Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v35i3.17542

# Biochar as substitute for organic matter in the composition of substrates for seedlings

**Stefany Lorrayny Lima[1], Ben Hur Marimon-Junior[1*], Fabiano André Petter[2], Suelen Tamiozzo[1], Guilherme Bossi Buck[3] and Beatriz Schwantes Marimon[1]**

*[1]Programa de Pós-graduação em Ecologia e Conservação, Universidade do Estado de Mato Grosso, BR-158, km 654, 78690-000, Nova Xavantina, Mato Grosso, Brazil. [2]Universidade Federal de Mato Grosso, Sinop, Mato Grosso, Brazil. [3]University of Florida, Institute of Food and Agricultural Science, Gainesville, Gainesville, Flórida, United States of America. *Author for correspondence: E-mail: bhmjunior@gmail.com*

**ABSTRACT.** In this study, we tested the hypothesis that pyrogenic carbon (biochar) has properties that enable it to replace fresh organic matter (cattle manure) in seedling substrates. These properties include specific electrophysiological interactions in soil-plant media, stability and longevity. The experiment was conducted in the nursery at the State University of Mato Grosso, located in the municipality of Nova Xavantina, between April and June 2011. The experimental design consisted of randomized blocks with ten treatments and four replicates, including a commercial substrate. Linear regression analysis showed a strong positive relationship between manure treatments and number of leaves, fresh and dry biomass, diameter, height and Dickson Quality Index at 30 and 40 days after sowing (DAS), with the exception of height at 30 DAS. There was no significant relationship for biochar dosage in any assessment for these parameters. The use of substrates with different dosages of cattle manure resulted in an increase of seedling quality compared to biochar and commercial substrates. The hypothesis that biochar can be substituted for fresh organic matter and is more stable in the substrate was not supported.

**Keywords:** *Solanum melongena*, charcoal, cattle manure, seedling production.

## Biochar como substituto de matéria orgânica na formação de substratos para mudas

**RESUMO.** Neste trabalho hipotetizamos que o carvão pirogênico (biochar) apresenta propriedades capazes de substituir a matéria orgânica fresca (esterco bovino) devido a ações eletrofisiológicas no complexo solo-planta atribuídas a este material, tendo ainda a vantagem de ser mais estável e duradouro. O experimento foi realizado no viveiro da Universidade do Estado de Mato Grosso, município de Nova Xavantina, no período de abril a junho de 2011. O delineamento experimental foi o de blocos casualizados, com dez tratamentos e quatro repetições, incluindo um substrato comercial. Testes de regressão linear demonstraram uma relação fortemente positiva dos tratamentos de esterco com biomassa fresca e seca, número de folhas, diâmetro, altura e Índice de Qualidade de Dickson aos 30 e 40 dias após a semeadura (DAS), à exceção da altura aos 30 DAS. Por outro lado, não foi verificada relação significativa com as doses de biochar em nenhuma avaliação para nenhum destes parâmetros. A utilização de substratos com diferentes doses de esterco bovino proporcionou melhora na qualidade das mudas superior ao biochar e ao substrato comercial. A hipótese de que o biochar substitui a matéria orgânica fresca, com a vantagem da maior estabilidade do material no substrato, não se sustentou.

**Palavras-chave:** *Solanum melongena*, carvão vegetal, esterco bovino, produção de mudas.

## Introduction

The addition of burnt plant residues to growing substrates can improve the nutritional performance of cultivated plants. This material, recently named *biochar*, shows the capacity for cation exchange as a result of the action of pyrogenic carbon in the soil complex (BENITES et al., 2009; CUNHA et al., 2009; GLASER et al., 2002; LIANG et al., 2006). The use of charcoal in agriculture has been intensely discussed over the past few years (GASKIN et al., 2010; GUNDALE; DELUCA, 2007; LEHMANN, 2007; LEHMANN; JOSEPH, 2009; LEHMANN et al., 2003; MAJOR et al., 2005, 2010; MASULILI et al., 2010; RONDON et al., 2007; STEINER et al., 2007; TOPOLIANTZ et al., 2005), and it could be a component of sustainable agriculture in the tropics (GLASER et al., 2001).

The first studies that investigated the use of charcoal to improve the chemical and physical characteristics of dystrophic tropical soil were focused on the origin of the fertility and the productivity of anthropogenic soils in Amazonia, popularly called the *Terra Preta de Índio* (Indian black earth) (GLASER et al., 2001). Research has shown that these soils, despite their dystrophic origin, are fertile and productive without fertilization because they have high amounts of fine charcoal fragments from the burning of vegetation and domestic fires by prehistoric Indians (LEHMANN et al., 2003). In Brazil, the first field studies to test biochar on large areas of crops showed significant increases in the harvest of upland rice in Nova Xavantina in eastern Mato Grosso (PETTER et al., 2012).

One of the major concerns related to urban lifestyles, especially in large urban centers, is the quality of food, including the context in which food is produced. The global demand for food cultivated with techniques that minimize the use of chemical products and rely on alternatives such as biochar amendments has increased. In particular, eggplant (*Solanum melongena* L.) has received a considerable amount of attention because of its nutritional value and medicinal properties (OLIVEIRA et al., 2009).

In addition to meeting market standards, production systems must efficiently meet quality, quantity and regularity requirements for the product supply (FURLANI; PURQUERIO, 2010). Thus, vegetable production systems must be improved by reducing chemical inputs. In the case of eggplant, this poses difficulties with proper establishment in the field, a factor essential for ensuring crop productivity (TRIGO; TRIGO, 1999).

The production of seedlings on trays in a protected area can improve the quality and standardization of plants, consequently yielding a greater uniformity of production in the field and higher productivity, ensuring the continuous supply of the product (COSTA et al., 2011). Tray production also results in a higher level of precocity, a reduction in the crop cycle in the field, greater use of a given area, less stress during transplanting and greater efficiency of phytosanitary control, all of which contribute to improved quality and lower risks (COSTA et al., 2011; GOMES et al., 2008).

In this type of system, substrate quality is important because it affects germination and seedling development (MEDEIROS et al., 2008). An appropriate substrate should have good cation exchange capacity, sufficient levels of nutrients, good moisture retention, appropriate ventilation and minimal costs (OLIVEIRA et al., 2008, 2009).

According to Moreira et al. (2010), the characterization of alternative substrate materials is essential for the production of seedlings of different plants, the reduction of costs and the promotion of residue utilization. Biochar is an efficient alternative because it significantly increases soil CTC (GLASER et al., 2002; LIANG et al., 2006), improves the nutritional balance (GASKIN et al., 2010; GLASER et al., 2002) and consequently increases soil fertility (GLASER et al., 2002; LEHMANN; JOSEPH, 2009); as a result, less chemical fertilizer is needed. The porous structure of biochar can increase water and nutrient retention in the soil, resulting in fewer leaching losses (GLASER et al., 2002; LEHMANN, 2007; LEHMANN; JOSEPH, 2009) and directly improving fertilizer efficiency (PETTER et al., 2012).

Due to these characteristics and its high stability in soil (LEHMANN; JOSEPH, 2009; MADARI et al., 2009), biochar is capable of increasing germination and vegetative growth, thereby directly affecting crop productivity (GLASER et al., 2002). As a result of its chemical-physical nature, biochar is a potential soil conditioner (PETTER et al., 2012) and substrate for the production of seedlings (MARIMON-JUNIOR et al., 2012); SOUCHIE et al., 2011) and should be tested as such for a variety of crops. Furthermore, it is a low-cost material and can be obtained in rural areas (BENITES et al., 2009).

In this study, we tested the hypothesis that biochar has properties that enable it to replace fresh organic matter (cattle manure) in seedling substrates. These properties, which include specific electrophysiological interactions in soil-plant media, stability and longevity, may enable the decreased use of chemical fertilizers. The objective of this work was to compare the effects of adding different dosages of biochar and different dosages of cattle manure to dystrophic red Latosol used as a substrate in the production of eggplant seedlings.

## Material and methods

The experiment was conducted at the Universidade do Estado de Mato Grosso nursery, in Nova Xavantina (14º 41' 25" S; 52º 20' 55" W), from April to June 2011 using seeds of the Purple Long eggplant cultivar (batch: 014079; germination: 88%). Seeds were sown in expanded polystyrene trays with 128, 1-cm deep cells. Two seeds were sown per cell. The trays were placed on iron supports at a height of 1.20 m and covered with a 50% shade cloth, chapel model. A micro sprinkler irrigation system was used as needed according to climatic conditions. The plants were thinned when they had their first pair of definitive leaves, 15 days after sowing (DAS), to select the more vigorous of the two plants.

The experimental design consisted of a randomized block, with ten treatments and four repetitions. Substrate mixtures were made of different dosages of biochar and dystrophic Red Latosol (0, 5, 10, 20 and 40%) and equal dosages (V/V) of cattle manure and the same dystrophic Red Latosol. A control consisting of the commercial substrate Germinar®, a material proven to be effective in the production of vegetable seedlings, was also used. In total, ten treatments were tested: RL (Red Latosol); GER (Germinar®); RL+B5 (Red Latosol + biochar at 5%); RL+B10 (Red Latosol + Biochar at 10%); RL+B20 (Red Latosol + biochar at 20%); RL+B40 (Red Latosol + biochar at 40%), RL+CM5 (Red Latosol + cattle manure at 5%); RL+CM10 (Red Latosol + cattle manure at 10%); RL+CM20 (Red Latosol + cattle manure at 20%); and RL+CM40 (Red Latosol + cattle manure at 40%). The main chemical characteristics are presented in Table 1.

**Table 1.** Chemical analysis of materials used in the substrates, including dystrophic Red Latosol (RL), Germinar® (GER), cattle manure (CM) and biochar (BIO), Nova Xavantina-Mato Grosso, State, Unemat, 2011.

| | pH | Ca | Mg | Al | H | CTC | P | K | Zn | Cu | Mn | B | S | V | MO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $CaCl_2$ | | cmol$_c$ dm$^{-3}$ | | | | | | | mg dm$^{-3}$ | | | | % | g dm$^{-3}$ |
| RL | 4.5 | 2.5 | 1.2 | 0.3 | 8.4 | 12.5 | 18.5 | 24 | -- | -- | -- | -- | -- | 30.2 | 55.8 |
| GER | 5.7 | 18.8 | 5.0 | 0.0 | 6.6 | 32.3 | 592.7 | 740 | 7.4 | 1.1 | 23.9 | 1.42 | 396.0 | 79.7 | 152.9 |
| CM | 8.0 | 3.5 | 9.5 | 0.0 | 0.3 | 14.6 | 438.4 | 9.1 | -- | -- | -- | -- | -- | 97.9 | 105.3 |
| BIO | 5.8 | 2.1 | 0.9 | 0.0 | 1.6 | 5.4 | 9.9 | 330 | -- | -- | -- | -- | -- | 71.0 | 17.4 |

Embrapa (1999) methodology of soil analysis.

The charcoal was obtained from wood species in Cerrado. It was produced in a conventional masonry furnace, with temperatures ranging from 200 to 500°C during the carbonization of the wood. After carbonization, the material was processed in a rotating knife mill until it was partially homogeneous. It was then sieved in a 1.0-mm mesh sieve to separate the coarser material. The particle sizes of the crushed charcoal were tested using standard soil sieves. More than 62% of the particles were smaller than 0.5 mm, and approximately 48% were smaller than 0.1 mm.

Prior to use, the charcoal was activated by stirring it in water in an electric mixer for one hour to eliminate pyrolysis residues and unblock pores, a process similar to that used in the production of activated coal. The resultant solution was drained in a sieve and dried in the open air until a constant weight was achieved. The substrates were combined in a mixer to ensure homogenization.

At 20, 30 and 40 DAS, the number of leaves and the height of the plants were evaluated, using 12 central plants per repetition for each treatment. A simple border was maintained to avoid the edge effect. The number of leaves was determined by manual counting, starting with the basal leaves and continuing to the most recently opened. Using a ruler, the height was measured from the base of the collar to the apex of the youngest leaf.

The diameter of the seedlings, root and shoot biomass were checked at 40 DAS. The stem diameter was measured with a precision digital pachymeter (0.01 mm). To determine the phytomass, the seedlings were washed in water to remove substrate and then cut at the base of the collar to separate the shoot from the root system. The material was weighed on a precision balance (0.001 g) to determine the fresh phytomass of the shoot and the fresh phytomass of the root. After weighing, the material was stored in a paper bag and dried in a forced air oven at 65°C to a constant weight. The samples were then weighed on a precision balance to determine the dry phytomass of the shoot and the root.

To assess seedling quality, the Dickson Quality Index (IQD) was used in each treatment, where IQD=MST/(Ratio height/diameter + ratio dry biomass aerial/root) (DICKSON et al., 1960). This index is a good quality reference because it considers the allometric coefficients of the shoot and the root as well as the distribution of biomass in the morphological structure of the seedlings.

The differences between the treatments were tested in a linear regression analysis (best-fit), using the statistical program BioEstat (AYRES et al., 2007).

## Results and discussion

### Number of leaves

At 20 DAS, the seedlings grown in the substrates with cattle manure had more leaves than those grown in the substrates with biochar, but no statistical significance was found in the linear regression analysis (Table 2). The seedlings grown in Geminar® had fewer leaves than the seedlings grown in the cattle manure substrates. This trend was maintained at 30 DAS with the Germinar® substrate, and there were fewer leaves than for the seedlings treated at the dosages of 10, 20 and 40% of either cattle manure or biochar.

In the final evaluation at 40 DAS, the seedlings grown with Germinar® had fewer leaves than the others, with almost half the number of leaves of the seedlings grown with 40% cattle manure. The seedlings grown in the cattle manure substrate had more leaves than those grown in the biochar substrate. The linear regression analysis showed no significant relationship between the number of leaves and the different dosages of biochar, while a strong relationship was found for the cattle manure treatments (Figure 1). These results demonstrate the effectiveness of fresh organic matter as a substrate conditioner.

**Table 2.** Results of the linear regression analysis testing the effects of biochar and cattle manure on the number of leaves (NL), plant height (H), diameter of seedlings (D), fresh mass of shoot (FMS), dry mass of shoot (DMS), fresh mass of root (FMR), dry mass of root (DMR), total dry mass (TDM) and Dickson quality index (DQI) of seedlings of eggplant cv. Purple Long. Nova Xavantina-Mato Grosso State, Unemat, 2011.

| Biochar | | | | |
|---|---|---|---|---|
| Parameter/DAS | Regression Model | $R^2$ | F | P |
| NL/20 | $Y = -0.0093 X + 2.7562^{ns}$ | 0.5656 | 3.6446 | 0.1518 |
| NL/30 | $Y = -0.0036 X + 3.1975^{ns}$ | 0.4495 | 2.7694 | 0.1944 |
| NL/40 | $Y = -0.0062 X + 3.3603^{ns}$ | 0.4608 | 2.5638 | 0.2074 |
| H/20 | $Y = -0.0027 X + 1.8879^{ns}$ | 0.2262 | 0.8808 | 0.5806 |
| H/30 | $Y = 0.002 X+ 2.3907^{ns}$ | 0.0535 | 0.1796 | 0.6980 |
| H/40 | $Y = 0.0007 X + 2.5908^{ns}$ | 0.0093 | 0.0281 | 0.8712 |
| D/40 | $Y = 0.0016 X + 0.8508^{ns}$ | 0.2422 | 0.9588 | 0.5984 |
| FMS/40 | $Y = -1^{-05} X + 0.0882^{ns}$ | 0.0005 | 0.0016 | 0.9699 |
| DMS/40 | $Y = 4^{-05} X + 0.0155^{ns}$ | 0.2653 | 1.0834 | 0.3759 |
| FMR/40 | $Y = -5^{-05} X + 0.0341^{ns}$ | 0.0323 | 0.1000 | 0.7667 |
| DMR/40 | $Y = 0.0001 X + 0.0051^{ns}$ | 0.6027 | 4.5503 | 0.1220 |
| TDM/40 | $Y = 0.0001 X + 0.0207^{ns}$ | 0.5935 | 4.3796 | 0.1269 |
| DQI/40 | $Y = 5^{-05} X + 0.0034^{ns}$ | 0.6152 | 4.7965 | 0.1156 |
| Cattle manure | | | | |
| NL/20 | $Y = 0.003 X + 2.9597^{ns}$ | 0.1624 | 0.6151 | 0.5073 |
| NL/30 | $Y = 0.0189 X + 3.2901^{**}$ | 0.9925 | 415.93 | 0.0003 |
| NL/40 | $Y = 0.022 X + 3.4192^{**}$ | 0.9765 | 136.98 | 0.0011 |
| H/20 | $Y = 0.0104 X + 2.0098^{ns}$ | 0.4202 | 2.2012 | 0.2344 |
| H/30 | $Y = 0.0245 X + 2.5231^{ns}$ | 0.6958 | 6.8769 | 0.0778 |
| H/40 | $Y = 0.0322 X + 2.6298^{*}$ | 0.8989 | 26.6724 | 0.0125 |
| D/40 | $Y = 0.0132 X + 0.9507^{*}$ | 0.8495 | 16.7110 | 0.0246 |
| FMS/40 | $Y = 0.0102 X + 0.0895^{**}$ | 0.9846 | 194.3832 | 0.0007 |
| DMS/40 | $Y = 0.0035 X + 0.0125^{**}$ | 0.9894 | 280.7776 | 0.0004 |
| FMR/40 | $Y = 0.0026 X + 0.0457^{*}$ | 0.9085 | 29.7899 | 0.0106 |
| DMR/40 | $Y = 0.0005 X + 0.0074^{**}$ | 0.9203 | 34.6358 | 0.0084 |
| TDM/40 | $Y = 0.004 X + 0.0199^{**}$ | 0.9889 | 266.2643 | 0.0005 |
| DQI/40 | $Y = 0.0004 X + 0.0047^{**}$ | 0.9571 | 66.9847 | 0.0031 |

$^{**}$Significant at 1% probability; $^{*}$significant at 5% probability; ns = not significant; DAS = days after sowing.

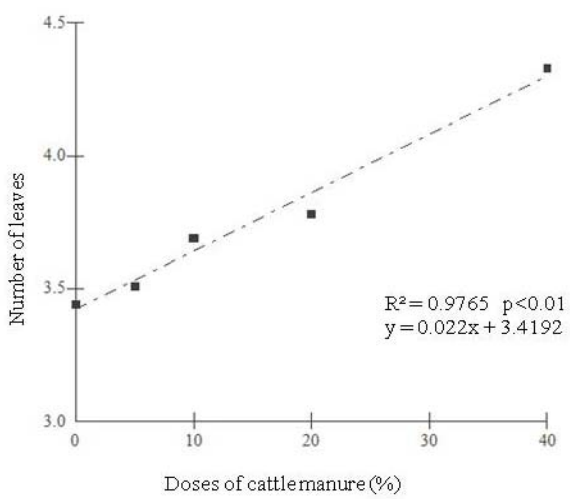


**Figure 1.** Relationship between cattle manure treatments and number of leaves on seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina-Mato Grosso State, Brazil, Unemat, 2011.

Rodrigues et al. (2008), working with rocket cultivated in vases in a greenhouse, also found an effect of increasing cattle manure dosages on the number of leaves. Canesin and Corrêa (2006) and Almeida et al. (2011) observed more leaves on papaya seedlings and passion fruit seedlings, respectively, with substrates of cattle manure. The efficiency of the cattle manure substrates is mainly due to the characteristics of organic matter. It provides nutrients, increases the volume of pore spaces, improves soil aeration, facilitates the development of roots and provides improved water retention (PENTEADO, 2003).

The effectiveness of organic matter on the development of aerial biomass was demonstrated by Medeiros et al. (2007) with cultivated rocket seedlings. In their study, the organic substrate yielded more leaves, demonstrating the ability of organic matter to increase photosynthesis activity in developing seedlings and improve performance and vigor after transplanting. Based on the results of the current study, biochar was not shown to be an effective substitute for organic matter considering the number of leaves, although it showed similar action to cattle manure during the early stages of seedling development. However, biochar was superior to the commercial substrate, and it may be used as a replacement during restrictions in the supply of this material.

## Height

In the first evaluations (20 and 30 DAS) of the height of eggplant seedlings, the treatments with larger dosages of cattle manure (10, 20 and 40%) showed superior results compared to the substrates with biochar, the control and Germinar. At 40 DAS, a statistical significance was found in the linear regression analysis for the treatment with cattle manure (Figure 2).

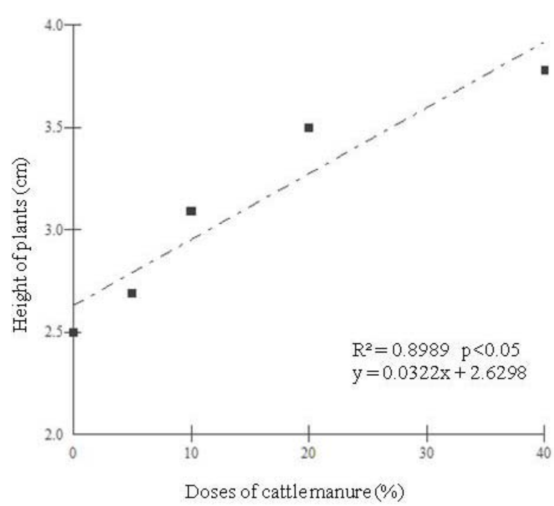


**Figure 2.** Relationship between cattle manure treatments and height of seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina- Mato Grosso State, Brazil, Unemat, 2011.

The biochar treatment did not show significance in the linear regression analysis (Table 2), but it was more effective than the commercial substrate, reinforcing the possibility of using biochar for the production of vegetable seedlings as way to reduce costs. However, the higher dosage of cattle manure (40%) yielded results superior to the commercial substrate and the control (RL); therefore, it is the most highly recommended alternative for the production of eggplant seedlings, at least in terms of height.

Araújo Neto et al. (2009) and Marques et al. (2010) observed plant height increases with increasing dosages of cattle manure for red pepper seedlings and beetroot seedlings, respectively. The latter authors affirmed that the positive effect could be related to the supply of nitrogen to the plants through the decomposition of cattle manure. Conversely, according to Almeida et al. (2011), the effectiveness of the manure substrate regarding the length of passion fruit seedlings was mainly due to the higher capacity for water retention provided by this organic material.

With the exception of the dosage of 10%, the other dosages of biochar could be viable alternatives to fresh organic matter, despite the clear superiority of the dosage of 40% manure. These results also highlight the need to determine optimum dosages of biochar for each type of crop and production system because inadequate dosages may be ineffective or even harmful (GLASER et al., 2002; ZANETTI et al., 2003).

Other issues related to the use of biochar are the raw material from which it originates and the method of production because these factors affect its characteristics and functioning in the soil. Furthermore, researchers have shown that different materials and production conditions cause variations in the final product (GASKIN et al., 2010; LEHMANN, 2007).

### Diameter

At 40 DAS, the diameters of the seedlings (Figure 3) grown in the commercial substrate Germinar® were smaller than those of the seedlings grown with dosages of 10, 20 and 40% cattle manure. The seedlings grown in 20 and 40% cattle manure were superior to those grown in different doses of biochar, whereas the seedlings grown in 10% cattle manure was significantly greater than only the seedlings grown in 5% biochar. The diameters of the seedlings grown with cattle manure showed statistical significance in the linear regression analysis (Figure 3, Table 2), while the diameters of those grown in the biochar treatments did not.

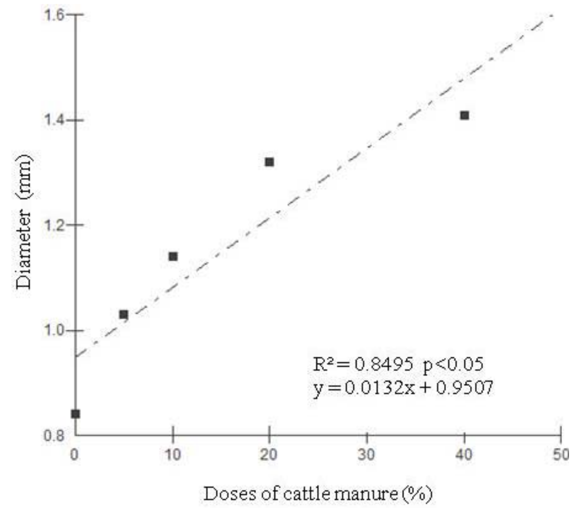


**Figure 3.** Relationship between cattle manure treatments and diameter of seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina- Mato Grosso State, Brazil, Unemat, 2011.

The superior diameter results for the manure treatment could be related to increased nutrient cycling, water retention and CTC (SILVA; RESCK, 1997). As a result of improvements in the chemical, physical and biological characteristics of a soil, adequate levels of organic matter can be maintained to ensure proper development, sufficient production and a high quality of cultures (MARQUES et al., 2010).

Costa et al. (2007) found increases in the diameter of seedlings grown with substrates consisting of cotton residue and coconut fiber, proving that fresh organic matter improves seedling quality when appropriate dosages are used. In this study, the dosages of biochar did not yield plant diameters similar to those obtained with dosages of 20 and 40% cattle manure.

### Phytomass

At 40 DAS, the values of dry and fresh shoot phytomass were greater for the 40% cattle manure treatment than for the other treatments. Unlike the biochar treatments, the linear regression analysis results for both fresh and dry phytomass were statistically significant for the different cattle manure dosages (Figure 4). These results clearly show that fresh organic matter was more effective than biochar in eggplant seedlings.

Almeida et al. (2011) found that substrates of cattle manure could be used to effectively increase the dry mass of shoots of passion fruit seedling. For the fresh and dry phytomass of rocket culture, Rodrigues et al. (2008) observed significant increases with increasing dosages of cattle manure and found that the composition and effectiveness of manure varied based on animal source, handling and decomposition time.

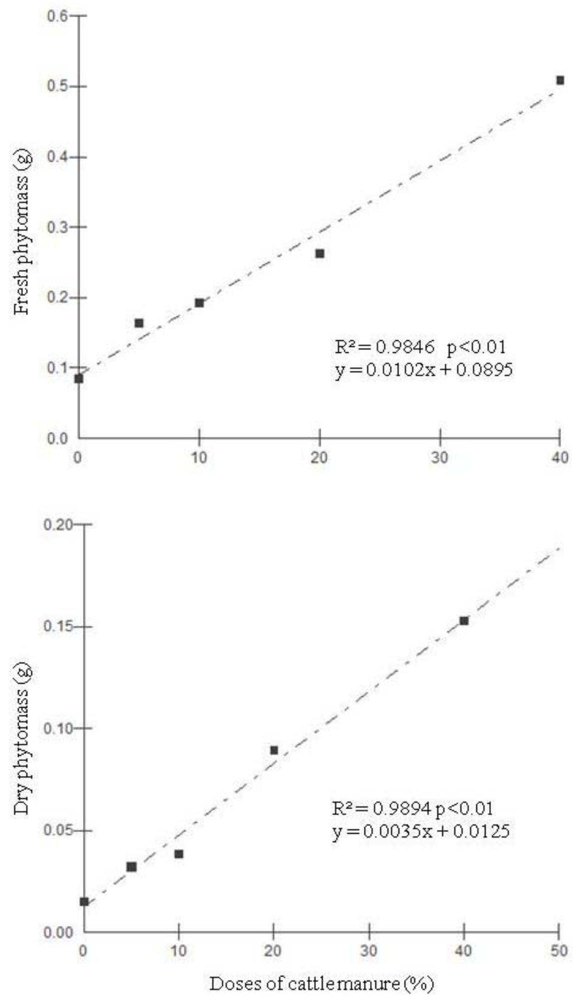


**Figure 4**. Relationship between cattle manure treatments and shoot phytomass of seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina-Mato Grosso State, Brazil, Unemat, 2011.

The way in which a substrate affects the formation of the shoot is extremely important in seedling production because good shoot formation is essential for the development of plants and the volume of substrate in which roots can grow is limited in seedling tray production (OLIVEIRA et al., 2008). The shoot phytomass results also show that biochar cannot effectively replace cattle manure, at least the dosage of 40% cattle manure. These results contradict certain findings in the literature (e.g., LEHMANN; JOSEPH, 2009).

At 40 DAS, the dosages of 20 and 40% cattle manure yielded more root phytomass than the other treatments. Similar to the shoot biomass results and contrary to the results for biochar, the linear regression analysis of the different dosages of cattle manure treatments was highly significant for both the fresh and dry phytomass (Figure 5), proving the efficacy of fresh organic matter compared to biochar.

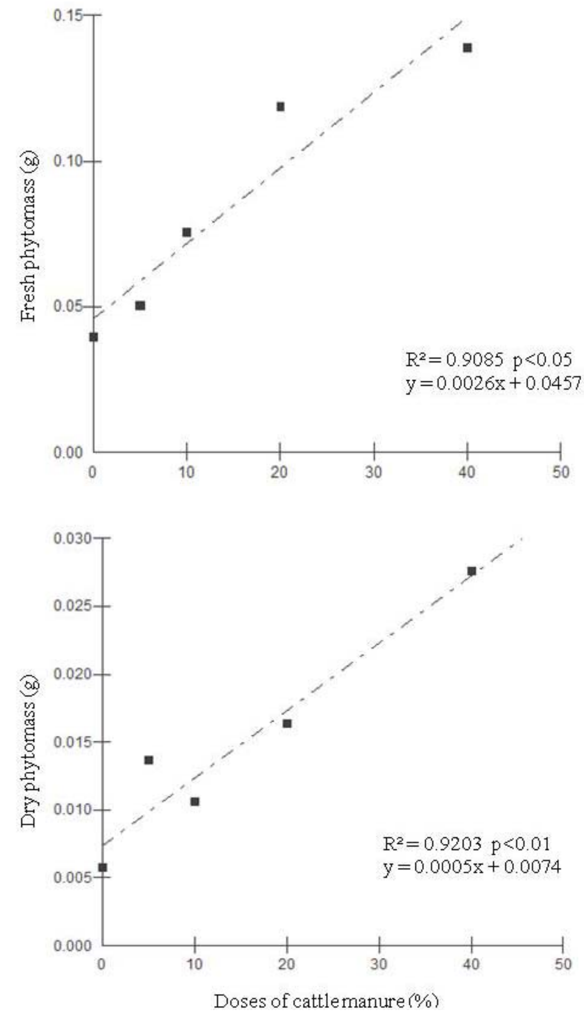


**Figure 5.** Relationship between cattle manure treatments and root phytomass of seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina-Mato Grosso State, Brazil, Unemat, 2011.

These results are similar to those obtained by Almeida et al. (2011), who showed increases in the dry mass of root systems grown in substrates with cattle manure. According to Canesin and Corrêa (2006), such positive results can be attributed to the fertility improvements provided by organic materials, which are sources of nutrients for plants. Similar to the shoot phytomass results, the root phytomass results do not show the effectiveness of biochar as a substitute for organic matter. According to Winsley (2007), biochar is not able to directly provide nutrients to vegetables, but it does improve soil structure, with a consequent increase in water retention and nutrient availability, both of which benefit crop development. Thus, the substrate base can determine the ability of biochar to release nutrients and balance ionic charges in the sorption complex (GLASER et al., 2002; MAJOR et al., 2010).

### Dickson Quality Index

The highest dosage of cattle manure (40%) yielded higher Dickson quality index (DQI) values compared to the other treatments. The values obtained with the biochar and commercial substrate treatments were, on average, less than half of the values obtained with a dosage of 40% cattle manure. The linear regression analysis for the DQI values was highly significant for cattle manure (Figure 6) but not for biochar (Table 2), proving the superiority of fresh organic matter in the improvement of seedling quality.

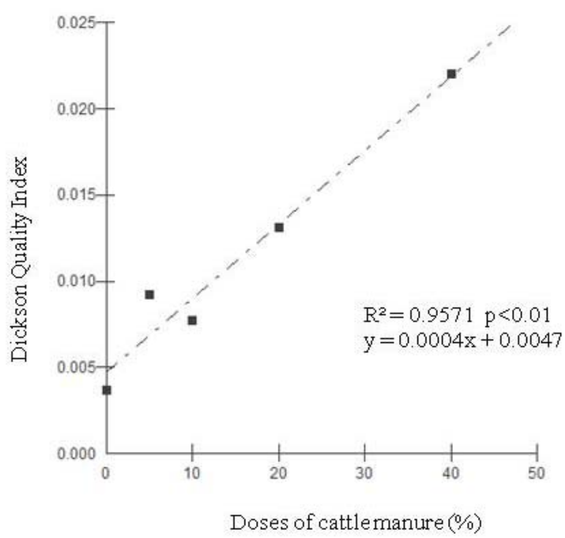


**Figure 6.** Relationship between cattle manure treatments and the Dickson Quality Index of seedlings of eggplant cv. Purple Long, at 40 DAS. Nova Xavantina-Mato Grosso State, Brazil, Unemat, 2011.

This parameter is the most important in the evaluation of seedling quality. Thus, the hypothesis that biochar, a stable form of organic matter, can be effectively substituted for organic matter, such as that found in fresh cattle manure, in vegetable production was not supported. The positive effects of organic matter were discussed by Araújo Neto et al. (2009) for red pepper seedlings and by Francisco et al. (2010) for papaya seedlings. Almeida et al. (2011) observed higher values of the DQI for yellow passion fruit seedlings grown in fresh organic matter. According to these authors, the positive effects of organic matter are related to water retention and aeration. However, because these features are also common to biochar, other attributes of fresh organic matter are likely responsible for the observed differences.

According to Costa et al. (2010), the superior quality of the seedlings could be related to the increased amounts of total dry matter and larger diameter seedlings. The same conclusion could be drawn from the results of this study because the substrate that yielded the highest quality seedlings was also the one with the greatest values for the evaluated parameters.

In general, the variables analyzed in this study show that biochar is not an effective substitute for fresh organic matter. However, although the original hypothesis was not supported, the evidence suggests that biochar can be used as a long-term soil/substrate conditioner to influence productivity, the most important parameter, without altering certain soil attributes (MARIMON-JUNIOR et al., 2012; PETTER et al., 2012).

## Conclusion

The dosages of cattle manure improved the evaluated agronomical parameters, confirming the significant influence of organic matter on seedling quality as measured by the Dickson Quality Index.

The effects of the different dosages of biochar did not justify their use as a substitute for fresh organic matter, indicating a need for the improvement of preparation techniques and methods for the use of pyrogenic carbon.

## Acknowledgements

We thank the Brazilian council of science and technology (*Conselho Nacional de Desenvolvimento Científico e Tecnológico*) for financial support for the *Projeto Biochar* (CNPq 555019/2008), coordinated by B.H. Marimon-Junior.

## References

ALMEIDA, J. P. N.; BARROS, G. L.; SILVA, G. B. P.; PROCÓPIO, I. J. S.; MENDONÇA, V. Substratos alternativos na produção de mudas de maracujazeiro amarelo em bandeja. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 6, n. 1, p. 188-195, 2011.

ARAÚJO NETO, S. E.; AZEVEDO, J. M. A.; GALVÃO, R. O.; OLIVEIRA, E. B. L.; FERREIRA, R. L. F. Produção de muda orgânica de pimentão com diferentes substratos. **Ciência Rural**, v. 39, n. 5, p. 1408-1413, 2009.

AYRES, M.; AYRES JUNIOR, M.; AYRES, D. L.; SANTOS, A. A. S. **BioEstat, aplicações estatísticas nas áreas das ciências bio-médicas**. Belém: Sociedade Civil Mamirauá, 2007.

BENITES, V. M.; TEIXEIRA, W. G.; REZENDE, M. E.; PIMENTA, A. S. Utilização de carvão e subprodutos da carbonização vegetal na agricultura: aprendendo com as Terras Pretas de Índio. In: TEIXEIRA, W. G.; KERN, D.

C.; MADARI, B. E.; LIMA, H. N.; WOODS, W. I. (Ed.). **As Terras Pretas de Índio da Amazônia**: sua caracterização e uso deste conhecimento na criação de novas áreas. Manaus: Embrapa Amazônia Ocidental, 2009. p. 285-296.

CANESIN, R. C. F. S.; CORRÊA, L. S. Uso de esterco associado à adubação mineral na produção de mudas de mamoeiro (*Carica papaya* L.). **Revista Brasileira de Fruticultura**, v. 28, n. 3, p. 481-486, 2006.

COSTA, C. A.; RAMOS, S. J.; SAMPAIO, R. A.; GUILHERME, D. O.; FERNANDES, L. A. Fibra de coco e resíduo de algodão para substrato de mudas de tomateiro. **Horticultura Brasileira**, v. 25, n. 3, p. 387-391, 2007.

COSTA, E.; MESQUITA, V. A. G.; LEAL, P. A. M.; FERNANDES, C. D.; ABOT, A. R. Formação de mudas de mamão em ambientes de cultivo protegido em diferentes substratos. **Revista Ceres**, v. 57, n. 5, p. 679-685, 2010.

COSTA, E.; DURANTE, L. G. Y.; NAGEL, P. L.; FERREIRA, C. R.; SANTOS, A. Qualidade de mudas de berinjela submetida a diferentes métodos de produção. **Revista Ciência Agronômica**, v. 42, n. 4, p. 1017-1025, 2011.

CUNHA, T. J. F.; NOVOTNY, E. H.; MADARI, B. E.; BENITES, V. M.; MARTIN-NETO, L.; SANTOS, G. A. O carbono pirogênico. In: TEIXEIRA, W. G.; KERN, D. C.; MADARI, B. E.; LIMA, H. N.; WOODS, W. I. (Ed.). **As Terras Pretas de Índio da Amazônia**: sua caracterização e uso deste conhecimento na criação de novas áreas. Manaus: Embrapa Amazônia Ocidental, 2009. p. 263-284.

DICKSON, A.; LEAF, A. L.; HOSNER, J. F. Quality appraisal of white spruce and white pine seedling stock in nurseries. **Forest Chronicle**, v. 36, n. 1, p. 10-13, 1960.

FRANCISCO, M. G. S.; MARUYAMA, W. I.; MENDONÇA, V.; SILVA, E. A.; REIS, L. L.; LEAL, S. T. Substratos e recipientes na produção de mudas de mamoeiro 'Sunrise Solo'. **Revista Agrarian**, v. 3, n. 9, p. 267-274, 2010.

FURLANI, P. R.; PURQUERIO, L. F. V. Avanços e desafios na nutrição de hortaliças. In: PRADO, R. M.; CECILIO FILHO, A. B.; CORREIA, M. A. R.; PUGA, A. P. (Ed.). **Nutrição de plantas**: diagnose foliar em hortaliças. Jaboticabal: FCAV/Fapesp/CAPES/FundUnesp, 2010. p. 45-62.

GASKIN, J. W.; SPEIR, R. A.; HARRIS, K.; DAS, K. C.; LEE, R. D.; MORRIS, L. A.; FISHER, D. S. Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. **Agronomy Journal**, v. 102, n. 2, p. 623-633, 2010.

GLASER, B.; HAUMAIER, L.; GUGGENBERGER, G.; ZECH, W. The 'Terra Preta' phenomenon: a model for sustainable agriculture in the humid tropics. **Naturwissenschaften**, v. 88, n. 1, p. 37-41, 2001.

GLASER, B.; LEHMANN, J.; ZECH, W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: a review. **Biology and Fertility of Soils**, v. 35, n. 4, p. 219-230, 2002.

GOMES, L. A. A.; RODRIGUES, A. C.; COLLIER, L. S.; FEITOSA, S. S. Produção de mudas de alface em substrato alternativo com adubação. **Horticultura Brasileira**, v. 26, n. 3, p. 359-363, 2008.

GUNDALE, M. J.; DELUCA, T. H. Charcoal effects on soil solution chemistry and growthof Koeleria macrantha in the ponderosa pine/Douglas-fir ecosystem. **Biology and Fertility of Soils**, v. 43, n. 3, p. 303-311, 2007.

LEHMANN, J. Bio-energy in the black. **Frontiers in Ecology and the Environment**, v. 5, n. 7, p. 381-387, 2007.

LEHMANN, J.; JOSEPH, S. Biochar for environmental management: an introduction. In: LEHMANN, J.; JOSEPH, S. (Ed.). **Biochar for environmental management**: science and technology. London: Earthscan, 2009. p. 1-09.

LEHMANN, J.; SILVA JUNIOR, J. P.; STEINER, C.; NEHLS, T.; ZECH, W.; GLASER, B. Nutrient availability and leaching in an archaeological Anthrosol and Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. **Plant and Soil**, v. 249, n. 2, p. 343-357, 2003.

LIANG, B.; LEHMANN, J.; SOLOMON, D.; KINYANGI, J.; GROSSMAN, J.; O'NEILL, B.; SKJEMSTAD, J. O.; THIES, J.; LUIZÃO, F. J.; PETERSEN, J.; NEVES, E. G. Black carbon increases cation exchange capacity in soils. **Soil Science Society of America Journal**, v. 70, n. 5, p. 1719-1730, 2006.

MADARI, B. E.; CUNHA, T. J. F.; NOVOTNY, E. H.; MILORI, D. M. B. P.; MARTIN NETO, L.; BENITES, V. M.; COELHO, M. R.; SANTOS, G. A. Matéria orgânica dos solos antrópicos da Amazônia (Terra Preta de Índio): suas características e papel na sustentabilidade da fertilidade do solo. In: TEIXEIRA, W. G.; KERN, D. C.; MADARI, B. E.; LIMA, H. N.; WOODS, W. I. (Ed.). **As Terras Pretas de Índio da Amazônia**: sua caracterização e uso deste conhecimento na criação de novas áreas. Manaus: Embrapa Amazônia Ocidental, 2009. p. 172-188.

MAJOR, J.; DITOMMASO, A.; LEHMANN, J.; FALCÃO, N. P. S. Weed dynamics on Amazonian Dark Earth and adjacent soils of Brazil. **Agriculture, Ecosystems and Environment**, v. 111, n. 1, p. 1-12, 2005.

MAJOR, J.; RONDON, M.; MOLINA, D.; RIHA, S. J.; LEHMANN, J. Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. **Plant and Soil**, v. 333, n. 1, p. 117-128, 2010.

MARIMON-JUNIOR, B. H.; PETTER, F. A.; ANDRADE, F.; MADARI, B. E.; MARIMON, B. S.; SCHOSSLER, T. R.; GONCALVES, L. G. V.; BELÉM, R. S. Produção de mudas de jiló em substrato condicionado com Biochar. **Comunicata Scientiae**, v. 3, n. 2, p. 108-114, 2012.

MARQUES, L. F.; MEDEIROS, D. C.; COUTINHO, O. L.; MARQUES, L. F.; MEDEIROS, C. B.; VALE, L. S. Produção e qualidade da beterraba em função da adubação com esterco bovino. **Revista Brasileira de Agroecologia**, v. 5, n. 1, p. 24-31, 2010.

MASULILI, A.; UTOMO, W. H.; SYECHFANI, M. S. Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. **Journal of Agricultural Science**, v. 2, n. 1, p. 39-47, 2010.

MEDEIROS, M. C. L.; MEDEIROS, D. C.; LIBERALINO FILHO, J. Adubação foliar na cultura da rúcula em diferentes substratos. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 2, n. 2, p. 158-161, 2007.

MEDEIROS, D. C.; FREITAS, K. C. S.; VERAS, F. S.; ANJOS, R. S. B.; BORGES, R. D.; CAVALCANTE NETO, J. G.; NUNES, G. H. S.; FERREIRA, H. A. Qualidade de mudas de alface em função de substratos com e sem biofertilizante. **Horticultura Brasileira**, v. 26, n. 2, p. 186-189, 2008.

MOREIRA, M. A.; DANTAS, F. M.; BIANCHINI, F. G.; VIÉGAS, P. R. A. Produção de mudas de berinjela com uso de pó de coco. **Revista Brasileira de Produtos Agroindustriais**, v. 12, n. 2, p. 163-170, 2010.

OLIVEIRA, A. B.; HERNANDEZ, F. F. F.; ASSIS JÚNIOR, R. N. Pó de coco verde, uma alternativa de substrato na produção de mudas de berinjela. **Revista Ciência Agronômica**, v. 39, n. 1, p. 39-44, 2008.

OLIVEIRA, A. B.; HERNANDEZ, F. F. F.; ASSIS JÚNIOR, R. N. Absorção de nutrientes em mudas de berinjela cultivadas em pó de coco verde. **Revista Caatinga**, v. 22, n. 2, p. 139-143, 2009.

PENTEADO, S. R. **Introdução à agricultura orgânica**. Viçosa: Aprenda Fácil, 2003.

PETTER, F. A.; MADARI, B. E.; SOLER, M. A. S.; CARNEIRO, M. A. C.; CARVALHO, M. T. M.; MARIMON-JUNIOR, B. H.; PACHECO, L. P. Soil fertility and agronomic response of rice to biochar application in the Brazilian savannah. **Pesquisa Agropecuária Brasileira**, v. 47, n. 5, p. 699-706, 2012.

RODRIGUES, G. S. O.; TORRES, S. B.; LINHARES, P. C. F.; FREITAS, R. S.; MARACAJÁ, P. B. Quantidade de esterco bovino no desempenho agronômico da rúcula (*Eruca sativa* L.), cultivar Cultivada. **Revista Caatinga**, v. 21, n. 1, p. 162-168, 2008.

RONDON, M. A.; LEHMANN, J.; RAMÍREZ, J.; HURTADO, M. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. **Biology and Fertility of Soils**, v. 43, n. 6, p. 699-708, 2007.

SILVA, J. E.; RESCK, D. V. S. Matéria orgânica do solo. In: VARGAS, M. A. T.; HUNGRIA, M. (Ed.). **Biologia dos solos dos Cerrados**. Planaltina: Embrapa, 1997. p. 465-524.

SOUCHIE, F. F.; MARIMON-JUNIOR, B. H.; PETTER, F. A.; MADARI, B. E.; MARIMON, B. S.; LENZA, E. Carvão pirogênico como condicionante para substrato de mudas de *Tachigali vulgaris* L.G. Silva & H.C. Lima. **Ciência Florestal**, v. 21, n. 4, p. 811-821, 2011.

STEINER, C.; TEIXEIRA, W. G.; LEHMANN, J.; NEHLS, T.; MACÊDO, J. L. V.; BLUM, W. E. H.; ZECH, W. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. **Plant and Soil**, v. 291, n. 1, p. 275-290, 2007.

TOPOLIANTZ, S.; PONGE, J. F.; BALLOF, S. Manioc peel and charcoal: a potential organic amendment for sustainable soil fertility in the tropics. **Biology and Fertility of Soils**, v. 41, n. 1, p. 15-21, 2005.

TRIGO, M. F. O. O.; TRIGO, L. F. N. Efeito do condicionamento osmótico na germinação e no vigor de sementes de berinjela (*Solanum melongena* L.). **Revista Brasileira de Sementes**, v. 21, n. 1, p. 107-113, 1999.

WINSLEY, P. Biochar and bioenergy production for climate change mitigation. **Science Review**, v. 64, n. 1, p. 5-10, 2007.

ZANETTI, M; CAZETTA, J. O.; MATTOS JÚNIOR, D.; CARVALHO, S. A. Uso de subprodutos de carvão vegetal na formação do porta-enxerto limoeiro 'Cravo' em ambiente protegido. **Revista Brasileira de Fruticultura**, v. 25, n. 3, p. 508-512, 2003.

*Received on June 10, 2012.*
*Accepted on June 21, 2012.*