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ORIGINAL ARTICLE

A Self-Sustaining Organic Fertilizer for Vegetable Production

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ABSTRACT

The objective of this study was to generate a sustainable organic fertilizer with physical, chemical, physicochemical and nutritional characteristics for continuous cropping of vegetables which develop normally without the application of chemical synthetic fertilizers. This study began making a pre-composted organic fertilizer which was composed by sugar cane rum, cattle manure, fish flour, and brewer yeast. In addition, coconut fiber dust, rice husk, phosphate rock, and dolomite in different proportion were added to the organic fertilizer. Then were prepared 16 treatments and mounted an experiment under a statistical completely randomized design with four replicates. Containers 12 L were used, which were filled with their different treatments and were watered to field capacity, as indicators crops serrano pepper, broccoli, and Swiss chard were planted. Yields of dry matter were obtained practicing an analysis of variance and means comparison test. In addition, was practiced linear regression analysis, considering the treatment physical, chemical and physicochemical characteristics and the fresh and dry matter yields of indicator crops; The best treatment was the T_{16} with yields of 945.50, 64.375 and 3.09 g/plant for serrano pepper, broccoli and Swiss chard crops respectively. In the research was concluded that it was generated a complete organic fertilizer nutritionally sustainable, for at least three consecutive vegetables crops, the first of which must be salt-tolerant. The organic fertilizer should include by volume: coconut fiber dust 24.6%, sugar cane rum 20.7%, rice husks 24.6%, cattle manure 24.0%, fish flour 5.0% phosphate rock 0.2%, dolomite 0.6% and brewer yeast 0.3%.

Key words: *organic substratum, vegetable nutrition, waste reuse.*

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INTRODUCTION

A problem which has contributed to environmental disturbances is the organic solid waste generation, and when to these are not given the proper management, it will become environmental contaminants affecting Man health [1]. Thus, a way to mitigate the problem mentioned is to use these by-products to produce composts, substrates and organic fertilizers to recycle nutrients for plant growth [2], in addition, improve the water storage capacity, soil permeability, increase the exchangeable bases concentration and decrease the exchangeable acidity [3].

Because of the pollution, many researchers in different countries have studied these materials for agricultural production: Nikajah *et al*. [4] fertilized the maize with 2 t ha^{-1} of composts derived from municipal solid waste + 300 kg NPK ha^{-1}, yields of 6822 kg ha^{-1} were obtained, that were higher than those obtained by the control treatment (2 ton ha^{-1} of compost) which yielded 5865 kg ha^{-1}. Rodríguez *et al*, [5] compared one vermicompost and one compost derived from the mixture of agave bagasse and sheep manure in the ratio 4:1 (v/v), used as controls the commercial peats Sunshine 3 and VTM Sogemix. They found that the physical and chemical properties of both vermicompost and compost were suitable and similar to those of the control treatments Sunshine 3 and VTM Sogemix, so it have a great potential in agriculture as organic substrates. Cruz *et al*., [6] compared various substrates for the tomato production under greenhouse conditions, it was found that the best substrate was the tezontle-vermicompost mix in the ratio of 65:35 and irrigated with the Steiner nutrient solution. Castillo *et al*., [7] recommended the preparation of a compost rich in nutrients by mixing suitable organic solid residuals, with inert materials to improve its physical and chemical characteristics. The nutrients contained in the compost are released in different ways: 11% of N, between 70 and 80% P and 80 to 90% of K is available the first year of its use [8]. Raviv *et al.* [9] indicated that the nutrients contained in compost, met the tomato plants requirements during the 4 months after the seedling transplant. Favara *et al*. [10] using *Brachiaria* sp. straw compost for the second time to cultivate the 99/30 and 04/49 strains of *Agaricus blazei*, found that in the compost used by first time, organic matter loss was greater with the 99/30 strain respect to the 04/49 strain. However, the 04/49 strain, contained higher protein percentage than 99/30 strain in both composts, and concluded: the compost used for second time was a good choice for the *Agaricus blazei* growth. As a compost does not contain all the essential elements for the plant growth, nobody has found a nutritionally sustainable substrate that be completely exhausting for the continuous cultivation of vegetables without the use of synthetic chemical fertilizers, the objective of this work was to obtain an organic fertilizer composed by organic and mineral materials, which gradually releases nutrients enough for consecutive growth of several horticultural species.

MATERIALS AND METHODS

To obtain a nutritionally self-sustaining organic fertilizer with the physical, chemical and physicochemical characteristics for the consecutive cultivation of various horticultural species, a base substrate (BS) was prepared using the following materials in volume (L): sugar cane rum (SCR 42%), cattle manure (CM 48%), fish flour (FF 10%) and brewer yeast (BY 0.3%) was added on the total volume prepared. In addition, coconut fiber dust (CFD), rice husks (RH), phosphate rock (PR), and dolomite (D) were added. The BS was mixed with different volumes of CFD FF, RH, PR and D; 16 treatments were generated: 1) BS 10 L (Control treatment), 2) BS 5L + CFP 5L, 3) BS 10L + PR 0.02L, 4) BS 5L + CFD 5L + PR 0.02L, 5) BS 10L + D 0.1L, 6) BS 5L + CFD 5L + D 0.1L, 7) BS 10L + PR 0.02L + D 0.1L, 8) BS 5L + CFD 5L + PR 0.02L + D 0.1L, 9) BS 5L + RH 5L, 10) BS 5L + CFD 2.5L + RH 2.5L, 11) BS 5L + PR 0.02L + RH 5L, 12) BS 5L + CFP 2.5L + PR 0.02L + RH 2.5L, 13) BS 5L + D 0.1L + RH 5L, 14) BS 5L + CFP 2.5L + D 0.1L + RH 2.5L, 15) BS 5L + RH 5L + PR 0.02L + D 0.1L, 16) BS 5L + CFP 2.5L + RH 2.5L + PR 0.02L + D 0.1L.

All of these materials were selected because they have characteristics and properties that must have looked for organic fertilizer with regional availability. The CFD has stability as organic substrate and has environmental sustainability characteristics. These characteristics imply that it is moderately resistant to the microbiological decomposition [11]. RH for its low density was chosen, and because during the composting process form compounds rich in N [12]. SCR through a humification process, come to get amendments for soil and organic substrates for the vegetable production [13]. When the SCR is applied, it raises the soil pH in a range that varies between 1 and 2 units. However, it is poor in Nitrogen (1.1%) but it is rich in phosphorus (4.9% P_2O_5) [14]. PR was chosen because of its P_2O_5 content (3 to 36) %. D is a double carbonate of calcium and magnesium; generally contains 30.41% CaO and 21.86% MgO [15]; it is used to raise the calcium and magnesium levels in the treatments. FF is an N and P source that are released slowly, becoming available for plants uptake. The BY produces bioactive substances such as hormones and enzymes useful to favor the presence of effective microorganisms such as lactic-acid bacteria and actinomycetes, and in order to reduce the composting time [16]. Bovine manure is rich in N, P, K, Ca, Mg and after its humification generates a high organic matter content.

Physical properties determined in the treatments: The apparent density (AD), particle density (PD), total porosity (TP), aeration porosity (AP) and water holding capacity (WHC), were analyzed with the Dilger porometers method [17].

Chemical properties determined in the treatments: The pH (1:5, potentiometric), EC (1:5, conductimetry), total N content by the Kjeldahl method [18], CEC with 1N ammonium acetate pH 7, P by the Olsen method (Olsen *et al*., 1954); Mg, K, Ca and Na extraction with ammonium acetate method; Fe, Cu, Zn and Mn by extraction with DTPA were determined [19].

Considering that the physical, chemical and physicochemical characteristics of the treatments are suitable from the agronomic point of view, and due to its nutrients gradual release as indicator crops of the treatments quality, three horticultural species were grown consecutively: serrano pepper (*Capsicum annum*) Darsena variety, broccoli (*Brassica oleracea*) Claudia Variety and Swiss chard (*Beta vulgaris*) Cicla variety.

Pots of 12 L capacity were used, which were filled with the different treatments. Then water to saturation was added and then serrano pepper seedlings were transplanted and after harvesting the pepper crops, broccoli and then Swiss chard seedlings were transplanted and grown consecutively in the same treatment, giving them the same handling than to pepper.

For the serrano pepper plant, fresh weight was taken. For the broccoli and Swiss chard crops, fresh and dry weights at the end of the harvest were taken.

It was worked with a completely randomized design with 16 treatments and 4 replications. To the yield data were practiced an analysis of variance and a mean comparison test Tukey$_{(0.05)}$ using the statistical package SAS 9.1 [20].

RESULTS AND DISCUSSION

Crops agronomic respond. The treatments significantly influenced on the serrano pepper, broccoli and Swiss chard yield, all three had the best answer with the T_{16}. However, broccoli crop responded favorably to the treatments T_3, T_6, and T_8 after harvesting the serrano pepper (Table 1), which was due in part to the physicochemical features that influenced the crop growth, in such a way that the pH, EC and CEC changed at favorable levels (Table 2).

Table 1 Crop production with different treatments

Treat.	Serrano pepper Yield (g/plant) Tukey (α=0.05)	Treat.	Brocoli Yield (g/plant) Tukey (α=0.05)	Treat.	Swiss chard Yield (g/plant) Tukey (α=0.05)
T_{16}	945.50 a	T_8	65.575 a	T_{16}	3.09 a
T_{13}	806.03 b	T_{16}	64.375 a	T_6	2.95 b
T_8	793.08 b	T_3	63.975 a	T_{10}	2.77 c
T_{12}	740.20 c	T_6	63.400 a	T_{14}	2.58 d
T_{14}	708.80 cd	T_7	61.575 ab	T_3	2.52 de
T_{15}	671.83 d	T_5	57.100 abc	T_8	2.48 e
T_{11}	613.90 e	T_2	56.400 abc	T_1	2.05 f
T_4	474.68 f	T_4	55.400 abc	T_{11}	1.97 g
T_{10}	469.70 f	T_{10}	52.850 abc	T_5	1.88 h
T_6	446.68 f	T_{14}	49.850 abc	T_{15}	1.85 hi
T_9	336.38 g	T_{12}	46.425 abc	T_4	1.83 hi
T_2	353.90 g	T_{13}	38.600 abc	T_{13}	1.79 i
T_7	343.23 g	T_{11}	38.150 abc	T_{12}	1.37 j
T_5	338.20 g	T_9	33.400 bc	T_7	1.28 k
T_1	245.58 h	T_1	32.825 c	T_2	1.23 k
T_3	232.98 h	T_{15}	31.350 c	T_9	1.15 l

All treatments with the same letter are statistically equal

Table 2 Physicochemical characteristics variation with treatments degradation during growing three horticultural species

Treatment	pH			EC (dS m^{-1})			CEC (me $100g^{-1}$)		
	Serrano Pepper	Broccoli	Swiss chard	Serrano Pepper	Broccoli	Swiss chard	Serrano Pepper	Broccoli	Swiss chard
T1	9.0	8.6	8.1	3.75	1.47	0.62	37.32	45.75	51.57
T2	8.1	7.1	6.8	3.37	2.30	0.58	58.97	52.40	56.78
T3	8.8	7.9	7.3	3.69	1.16	0.45	50.75	38.15	44.45
T4	8.1	7.5	7.1	2.56	1.27	0.62	42.37	46.45	44.41
T5	8.7	7.9	7.2	3.20	0.94	0.48	40.37	42.55	41.46
T6	8.3	7.6	7.2	2.55	1.58	0.63	44.65	49.25	46.95
T7	8.8	8.0	7.4	3.12	1.12	0.49	44.50	42.30	43.4
T8	8.3	7.5	6.8	3.17	1.66	0.59	41.57	43.60	42.58
T9	8.6	7.9	7.4	2.76	0.79	0.35	32.57	38.35	43.52
T10	8.1	7.7	7.1	2.78	0.79	0.41	50.40	40.80	45.86
T11	8.5	7.9	7.2	2.81	0.74	0.43	29.00	39.85	40.27
T12	8.4	7.7	7.1	2.77	0.82	0.44	37.60	44.55	41.07
T13	8.5	8.0	7.4	2.39	0.75	0.39	24.27	39.60	31.93
T14	8.5	7.7	7.1	2.54	0.81	0.39	44.05	38.90	41.47
T15	8.1	7.9	7.6	2.64	0.54	0.41	27.20	33.00	35.67
T16	8.1	7.8	7.5	2.41	0.71	0.46	34.00	45.80	49.14

Treatment physical properties The treatments had a wide variation in their physical properties, for instance, treatments T_9, T_{11}, T_{13}, and T_{15} had lowest AD with 0.14, 0.13, 0.14, and 0.12 g cm^{-3} respectively, and lowest WHC too, with 39.78, 40.82, 40.23, and 38.36 % respectively. These results were due to low density of RH which it was included in all four treatments because this has a high resistance to degradations as well as a low density. On the contrary T_2, T_5, T_6, T_8 treatments had the highest AD with 0.3, 0.4, 0.31, and 0.35 g cm^{-3}, respectively. In this case, the variation was because these treatments included CFD that directly influenced the physical properties of the treatments.

Treatment physicochemical properties The pH behavior was high at the time of transplanting the serrano pepper seedlings. This was due to the basic nature of organic materials which have undergone a degradation process and the pH was raised by the effect of evolution of ammonia from the decomposition of proteins [21]. During the humificative process, humic substances containing functional groups are generated, whose dissociation releases OH^- ions and increase the treatments pH; However as advanced the crop development and the treatment humification, pH decreased to optimal levels for growing vegetables at end of the Swiss chard growth (Table 2).

During the treatments humification process, its physicochemical properties as pH and its EC were changing to lower values, which coincide with the results obtained by Ikenganyia *et al*. [2], especially those associated with the treatments acidity. However, it was observed that CEC manifested an upward trend, being the treatments T_1, T_4, T_9, T_{11}, T_{15} and T_{16} those that had an increase more regular (Table 2). These changes favored treatment conditions for plant nutrition. This behavior of the chemical properties of the material does not coincide with the opinion of Fortis *et al*. [3] because they consider that the composts are biostable materials and preserve their physical and chemical characteristics for months. It was observed that EC was correlated with the K content in the different treatments (figure 1). This information is consistent with that of Shalhevet and Bernstein [22] who in their work related the effect of the soil salinity on the growth of alfalfa plants and the absorption of water and salts, and found that the treatments which increased salinity tended to absorb more potassium than the less saline treatments By relating the EC with the pepper yield, it was found that EC greater than 3.0 dSm^{-1} had a negative effect.

Nitrogen The total N content in the treatments prior to the Serrano pepper transplantation was influenced by the different treatments (Table 3). When the total N content was related with the serrano pepper yield, it was observed that as increased this nutrient content, a decrease in yield was obtained, because this was present in ionic forms; i.e. as ammonia, nitrites and nitrates, increasing the EC.

Table 3 Macronutrient content of the base substrate with different treatments

	N (%)			P (ppm)			K (ppm)		
Treat.	Serrano Pepper	Broccoli	Swiss Chard	Serrano Pepper	Broccoli	Swiss Chard	Serrano Pepper	Broccoli	Swiss Chard
T1	0.80 e	1.25 a	1.43 a	1038 f	488 ab	2.666c	41.88 d	27.1 a	8.19 b
T2	1.34 a	1.20 a	1.49 a	813 k	660 a	1.812g	42.99 c	13.80 c	2.01 h
T3	0.62 f	1.18 a	1.31 a	1132 e	523 ab	2.429d	49.10 a	15.85 b	5.08 e
T4	1.25 b	1.15 a	1.39 a	1043 f	490 ab	1.582h	40.90 d	10.2 f	4.09 f
T5	1.26 b	1.18 a	1.32 a	2205 a	554 ab	2.876c	47.08 ab	13.80 c	8.19 b
T6	1.15 c	1.25 a	1.32 a	877 j	582 ab	2.173e	38.89 e	13.30 d	12.29 a
T7	1.19 c	1.22 a	1.33 a	1043 f	589 ab	3.323b	45.01 b	16.35 b	7.19 c
T8	0.84 e	1.18 a	1.26 a	1628 d	523 ab	1.615h	38.89 e	13.30 d	3.09 g
T9	1.23 b	1.13 a	1.00 d	1005 g	475 ab	3.631b	41.91 d	10.8 e	3.09 g
T10	1.26 b	1.10 a	1.16 b	973 h	486 ab	2.338d	41.91 d	9.8 f	1.00 i
T11	1.20 b	1.08 a	0.95 d	1941b	516 ab	5.562a	32.71 f	9.2 f	3.09 g
T12	1.15 c	1.12 a	1.08 c	973 h	466 b	2.088f	33.78 f	8.2 g	3.09 g
T13	1.07 d	1.05 a	1.02 d	1907 c	503 ab	2.521d	29,69 g	6.2 h	2.01 h
T14	1.03 d	1.15 a	1.17 b	879 j	479 ab	2.574c	29.72 g	5.1 i	1.00 i
T15	1.03 d	1.10 a	1.09 c	894 i	480 ab	2.397d	24.58 h	9.2 f	4.09 f
T16	1.16 c	1.12 a	1.06 c	978 h	508 ab	2.134e	28.61 g	12.75 d	6.11 d

All treatments with the same letter are statistically equal

Phosphorus The available P behavior in the treatments since the beginning of pepper growth until the end of the broccoli and Swiss chard crops was noteworthy, presumably because crops absorbed it in high amounts. As the treatments were degraded, it was found high phosphorus levels (Table 3). This phenomenon is explained by Iñiguez *et al*. [23] since the beginning of the first crop, the material degradation was minimal and consequently that of available P liberation, which was intensified in the second and third crop, so that the release of available P was intense.

Potassium By relating the available K content with the pepper yield, an inverse relationship was found, because the higher the treatment salt contents, the greater the available K absorption by plants (Figure 3). However, considering together available potassium content and EC and relate them to the serrano pepper yield, it was observed that the lower available potassium contents associated with lower EC_s, influenced its yield, as can be observed with treatments T_8, T_{12}, T_{13}, T_{14}, T_{15} and T_{16}.

Figure 1 Relationship between the available K content and EC in the treatments

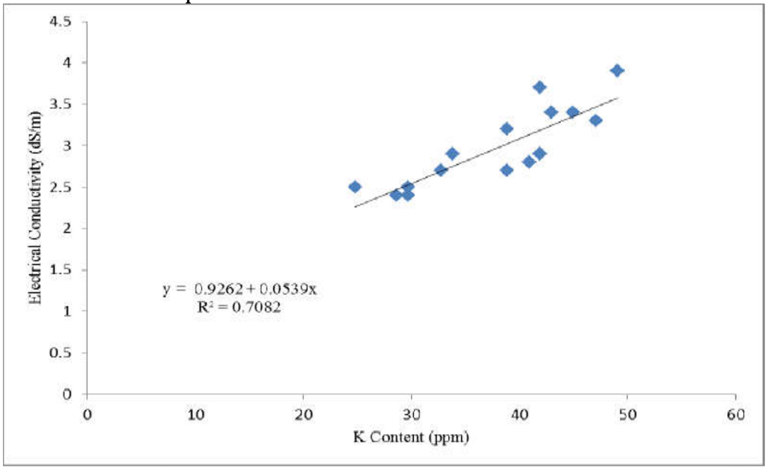


Figure 2 Relationship between the total N content in the base substrate with different treatments and the serrano pepper yield

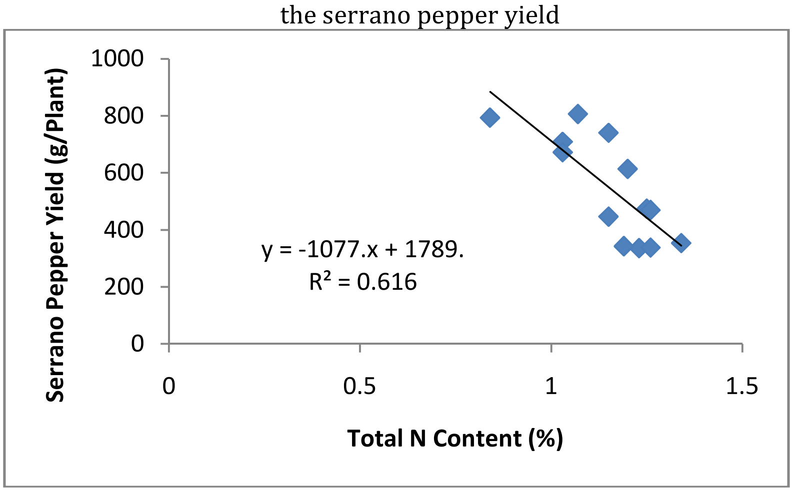
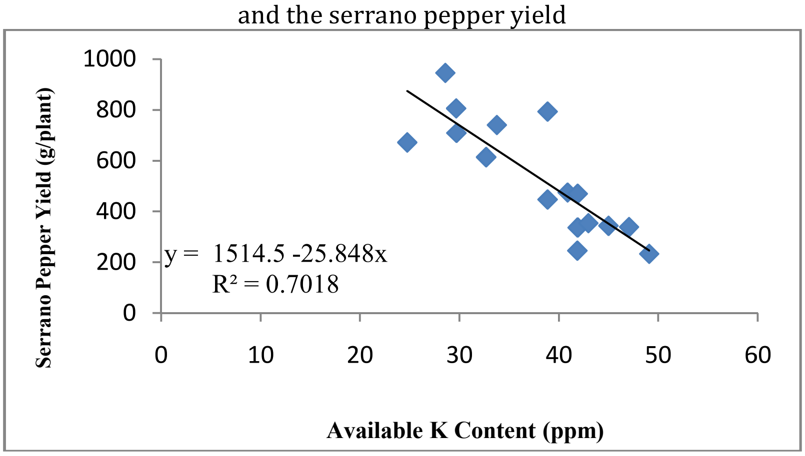


Figure 3 Relationship between the available K content in the base substrate with different treatments and the serrano pepper yield



CONCLUSIONS

After analyzing the physical and chemical characteristics of the different treatments through its degradation, as well as the behavior of the three crops, it was concluded:

1. It has a complete and nutritionally sustainable organic fertilizer for growing at least three consecutive vegetables, the first of which must be salt tolerant.
2. The organic fertilizer should include by volume: CFD 24.6%, SCR 20.7%, RH 24.6%, BM, 24.0%, FF 5.0% PR 0.2%, D 0.6% and BY 0.3%.

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