderia sp.* and *Azospirillum brasiliense*. Guimarães et al. (2013), studying the viability of peat inoculant produced with associative bacteria and molybdenum, raised the pH of the peat to 7.0, with the addition of CaCO$_3$, in order to guarantee an enabling environment for growth of the studied microorganisms.

Electrical conductivity (EC) in general showed a decrease with the reduction in the amount of chicken manure in the substrate composition. The SUB-A0 formulated showed the highest EC (35.90 mS cm$^{-1}$) whereas the lowest EC value (10.28 mS cm$^{-1}$) was observed in treatment with the highest levels of cottonseed hulls (SUB-A5), differing from the others. By comparing the EC of the
substrates obtained with peat, it is noted that the value thereof come to be approximately between 2 and 8 times superior, quite possibly due to greater presence of basic cations. The EC and the pH showed similar effects, reducing the extent to which the proportion of cottonseed hulls increased and chicken manure decreased. The more alkaline is the pH, the higher is the presence of basic cations, which contributes to increase the EC, and this was confirmed in the analysis of residues previously described in Table 1.

The data presented in Table 4 show the variation of the chemical parameters analyzed in the different obtained substrates. The content of organic carbon (OC) becomes increasing the extent to which it increases the proportion of cottonseed hulls ranging from 26.98% to 30.86%. Seoudi (2013) observed a variation in OC content between 30.65% and 36.06% on substrates obtained by composting cotton waste with chicken manure or inoculated with different microbial decomposers. The increase in the OC content probably was due to the increase of lignocellulosic compounds, carbon-rich, naturally present in this type of residue (Shi et al., 2006; Yu et al., 2007).

The total nitrogen content (total-N) did not vary between treatments, and the mean observed value was 2.89%. Evaluating composting residues of cotton industry with sheep manure, Albanell et al. (1988) also found no change in total-N content throughout its evaluation, which 2.19% is the average total-N, after twelve weeks of composting. The observed values of the total-N content were close to those found by Seoudi (2013).

The ratio of C/N among the studied formulated varied from 9.10 (SUB-A0) to 10.49 (SUB-A5), and the mean value was 10.08. The SUB-A2, SUB-A3, SUB-A4 and SUB-A5 formulated did not differ between themselves, although they differed from the others. Compared with peat that is a widely used inoculant, it can be seen that the value of C/N ratio of the obtained substrates can be increased by adding more cottonseed hulls or reducing laying hen manure, in the proportion thereof. However, the use of substrates with C/N ratio above 30 may result in an inoculant with a limited ability to maintain the viability and survival of microorganisms due to the low availability of nitrogen, since this is essential for the growth and reproduction of the microorganism (Valente et al., 2009).

The NH₄⁺ concentration (table 4) varied between 460.18 and 1191.75 mg kg⁻¹, and the mean value observed was 755.17 mg kg⁻¹. Comparing to the peat, the concentration of NH₄⁺ in studied formulated was inferior suggesting that these substrates have achieved greater state of maturity. Another reason is that at high pH and moisture conditions occurs the conversion of NH₄⁺ into ammonia (NH₃), which is lost in the form of gas. The SUB-A0 and SUB-A1 formulated showed the
highest concentration of NO$_3^-$, 601.78 and 342.19 mg kg$^{-1}$, differing from each other and the other formulated.

The ammonium (NH$_4^+$) is the dominant form of nitrogen in chicken manure (Oviedo-Rondon, 2008), which is the main reason to be present in higher concentrations in the formulated where the proportion of the residue is greater. Nitrate (NO$_3^-$) is present in chicken manure, however it is in lower proportion and more likely to be lost by leaching due to its ionic form.

Melo et al. (2008), characterizing the organic matrix of residues from diverse origins, also noted that the NH$_4^+$ levels were higher than those of NO$_3^-$ in chicken manure, in which the values were 608.00 and 58.00 mg kg$^{-1}$, respectively. The inorganic nitrogen contents are useful to indicate the degree of decomposition of these residues, and with a greater degree of maturity, there is a tendency of decrease of NH$_4^+$ and increasing of NO$_3^-$, due to the action of nitrifying bacteria (Sanchez-Monedero et al., 2001).

Table 5 shows contents of macro and micronutrients are exposed present on different substrates obtained and also in the peat used as reference. Note that if, except for S, the average content for the nutrients P, K, Ca and Mg were higher than the reference substrate. As observed by Silveira et al. (2013), macro and micronutrients reduced with increasing carbon in the substrate composition except Fe and B (table 5).

In a study to evaluate the effect of heavy metals on microbial activity in a contaminated soil from discarded and zinc industry, Dias-Junior et al (1998) observed the presence of *A. brasilense* on soils with 18 mg kg$^{-1}$ of Cu and 135 mg kg$^{-1}$ of Zn. However, it has not detected the presence of the bacteria in soil with mean levels of 532 mg kg$^{-1}$ of Cu and 5730 mg kg$^{-1}$ of Zn.

For the content of heavy metals, it is observed in Table 6 that the peat had lower content of Ni and Cr, as compared to those produced substrates. However, the average content Pb of the substrate produced was smaller than that found in the peat.

The content of some heavy metals in the reference substrate (peat) were similar to those observed by Prado Junior (2012), analyzing the peat used as in mitigating and degraded areas contaminated by these elements, whose average value was 4.1 mg kg$^{-1}$ of Ni, 18.6 mg kg$^{-1}$ of Pb and 38.1 mg kg$^{-1}$ of Cr.

Prado Junior (2012), "in vitro" on trial, noted that the bacteria *H. seropedicae* and *A. amazonense* were tolerant to the maximum concentration of 40 mg L$^{-1}$ of Ni; 248 mg L$^{-1}$ de Pb and 17 mg L$^{-1}$ of Cr. However, it is noteworthy that, contrary to what occurs in conditions "in vitro" these metals in the soil or substrate may be at the low valence, being a part linked to organic matter and thus cannot limit the activity of these bacteria. Sundar et al. (2010), evaluating the impact of
contamination tanneries in the Palar basin, Cr tolerant bacteria found in concentrações ranging between 100 and 400 mg L\(^{-1}\).

According to still Prado Junior (2012), the order of toxicity of metals for bacteria \textit{A. amazonense} and \textit{H. seropedicae} was: Cr > Ni > Pb. In growth medium, Moreira et al. (2008) demonstrated that \textit{A. brasilense} exhibited tolerance to 1000 mg L\(^{-1}\) of Zn\(^{+2}\) and 60 mg L\(^{-1}\) of Cd\(^{+2}\).

Although the laying hen manure is richer in nutrients, the increasing of the percentage of cottonseed hulls provided a substrate with desirable characteristics, such as: density reduction, which makes easier marketing and transport; increase of the water retention capacity; increase in organic carbon which is an energy source for microorganisms; reduced the pH to a value closer to neutrality; reduction of electrical conductivity, which is directly related to the presence of basic cations and consequently reduces the osmotic potential.

4 CONCLUSIONS

The obtained substrates have potential for use as inoculant carrier, and it can be an alternative to peat. The total-N content did not differ among formulated. The elevation of laying hen manure proportion results in a substrate with higher pH and EC. The SUB-A5 formulated showed lower pH and EC. The content of macro and micronutrients heavy metals formulated in peat substrate is similar, except for the Ni content and Cr are high, thus requiring evaluate their potential toxic for microorganisms intended to inoculate.

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REFERENCES

Albanell, E., Plaixats, J. & Cabrero, T. (1988). Chemical changes during vermicomposting (Eisenia fetida) of sheep manure mixed with cotton industrial wastes. Biology and Fertility of Soils 6(3):266-269.

Bailey, D.A., Nelson, P.V. & Fonteno, W.C. (2000). Substrates pH and water quality. Raleigh: Nort Carolina State University. Available at http://www.ces.ncsu.edu/depts/hort/floriculture/plugs/ph.pdf (accessed August 2015).

Barbosa, C.A. (2009). Manual de adubação orgânica. 1ª ed. Editora Agrojuris, Viçosa, 224p.

Brady, N.C. & Weil, R.R. (2013). Elementos da natureza e propriedades dos solos. Bookman, Porto Alegre, 716p.

Brasil. (2007). Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº 17 de 21/05/2007. Aprova os Métodos Analíticos Oficiais para Análise de Substratos e Condicionadores de Solos e revoga a Instrução Normativa nº46 de 12 de setembro de 2006. Available at http://goo.gl/rcJg6N (accessed May 2016).

Brasil. (2010). Lei 12.305 de 02 de agosto de 2010. Institui a Política Nacional dos Resíduos Sólidos - PNRS e dá outras providências. Available at http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm. (accessed June 2013).

Brasil. (2011). Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº13 de 24/03/2011. Aprovar as normas sobre especificações, garantias, registro, embalagem e rotulagem dos inoculantes destinados à agricultura, bem como as relações dos micro-organismos autorizados e recomendados para produção de inoculantes no Brasil. Available at http://www.inoleg.dcs.ufla.br/index.php/downloads?download=3:instrucao-normativa. (accessed January 2015).

Canellas, L.P., Balmori, D.M., Médici, L.O., Aguiar, N.O., Campostrini, E., Rosa R.C. & Olivares, F.L. (2013). A combination of humic substances and Herbaspirillum seropedicae inoculation enhances the growth of maize (Zea mays L.). Plant and soil 366(1-2):119-132. http://dx.doi.org/10.1007/s11104-012-1382-5

Czerniak, M.J. & Stürmer, S.L. (2014). Produção de inoculante micorrízico on farm utilizando resíduos da indústria florestal. Revista Brasileira de Ciência do Solo 38(6):1712-1721. http://dx.doi.org/10.1590/S0100-06832014000600006

Fermino, M.H. & Kämpf, A.N. (2012). Densidade de substratos dependendo dos métodos de análise e níveis de umidade. Horticultura Brasileira 30(1):75-79. http://dx.doi.org/10.1590/S0102-05362012000100013

Ferreira, D.F. (2011). Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia 35(6), 1039-1042. http://dx.doi.org/10.1590/S1413-70542011000600001
Ferreira, J.S., Sabino, D.C.C. Guimarães, S.L., Baldani, J.I., & Baldani, V.L.D. (2003). Seleção de veículos para o preparo de inoculante com bactérias diazotróficas para arroz inundado. Agronomia 37(2):06-12.

Ferreira, J.S., Baldani, J.I. & Baldani, V.L.D. (2010). Seleção de inoculantes à base de turfa contendo bactérias diazotróficas em duas variedades de arroz diazotróficas em duas variedades de arroz. Acta Scientiarum Agronomy 32(1):179-185. http://doi:10.4025/actasciagron.v32i1.732

Guimarães, S.L., Baldani, V.L.D. & Jacob-Neto, J. (2013). Viabilidade do inoculante turfoso produzido com bactérias associativas e molibdênio. Revista Ciência Agronômica 44(1): 10-15. http://dx.doi.org/10.1590/S1806-66902013000100002

Inácio, C.T. & Miller, P.R.M. (2009). Compostagem: ciência e prática para a gestão de resíduos orgânicos. Embrapa, Brasília. 156p.

Lorda, G., Breccia, J.D., Barbeito,V., Pagliero,F., Boeris, S., Castaño, C., Pordomingo, A., Altolaguirre, F. & Pastor, M.D. (2007). Peat-based inoculum of Bradyrhizobium japonicum and Sinorhizobium fredii supplemented with xanthan gum. World Journal Microbiology Biotechnology 23:01-05. http://doi: 10.1007/s11274-006-9186-5

Marques, M.O., Bellingieri, P.A., Marques, T.A. & Nogueira, T.A.R. (2007). Qualidade e produtividade da cana-de-açúcar cultivada em solo com doses crescentes de lodo de esgoto. Bioscience Journal 23(2):111-122.

Melo, L.C.A., Silva, C.A. & Dias, B.O. (2008). Caracterização da matriz orgânica de resíduos de origens diversificadas. Revista Brasileira de Ciência do Solo 32:101-110. http://dx.doi.org/10.1590/S0100-06832008001000010

Oustani, M., Halilat, M.M. & Chenchouni, H. (2015). Effect of poultry manure on the yield and nutrients uptake of potato under saline conditions of arid regions. Emirates Journal of Food and Agriculture 27(1):106-120. http://doi: 10.9755/ejfa.v27i1.17971

Oviedo-Rondón, E.O. (2008). Technologies to mitigate the environmental impact of broiler production. Revista Brasileira de Zootecnia 37(SPE):239-252. http://dx.doi.org/10.1590/S1516-35982008001300029

Sanches-Monedero, M.A., Roig, A., Cegerra, J. & Bernal, M.P. (2001). Nitrogen transformation during organic waste composting by the Rutgers system and its effects on pH, EC and maturity of the composting mixtures. Bioresource Technology 78:301-308. http://dx.doi.org/10.1016/S0960-8524(01)00031-1

Schlemper, T.R. & Stürmer, S.L. (2014). On farm production of arbuscular mycorrhizal fungi inoculum using lignocellulosic agrowastes. Mycorrhiza 24(8):571-580. http://doi:10.1007/s00572-014-0576-5

Schmitz, J.A.K., Souza, P.V.D. & Kämpf, A.L. (2002). Propriedades químicas e físicas de substratos de origem mineral e orgânica para o cultivo de mudas em recipientes. Ciência Rural 32:937-944. http://dx.doi.org/10.1590/S0103-84782002000600005
Seoudi, O.A. (2013). Enhancement of cotton stalks composting with certain microbial nociulations. Journal of Advanced Laboratory Research in Biology 4(1):26-35.

Shi, J.G., Zeng, G.M., Yuan, X.Z., Dai, F., Liu, J. & Wu, X.H. 2006. The stimulative effects of surfactants on composting of waste rich in cellulose. World Journal of Microbiology and Biotechnology 22: 1121–1127. http://dx.doi.org/10.1007/s11274-006-9152-2

Silva, F.C. (2009). Manual de análises químicas de solos, plantas e fertilizantes. 2ed. Embrapa Informação Tecnológica, Brasília, 627p.

Silva, V.M.D., Ribeiro, P.H. & Teixeira, A.F.R. (2011). Caracterização de compostos orgânicos em propriedade de base familiar: aspectos qualitativos, quantitativos e econômicos. Current Agricultural Science and Technology 17(3):405-409. http://dx.doi.org/10.18539/cast.v17i3.2075

Silveira, S.V., Fialho, F.B., Schwarz, S.F. & Souza, P.V.D. (2013). Combinación entre turfa vermelha e areia na obtenção de substrato-inóculo do fungo micorrízico arbuscular Glomus clarum. Ciência Rural 43(3):419-425.http://dx.doi.org/10.1590/S0103-847820130005000022

Trannin, I.C.B., Siqueira, J.O. & Moreira, F.M.S. (2007). Atributos químicos e físicos de um solo tratado com biossólido industrial e cultivado com milho. Revista Brasileira de Engenharia Agrícola e Ambiental 12(3):223-230. http://dx.doi.org/10.1590/S1415-43662008000300001

Valente, B.S., Xavier, E.G., Morselli, T.B.G.A., Jahnke, D.S., Brum Jr, S., Cabrera, B.R., Moraes, P.O. & Lopes, D.C.N. (2009). Fatores que afetam o desenvolvimento da compostagem de resíduos orgânicos. Arquivos de Zootecnia 58:59-85.

Yu, H.Y., Zeng, G.M., Huang, H.L., Xi, X.M., Wang, R.Y., Huang, D.L., Huang, G.H. & Li, J.B. (2007). Microbial community succession and lignocellulose degradation during agricultural waste composting. Biodegradation 18:793–802. http://dx.doi.org/10.1007/s10532-007-9108-8

Zucconi, F. & De Bretoldi, M. (1987). Compost specifications for the production and characterization of compost from municipal solid waste. p.30-50 In: Bertoldi, M., M.P. Ferranti, P. L’Hermite, F. Zucconi (eds.) Compost: production, quality and use. Elsevier Applied Science Publishers.
### ANNEX

**Table 1.** Macro and micronutrients content in the different used residues

| WASTE | C     | N     | P     | K     | Ca    | Mg    | S    |
|-------|-------|-------|-------|-------|-------|-------|------|
|       | dag kg\(^{-1}\) |       |       |       |       |       |      |
| CH    | 53.50 | 1.50  | 0.10  | 1.64  | 1.29  | 0.23  | 0.29 |
| HM    | 34.60 | 3.82  | 2.10  | 2.90  | 10.13 | 0.63  | 0.65 |
|       |       |       |       |       |       |       |      |

|       | Fe    | Zn    | Mn    | B     | C/N   |
|-------|-------|-------|-------|-------|-------|
| CH    | 6.25  | 1253  | 24.05 | 47.80 | 30.60 |
| HM    | 55.00 | 2308  | 357.00| 353.80| 44.59 |

CH = cotton seed hull and HM = laying hen manure

**Table 2.** Quantitative characterization of the studied formulated in the end of composting.

| VARIABLE     | FORMULATED |
|--------------|------------|
|              | SUB-A0     | SUB-A1    | SUB-A2    | SUB-A3    | SUB-A4    | SUB-A5    |
| IDM (kg)     | 30.0       | 30.0      | 30.0      | 30.0      | 30.0      | 30.0      |
| FDM (kg)     | 14.6       | 14.6      | 15.0      | 14.7      | 17.3      | 18.5      |
| RED %        | 51.0       | 51.0      | 50.0      | 51.0      | 44.0      | 38.0      |
| MOI %        | 19.0       | 20.0      | 21.0      | 22.0      | 27.0      | 28.0      |

IDM= Initial dry matter. FDM= Final dry matter. RED= reduction. MOI= moisture.

**Table 3.** Physicochemical characterization of the different formulated.

| FORMULATED | CM | WD | DD | WRC\(_{10}\) | pH | EC |
|------------|----|----|----|------------|----|----|
|            | %  | kg m\(^{-3}\) | %  | %          |    | mS cm\(^{-1}\) |
| Peat       | 1.20 | 1160.2 | 1125.3 | -        | 6.22 | 4.35 |
| SUB-A0     | 2.24 c | 1337.2 a | 1307.3 a | 45.1 c | 7.91 a | 35.90 a |
| SUB-A1     | 1.79 c | 807.5 b | 793.1 b | 46.6 c | 7.90 a | 14.80 b |
| SUB-A2     | 2.61 b | 690.0 c | 672.0 c | 53.3 b | 7.78 b | 12.19 d |
| SUB-A3     | 2.48 b | 678.8 c | 662.7 c | 53.5 b | 7.50 c | 12.79 c |
| SUB-A4     | 2.13 c | 677.1 c | 662.1 c | 54.3 b | 7.21 c | 12.72 c |
| SUB-A5     | 3.36 a | 561.4 d | 542.7 d | 56.0 a | 7.18 c | 10.28 e |

Pr>Fc

|          | ** | ** | ** | ** | ** | ** |
|----------|----|----|----|----|----|----|
| Average  | 2.43 | 792.0 | 773.3 | 51.5 | 7.58 | 16.45 |
| CV(%)    | 13.60 | 3.78 | 3.88 | 1.98 | 1.11 | 2.06 |

CM= current moisture a 65°C. WD= wet density. DS= dry density. WRC\(_{10}\)= water retention capacity a 0.98 kPa. pH= water extract 1:5. CE= Electrical conductivity 1:5. ** p<0.01 by the F test. Same letters in the column do not differ from each other by the Scott-Knott test (p<0.05).
**Table 4.** Chemical characterization of the different formulated.

| FORMULATED | CO   | N-total | C/N  | NH$_4^+$ | NO$_3^-$ |
|------------|------|---------|------|----------|----------|
| Peat       | 47.82 | 1.73    | 27.64 | 2713.90  | 47.20    |
| SUB-A0     | 26.98 | 2.97 a  | 9.10  | 1191.75 a | 601.78 a |
| SUB-A1     | 27.73 d | 2.81 a | 9.87 b | 837.77 b | 342.19 b |
| SUB-A2     | 29.52 c | 2.90 a | 10.19 a | 802.37 b | 47.20 c |
| SUB-A3     | 29.76 c | 2.89 a | 10.43 a | 731.57 b | 47.20 c |
| SUB-A4     | 30.07 b | 2.87 a | 10.37 a | 507.28 c | 47.20 c |
| SUB-A5     | 30.86 a | 2.94 a | 10.49 a | 460.18 c | 47.20 c |

**Pr>Fc** | **Ns** | **Ns** | **Ns** |

Average | 29.15 | 2.89 | 10.08 | 755.17 | 188.79 | 13.82

**Table 1 - Macro and micronutrients content in formulated substrates.**

| FORMULATED | P     | K     | Ca    | Mg    | S     |
|------------|-------|-------|-------|-------|-------|
| Peat       | 0.06  | 0.29  | 0.78  | 0.16  | 2.14  |
| SUB-A0     | 3.25  | 2.94  | 13.45 | 1.24  | 1.18  |
| SUB-A1     | 2.53  | 2.91  | 11.87 | 1.02  | 0.75  |
| SUB-A2     | 2.92  | 2.52  | 10.76 | 0.87  | 1.29  |
| SUB-A3     | 2.27  | 2.94  | 9.62  | 0.82  | 1.01  |
| SUB-A4     | 1.99  | 2.58  | 9.40  | 0.80  | 1.05  |
| SUB-A5     | 1.69  | 1.41  | 7.93  | 0.75  | 0.94  |

Average | 2.44  | 2.55  | 10.50 | 0.92  | 1.03  |

| FORMULATED | Cu    | Fe    | Zn    | Mn    | B     |
|------------|-------|-------|-------|-------|-------|
| Peat       | 28.65 | 10.891.00 | 605.50 | 338.55 | 20.26 |
| SUB-A0     | 50.10 | 7.610.00 | 706.00 | 438.55 | 34.85 |
| SUB-A1     | 49.40 | 9.336.50 | 658.00 | 426.65 | 35.20 |
| SUB-A2     | 43.00 | 8.950.50 | 592.50 | 411.25 | 36.27 |
| SUB-A3     | 50.65 | 9.108.50 | 528.00 | 424.35 | 31.70 |
| SUB-A4     | 42.05 | 12.136.50 | 595.50 | 379.85 | 31.70 |
| SUB-A5     | 38.15 | 10.605.50 | 606.50 | 438.30 | 38.98 |

Average | 45.55 | 9.624.58 | 614.33 | 419.83 | 34.11 |

**p<0.01** by the F-test. **ns**= no significant. Same letters in the column do not differ from each other by the Scott-Knott test (p<0.05).
### Table 2 - Heavy metal content in formulated substrates

| FORMULATED | Ni (mg kg⁻¹) | Pb (mg kg⁻¹) | Cr (mg kg⁻¹) |
|------------|--------------|--------------|--------------|
| Peat       | 10.25        | 4.80         | 31.45        |
| SUB-A0     | 23.45        | 3.30         | 62.65        |
| SUB-A1     | 46.05        | 0.50         | 110.75       |
| SUB-A2     | 48.10        | 2.20         | 121.65       |
| SUB-A3     | 68.70        | 3.75         | 186.85       |
| SUB-A4     | 92.40        | 6.60         | 238.70       |
| SUB-A5     | 44.40        | 5.80         | 116.70       |
| **Average**| **53.85**    | **3.69**     | **139.55**   |