

Original Research Article

The Use of Sewage Sludge in Bell Pepper Plants to Help Low Input Sustainable Agriculture

Bruno E. Távora¹, Ricardo V. Trótski O. Silva², Rosileide F.S. Andrade³,
Carlos A. Alves da Silva³, Galba M. Campos-Takaki^{3*} and Arminda Saconi Messias³

¹Environmental Engineering Course, Catholic University of Pernambuco, 50.050-900,
Recife, Pernambuco, Brazil

²Master in Development of Environmental Processes, Catholic University of Pernambuco,
50.670-901, Recife, Pernambuco, Brazil

³Nucleus of Research in Environmental Sciences and Biotechnology, Catholic University of
Pernambuco, 50050-590, Recife, Pernambuco, Brazil

*Corresponding author

ABSTRACT

Keywords

Solid waste,
Culinary
plants,
*Capsicum
annuum*

The waste produced by sewage treatment stations has an important addition to its agronomic characteristic value. The correct utilization of this resource is fundamental to the sustainability of its use for studying the applications of sewage sludge in the cultivation of bell pepper (*Capsicum annum*). In order to achieve that a germination experiment in 128 cells trays using five doses of sewage sludge were employed using the ratio of sludge/soil of 0, 25, 75 and 100 %, with four repetitions. Germination speed index (GSI) and sixth leaf development index (SDI) were determined. The influence of sludge was only noted in the SDI. After the germination period an experiment was set at a plant house, using eight liter vases and sludge doses equivalent to 0, 10, 20, 30, 40, and 50 m³ha⁻¹. In a period of 90 days it has been observed a better development of height and diameter at a dose of 20 m³ha⁻¹; however, there has been anticipation in development of fruits in doses of 40 and 50 m³ha⁻¹. The regression analysis has shown that concerning production, its maximum values occurred in doses of 45.8 m³ha⁻¹.

Introduction

The application in soil is one of the oldest treatments and final destination of sewage. “Sewage farms”, as they became known in their first attempts in England, early 19th century, soon spread across Europe and United States (Bastos, 2003; Quintana *et al.*, 2011).

According to Campos (1999) and Andreoli (2006), biological treatment of sewers is a phenomenon that can occur naturally either in the soil or in the water, as long as there are appropriate conditions. A sewage treatment station is then, in essence, a system that exploits these organisms,

optimizing the processes and minimizing costs in order to achieve the highest efficacy possible.

As stated by Andreoli *et al.* (2001), there are three types of sewage sludge. There is crude sludge, produced in the primary settlers, of greyish color, displeasing odor and easily fermented. There is activated sludge, product of the bioreactors, with a flocculent appearance, brownish color and a less displeasing odor. There is also digested sludge, the one who underwent biological stabilization processes, through biodigesters, with a variable color mostly dependent on the process (aerobic or anaerobic) and both do not possess an offensive odor.

As stated by Bettioli and Camargo (2006, 2014) sewage sludge presents a wide range of compositions, depending on the source and collection method employed. It is, though, a material rich in organic matter (40 to 60%), nitrogen and some micronutrients. The average sewage sludge contains 40% organic matter, 4% nitrogen, 2% phosphorus and 0.4% potassium.

Vegetables need approximately 16 chemical elements considered essential to their development, being N, P, Ca and Mg considered macronutrients owing to their higher percentages in plant tissue.

The elements Cu, Fe, Mn and Zn are named micronutrients due to their smaller but nonetheless important participation on vegetable tissue composition. Thus, soil, in a rational production system, should be able to supply plants with adequate amounts of nutrients in the adequate time (Bettioli and Ghini, 2011; Bettioli and Camargo, 2014).

The use of sewage sludge as an organic fertilizer has been mentioned as an alternative to the final destination of this waste, chiefly because of its high nutrient

content and role as a conditioner of physicochemical and biologic properties of soil (Andreoli *et al.*, 2001).

The application of sewage sludge has increased the absorption of the nutrients N, P, K, Ca, Mg and Zn and production of dry matter in corn crops, raising pH and decreasing the toxic levels of Al^{+3} in five soils of the state of São Paulo, Brazil (Berton *et al.*, 1989, quoted by Ferraz Junior *et al.*, 2003).

Sludge generated in sewage treatment stations has proven to be fit as a fertilizer of organic crops such as sunflower, (Ribeirinho *et al.*, 2012), peach-palm (Vega *et al.*, 2004), corn and black beans (Gadioli and Fortes Neto, 2004), rice (Pires and Mattiazzo, 2003) and cotton plant (Pedroza *et al.*, 2003) owing to an increase in production of several species of agronomic interest (Silva *et al.*, 2010).

However, few studies report the relation of this waste in the cultivation of culinary plants. The use of culinary plants dates back to ancient civilizations that, motivated by their commercial relevance and wealth generation, favored the discovery of new land, particularly Brazil. Special flavors and aromas of food as well as refinement and embellishment of dishes in local and international cuisine are the ones responsible for high demand of such spices around the world (Trindade *et al.*, 1998).

The choice of using spices in their natural state (fresh and/or frozen) has suffered a notorious increase due to the popularity of ethnic foods that stimulate such use therefore the higher demand and need to increase production of these vegetables (Souza *et al.*, 2011).

According to Souza and Casali (1984) bell pepper (*Capsicum annum*) is one of the ten

most important vegetables of the market. It can be consumed both unripe and ripe. Even though its origin is the Americas, plants of the genre *Capsicum* are cultivated in regions of tropical and temperate climates. Portuguese navigators and explorers were looking for black pepper (*Piper nigrum*) finding peppers of the *Capsicum* genre instead. The plants found acceptance in the old world quicker than tomato and potato.

Bell pepper presents less demands concerning nutrition. However, it is produced in clay-sandy or sandy-clay, deep, well drained, preferably of high fertility soils. Soils with excessive clay are not favorable to the plant normal growth and accumulate water in excess during rainy periods. Excessively sandy soils require heavy organ mineral fertilizations and large amounts of water during irrigation, making its cultivation more expensive (Blank *et al.*, 1995; Araújo *et al.*, 2014).

Studies concerning nutrient absorption by bell pepper crops showed that the highest nitrogen, phosphorus, potassium, calcium and magnesium storage occur in the early stages of the plant cycle until the appearance of the first fruits, increasing after seventy five days.

The elements that are more absorbed by the bell pepper fruits are potassium and nitrogen, followed by phosphorus, sulfur, calcium and magnesium (Hagg *et al.*, 1970; Fernandes, 1971; Miller *et al.*, 1979, quoted by Fontes; Monnerat, 1984; Sediyma *et al.*, 2009).

Therefore, the purpose of this work was to assess the influence of sewage sludge in the fertility attributes of the soil cultivated with bell pepper, contributing to the sustainable development and family income elevation, as to attend to the economic, social and environmental preservation aspects.

Materials and Methods

Step 1: Germination

In the beginning of the experiment, seedlings were prepared in trays of 128 cells (Figure 1) where the direct sowing was performed, one seed per cell (Blank *et al.*, 1995).

To assess the influence of sewage sludge in germination potential of bell pepper seeds an experiment was performed employing five doses of sewage sludge in sludge/soil rates of 0, 25, 50, 75 and 100%, with four repetitions, in the external area of the Environmental Sciences Research Nucleus of the Catholic University of Pernambuco.

Growth Speed Index was calculated by the sum of the number of normal plants germinated each day (G1, G2, G3 ... Gn) divided by the number of days (D1, D2, D3 ... Dn) between sowing and germination. Therefore, GSI was represented by Equation 1:

(Eq.1)

$$IVG = \frac{G1}{D1} + \frac{G2}{D2} + \frac{G3}{D3} + \dots + \frac{Gn}{Dn}$$

In order to assess the seedlings development a similar index to the former was applied (SDI: sixth leave development index – Equation 2). To rule out occasional lack of homogeneity due to sample size, owing to the event of non-germinated seeds, the index was calculated by adding the number of normal seedlings with six leaves (F1, F2, F3 ... Fn) each day, divided it by the number of days passed (D1, D2, D3 ... Dn) and divided the result by the number of seedlings in the sample (Ft).

(Eq. 2)

$$IDF = \frac{\frac{F1}{D1} + \frac{F2}{D2} + \frac{F3}{D3} + \dots + \frac{Fn}{Dn}}{Ft}$$

The irrigation with deionized water, by dripping, started soon after sowing, twice a day during the first 15 days, tapering down to once daily until transplanting (Oliveira; Luz, 1998; Rigo *et al.*, 2014).

Step 2: Fertility

In Pernambuco Agronomic Institute (IPA), in Recife, Pernambuco, Brazil, an experiment was performed in greenhouse conditions with vases of 8 liters of soil to assess the agronomic potential of sewage sludge in vegetable cultivations. In order to measure such the Big All variety bell pepper (*Capsicum annum*) was used as test-plant (Figure 2).

The experimental design was of complete randomization with three repetitions, in a factorial scheme of 1 x 6 (one soil and six doses) in 18 vessels. Sewage sludge doses were calculated so as to provide a fertilizing of 0, 0.5, 1, 1.5, 2 and 2.5 times the recommended organic matter to cultivation of soil in the state of Pernambuco, Brazil, that is, for bell pepper crops, 20 m³ha⁻¹ (Cavalcanti and Santos, 1998).

The soil used in the experiments was collected in the Experimental Station of Itapirema/IPA, city of Goiana, in the state of Pernambuco, Brazil, preferring soils with median texture (EMBRAPA, 1999), more suitable to bell pepper crops. After collection, soil was mixture, air dried, grounded and sieved. Sewage sludge was collected in the drying bed of the Sewage Treatment Station of Mangueira, from Pernambuco Sanitation Company – COMPESA, in the city of Recife,

Pernambuco, Brazil. After collection, the sample was air dried, grinded and passed a 0.004 m sieve to further chemical analysis. Sewage sludge was incubated in the soil for a period of seven days (Gomes, 2004).

After incubation, transplanting of the seedlings of Step 1 to the vessels was performed. A transplanted seedling presented from six to eight leafs and from 10 to 15 cm of height, withdrawing border effect. These conditions happened between 30 and 45 days after sowing.

Harvest started 90 days after sowing, Step 1, when the fruits presented firm consistency and bright green color, in order to assess the production. The airy part of the plant neck was collected and washed with deionized water. The material was stored in paper bags, air and oven dried at 60 °C until constant mass was achieved. The data obtained to bell pepper production was submitted to statistical analysis using regression tests.

Results and Discussion

Table 1 presents the chemical characteristics of the employed sludge. It can be observed the possible need of whitewashing, due to its acid character. Concerning macronutrients, phosphorus presents high above the average observed in sewage sludge though magnesium is a little below average. Values of heavy metals, elements that need monitoring according to Andreoli *et al.* (2001), presented well below the inferior limits, 1000, 2500 and 750 mg.kg⁻¹, respectively to copper, zinc and led.

Table 2 presents the results of the variation analysis applied to data from the germination experiment. It can be observed that no significant difference was found do growth speed index (GSI). Such findings demonstrate that even though sewage sludge

has not improved the germination speed there has been no toxicity in this first stage of bell pepper development.

During Step 1 of the experiment, it was observed that adding sewage sludge increases the tolerance to hydric stress that,

in conjunction with nutrients availability in the sludge, contributes to seedlings development as shown by the variation analysis followed by the Tukey post-test, in table 3. The test has shown a significant difference in the sixth leaf development.

Table.1 Chemic characteristics of sewage sludge from STS Mangueira, Recife, Pernambuco, Brazil

Characteristics	Value
pH (water 1:2,5)	5.1
N-total (g kg ⁻¹)	22.5
Carbon (g kg ⁻¹)	285.9
Organic Matter (g kg ⁻¹)	493.0
C/N rate	12.7
P (g kg ⁻¹)	45.0
K (g kg ⁻¹)	2.1
Na (g kg ⁻¹)	0,3
Ca (g kg ⁻¹)	9.4
Mg (g kg ⁻¹)	1.2
Cu (mg kg ⁻¹)	155.0
Zn (mg kg ⁻¹)	548.0
Mn (mg kg ⁻¹)	207.0
Pb (mg kg ⁻¹)	120.0
Fe (mg kg ⁻¹)	16.9

Table.2 Variation analysis of the germination experiment

	GL	SQ	QM	Fc	Pr>Fc
Sludge dose	4	0.156855	0.039214	1.391	0.2843
Error	15	0.42289	0.028193		
Corrected total	19	0.579745			
CV (%)	25.66				
Global average	0.65435		Number of Observations: 20		

Table.3 Variation analysis of seedlings development

	GL	SQ	QM	Fc	Pr>Fc
Sludge dose	4	0.892227	0.223057	14.123	0.0004
Error	10	0.157933	0.015793		
Corrected total	14	1.050160			
CV (%)	22.68				
Global average	0.5540		Number of Observations: 15		

Tukey test for the variation source

Treatment (%)	Average GSI	Test result
0	0.110	a
75	0.566	b
25	0.590	b
50	0.650	b
100	0.853	b

Figure.1 Germination tray of bell pepper



Figure.2 Greenhouse experimente



Figure.3 Development of bell pepper seedlings



Figure.4 Average stalk diameter after 60 days of bell pepper development

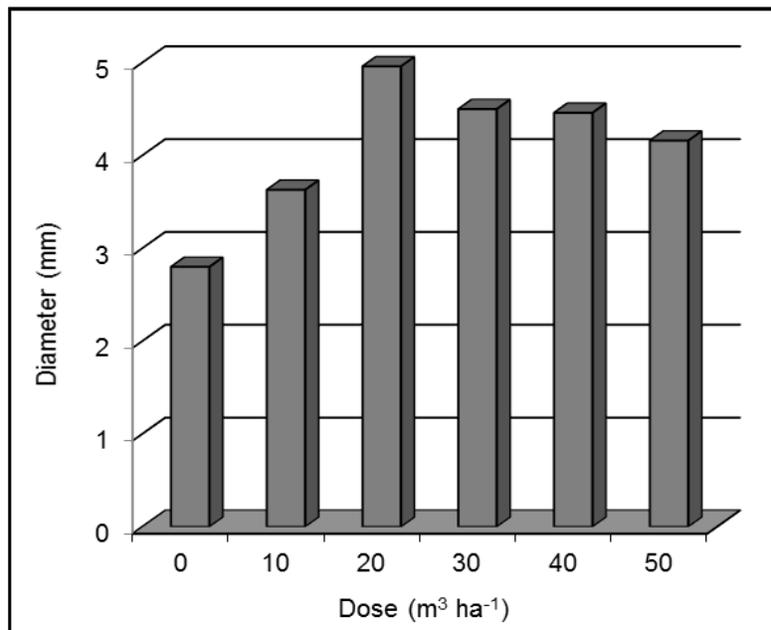


Figure.5 Average height after 60 days of bell pepper development

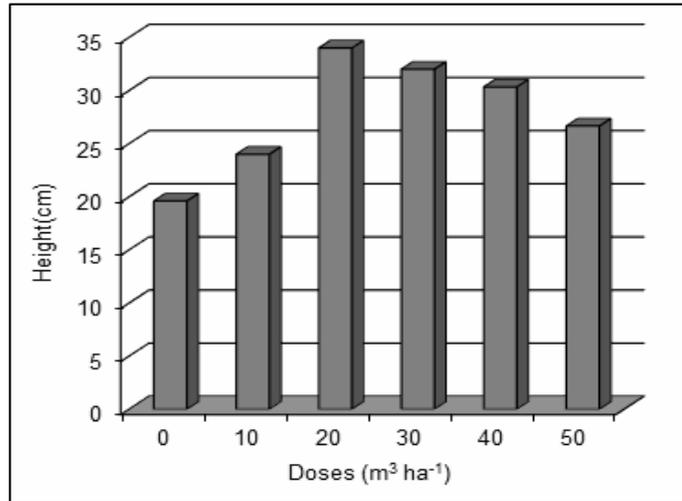


Figure.6 Development of bell pepper in the dose of $0 m^3 ha^{-1}$



Figure.7 Development of bell pepper in the dose of $10 m^3 ha^{-1}$



Figure.8 Development of bell pepper in the dose of $20 m^3 ha^{-1}$



Figure.9 Development of bell pepper in the dose of $30 m^3 ha^{-1}$



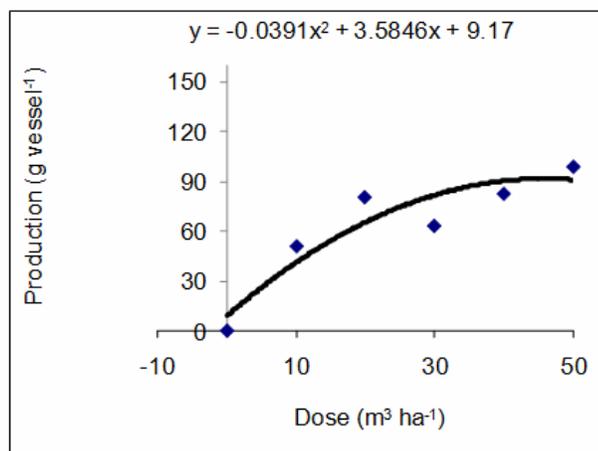
Figure.10 Development of bell pepper in the dose of 40 m³ha⁻¹



Figure.11 Development of bell pepper in the dose of 50 m³ha⁻¹



Figure.12 Regression analysis for the production of bell pepper in function of dose



It can be observed a higher primary growth speed at dose zero (Figure 3) when compared to other doses where the insertion of the first pair of leaves occurs at a greater height than that of the other treatments. The leaves, however, have little development, something that has not happened in doses that had the presence of sludge, starting the differentiation due to the addition of sludge not previously detected during germination.

Regarding development of bell peeper after transplanting it can be observed in Figures 4 and 5 the development of stalk diameter and

average plant height respectively in function of the applied sewage sludge dose applied (equal letters have no statistical difference in the Tukey test at a 5% probability rate). In both cases the best results were observed at a dose of 20 m³ ha⁻¹. However, only to plant height this result was statistically different from the other doses according Araújo *et al.* (2009).

It can be observed that the application of sludge has anticipated the flowering of the cultivation, in more than 35 days, resulting in the appearance of fruits with,

approximately, sixty days to the doses of 20, 30, 40 and 50 m³ha⁻¹ (Figures 6, 7, 8, 9, 10 and 11). Even though the developments in height and diameter have been more expressive in the 20m³ha⁻¹ a higher anticipation in fruit development was noted in the doses of 40 and 50 m³ha⁻¹.

In Figure 12 it can be observed the production of bell pepper related to the dose of sewage sludge. Through the function obtained by linear regression it was possible to determine the maximum production value at a dose of 45.6 m³ha⁻¹ with a production of 91.32 g of bell pepper per vessel, though the dendrometric data previously presented pointed to a dose of 20 m³ha⁻¹ as the one of better development. Such model should not be considered as a field crop production estimator, even though it is highly useful in determining the dose with better yield of bell pepper (Albuquerque *et al.*, 2011). The variance analysis to the proposed model was significant at a 5% probability.

Acknowledgments

This work was financially supported by International Federation of Catholic Universities (FIUC), National Council for Scientific and Technological Development (CNPq), and Science and Technology of the State of Pernambuco (FACEPE).

References

- Accorsini, F.R., Mutton, M.J.R., Lemos, E.G.M., Benincasa, M. 2012. Biosurfactants production by yeasts using soybean oil and glycerol as low cost substrate. *Braz. J. Microbiol.*, 43: 116–125.
- Albuquerque, F.S., Silva, E.F.F., Souza, A.E.R., Rolim, M.M. 2011. Lixiviação de potássio em um cultivo de pimentão sob lâminas de irrigação e doses de potássio. *Ver. Caat.*, 24: 135–144.
- Andreoli, C.V. 2006. Alternativas de uso de resíduos de saneamento. Curitiba: Sanepar, 417 Pp.
- Andreoli, C.V., Lara, A.I., Fernandes, F. 2001. Reciclagem de biossólidos: transformando problema em solução. Sanepar, Curitiba, 2nd edn., Pp. 28–35.
- Araújo, Diva L., Araújo, Danila L., Melo, E.N., Santos, J.G.R., Azevedo, C.A.V. 2014. Crescimento do pimentão sob diferentes concentrações de biofertilizante e lâminas de irrigação. *Rev. Verd.*, 9: 172–181.
- Araujo, J. S., Andrade, A. P., Ramalho, C. I., Azevedo, C. A. V. 2009. Características de frutos de pimentão cultivado em ambiente protegido sob diferentes doses de nitrogênio via fertirrigação. *Rev. Bras. de Engenh. Agríc. Ambient.*, 13: 152–157.
- Bastos, R.K.X. 2003. Utilização de esgoto tratado em fertirrigação, hidroponia e piscicultura. Rio de Janeiro, ABES. Pp. 1–28.
- Bettiol, W., Camargo, A. O. 2014. Impacto ambiental do uso de lodo de esgoto. Jaguariúna: EMBRAPA. Pp. 11–115.
- Bettiol, W., Camargo, O. A. 2006. Lodo de esgoto: impactos ambientais na agricultura. Jaguariúna, ed. Embrapa Meio Ambiente, 394 Pp.
- Bettiol, W., Ghini, R. 2011. Impacts of sewage sludge in tropical soil: a case study in Brazil. *Appl. Environ. Soil Sci.*, 1: 1–11.
- Blank, A.F., Souza, R.J., Gomes, L.A.A. 1995. Produção de pimentão em estufa. Lavras: Universidade Federal de Lavras. 15 Pp.
- Campos, J.R. 1999. Tratamento de esgoto sanitário por processo anaeróbio e disposição controlada em solo. ABES
- Cavalcanti, F.J.A., Santos, J.C.P. 1998. Recomendações de adubação para o estado de Pernambuco: 2.

- aproximação. 1st edn. Recife: Ipa, 198 Pp.
- EMBRAPA - Empresa Brasileira De Pesquisa Agropecuária. 1999. Manual de métodos de análise de solo. 2nd ed. Rio de Janeiro, Embrapa-cnps, 212 Pp
- Ferraz Junior, A.S.L., Souza, S.R.; Castro, S.R.P., Pereira, R.B. 2003. Adubação de alface com lodo de esgoto de cervejaria. *Horticult. Brasil.*, 21: 60–63
- Fontes, P.C.R., Monnerat, P.H. 1984. Nutrição mineral e adubação das culturas de pimentão e pimenta. *Info. Agropec.*, 113: 26–29.
- Gadioli, J.L., Fortes Neto, P. 2004. Rendimento de milho (*Zea mays*) e de feijão preto (*Phaseolus vulgaris*) utilizando doses sucessivas de lodo de esgoto. Anais do Congresso Brasileiro de Ciência e Tecnologia em Resíduos e Desenvolvimento Sustentável, 140 Pp.
- Gomes, S.B.V. 2004. Utilização de lodo de esgoto com fertilizante para a cultura do milho: efeitos no solo e na planta. 54 Pp.
- Oliveira, J.M.F. de; Luz, F.J.de F. 1998. Orientação para o cultivo do pimentão em Roraima. Boa Vista: Embrapa-CPAF-Roraima, 24 Pp.
- Pedroza, J.P., Haandel, A.C. Van., B., Napoleão, E. de M. 2003. Production and components of herbaceous cotton as a function of application of biosolids. *Rev. Brasil. de Engenh. Agríc. e Ambient.*, 7: 483–488.
- Pires, A.M.M., Mattiazzo, M.E. 2003. Biosolids conditioning and the vailability of Cu and Zn for rice. *Scient. Agric.*, 60: 161–166.
- Quintana, N. R. G., Carmo, M. S. do, Melo, W. J. de. 2011. Lodo de esgoto como fertilizante: produtividade agrícola e rentabilidade econômica. *Nucleus*, 8: 1–4
- Ribeirinho, V. S., Melo, W. J. de; Silva, D. H. da; Figueiredo, L. A., Melo, G. M. P. de. 2012. Fertilidade do solo, estado nutricional e produtividade de girassol, em função da aplicação de lodo de esgoto. *Pesq. Agropec. Trop.*, 42: 166–173.
- Rigo, M.M., Ramos, R.R., Cerqueira, A.A., Souza, P.S.A., Marques, M.R.C. 2014. Destinação e reuso na agricultura do lodo de esgoto derivado do tratamento de águas residuárias domésticas no Brasil. *Gaia Scient.*, 8: 174–186.
- Sediyama, M. A. N., Vidigal, S. M., Santos, M. R., Salgado, L. T. 2009. Rendimento do pimentão em função da adubação orgânica e mineral. *Horticult. Brasil.*, 27: 294–299.
- Silva, F.C., Boaretto, A. E., Abreu Junior, C. H., Berton, R.S., Basso, L. C. Barbieri, V. 2010. Impactos da aplicação de lodo de esgoto na cultura da cana-de-açúcar e no ambiente. *LOS Environment*, 10: 1–5.
- Souza, A.P., Pereira, J.B.A., Silva, L.D.B., Guerra, J.G.M., Carvalho, D.F. 2011. Evapotranspiração, coeficientes de cultivo e eficiência do uso da água da cultura do pimentão em diferentes sistemas de cultivo. *Acta Scient. Agron.*, 33: 15–22.
- Souza, R.J., Casali, V.W.D. 1984. Cultivares de pimentão e pimenta. *Infor. Agropec.*, 113: 14–18.
- Trindade, C., Sartório, M. L., Resende, P. 1998. Cultivo e uso de plantas condimentares. Centro de Produções Tecnológicas. 43 Pp.
- Vega, F.V.A., Bovi, M.L.A., Berton, R.S., Godoy Junior, G., Cembranelli. M. de A.R. 2004. Aplicação de biossólido na implantação da cultura da pupunheira. *Hortic. Brasil.*, 22: 131–135.