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The vermicompost anticipates flowering and increases tomato productivity

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Summary

Apart from supplying nutrients, a substrate for plant production should provide adequate conditions for root growth and development. To this effect, the use of vermicompost in the composition of substrates presents itself as an alternative to promote increments in plant production. This study aimed to determine the effective ness of vermicompost in productivity and flowering in tomato crops when partially replacing mineral fertilizers with vermicompost. Five treatments corresponding to different proportions of vermicompost and mineral fertilization were evaluated in the cultivation of two hybrid varieties of tomato (Tinto and Absoluto) in a protected environment. The percentages of vermicompost evaluated were: 0; 10; 20; 40 and 50 % in relation to mineral supplementation. The use of vermicompost to replace the mineral fertilization in 40 and 50 % provided early flowering and fruiting of tomato. For both evaluated tomato hybrids, the substitution of 40 and 50 % of mineral fertilizers for vermicompost provided mature fruits with higher mean values of fresh mass and total productivity per plant. The incorporation of vermicomposts in substrates for commercial production of tomato promotes significant benefits, such as early flowering and fruiting and productivity increase.

Keywords: *Lycopersicon esculentum,* organic fertilization, vermicomposting, organic waste, vegetable production

Vermicompuesto anticipa la floración y aumenta la productividad de los frutos de tomate

Resumen

Más que suministrar nutrientes, un sustrato para la producción de plantas debería proporcionar las condiciones adecuadas para el crecimiento y desarrollo de las raíces. En este sentido, el uso de vermicompost para la composición de sustratos se presenta como una alternativa para promover incrementos en la producción de plantas. Este estudio tuvo como objetivo determinar la efectividad del vermicompost en reemplazo parcial de fertilizantes minerales sobre la productividad y la floración en cultivos de tomate. Se evaluaron cinco tratamientos correspondientes a diferentes proporciones de vermicompost y fertilización mineral en un cultivo de dos variedades híbridas de tomate (Tinto y Absoluto) en un ambiente acondicionado. Los porcentajes de vermicompuesto evaluados fueron: 0; 10; 20; 40 y 50 % en relación con la suplementación mineral. El uso de vermicompuesto para reemplazar la fertilización mineral en 40 y 50 % proporcionó floración temprana y fructificación del tomate. Para ambos híbridos de tomate evaluados, la sustitución de 40 o 50 % de fertilizante mineral por vermicompuesto produjo frutos maduros con valores promedio más altos de masa fresca y de productividad total por planta. La incorporación de vermicompost en los sustratos para producción comercial de tomate registró beneficios importantes, proporcionando una floración y fructificación tempranas y aumentando la productividad.

Palabras clave: *Lycopersicon esculentum*, fertilización orgánica, vermicompostaje, residuos orgánicos, producción vegetal

Introduction

Tomato (*Lycopersicon esculentum* Mill) is the second most important vegetable in Brazil being among the ten largest tomato producers in the world. In 2015 tomato production in Brazil exceeded 4 million tons(1). Tomato productivity, as with other vegetables, is influenced by several factors, such as the productive potential of the genetic material, soil or substrate characteristics, adequate nutrient supply, water availability, temperature, luminosity, crop management techniques and pressure of pathogens(2)(3). Water and nutrient availability are the production factors that limit the yield of the tomato more intensely(4), being these factors directly related to the type of soil or substrate used for tomato cultivation.

Substrate plays an important role in plant production, providing mechanical support and a source of nutrients for the growth and development of plants. According to Tao and others(5), cultivating in a substrate can provide higher productivity, better product quality and better use of nutrients, as well as allowing the continuous use of areas by reducing the risk of salinization. For this purpose, it is necessary to use a suitable substrate for each crop, respecting the requirements of each plant species.

Organic compounds represent an alternative to improve the physical, chemical and biological characteristics of substrates. Among the organic compounds, vermicompost or earthworm humus has several benefits to plant growth and development(6)(7). The vermicompost is a stable compound obtained from the organic waste transformation by the activity of earthworms and microorganisms that inhabit their digestive tract. The use of vermicompost as a component of substrates provides benefits to plant development due to excellent nutrient availability, high porosity, good aeration, water holding capacity and microbial activity(8)(9).

In addition, research has shown that benefits of vermicompost in plant production are due to the presence of plant growth regulating substances, as phytohormones, soluble humic substances and enzymes derived from microbial metabolism, which act to promote growth, development and protection of plants under different stress conditions(6)(10)(11)(12)(13). Thus, the present study aimed to evaluate the efficiency of partially replacing mineral fertilization with vermicompost in the productivity and flowering of the tomato crop.

Material and Methods

Five treatments corresponding to different proportions of vermicompost and mineral fertilization were evaluated in the cultivation of two hybrid varieties of tomato (Absoluto and Tinto) in a protected environment. The percentages of vermicompost under evaluation were: 0; 10; 20; 40 and 50 % in relation to mineral supplementation. The concentrations of vermicompost and mineral formulation (10-18-20 N-P-K) were calculated according to nutrient content indicated by the chemical analysis of the soil and the vermicompost (Table 1) and crop requirements(14).

Vermicompost was produced with the aid of earthworms *Eisenia andrei* Bouché (1972) from tanned bovine manure. After 100 days of transformation, vermicompost was sieved in a 2 mm mesh and evaluated for nutrient content. Total carbon and nitrogen contents were determined in an elemental analyzer (model FlashEA 1112, Thermo Electron Corporation, Milan, Italy). Organic matter content was calculated by multiplying the organic carbon content by 1.724 (Van Bemmelen factor). Phosphorus, potassium, calcium and magnesium contents were determined according to Tedesco and others(15). The soil sample was used to determine values of pH (water 1:1), clay (densimeter), Ca, Mg, P and K (Mehlich-1) and organic matter (Walkley-Black) according to Tedesco and others(15) (Table 1).

Tomato seedlings of the Absoluto and Tinto hybrid varieties were produced in styrofoam trays containing Carolina Soil® commercial substrate. After 30 days, the seedlings were transplanted into black plastic pots (11 L) containing 10 liters of the substrate corresponding to each treatment. Mineral fertilization was added through a groove made approximately five centimeters on the side of the previously transplanted molt. The pots were kept in a greenhouse in the Center for Forests Research of the Department of Diagnosis and Agricultural Research of Rio Grande do Sul State, Santa Maria, RS., in a completely randomized design with ten replicates of each of the five treatments, for each tomato hybrid, with a total of 100 experimental units. Irrigation occurred manually and daily, according to the water requirements of the crop.

To evaluate the effect of anticipation of tomato development, the percentage of plants with inflorescences and fruits in formation was determined 48 days after transplanting the seedlings to the pots. The mean number

Table 1. Chemical characterization of soil and vermicompost used for substrate composition in tomato production.

Chemical parameters	Soil	Vermicompost
pH water 1:1	5.4	6.3
C (%)	0.75	17.23
N (%)	0.065	1.33
MO (%)	1.3	29.7
Ca	3.3 cmolc/dm^3	6.54 g kg^{-1}
Mg	0.9 cmolc/dm^3	4.58 g kg^{-1}
P	6.0 mg/dm^3	2.41 g kg^{-1}
K	48.0 mg/dm^3	19.05 g kg^{-1}
Clay content (g kg^{-1})	190	-

of bunches and the number of green fruits per plant were determined 71 days after transplanting.

When evaluating the productivity of each tomato hybrid, the mean number and total fresh mass of mature fruits per plant during the crop cycle were determined between January 7 and March 3 with a total of 11 collection dates. Fruits were harvested at the stage of complete maturation (fully ripened and developed), characterized by red coloration. The only harvested and evaluated fruits were the healthy ones according to a commercial standard: fruits with a transverse diameter greater than 30 mm and that had no defects such as rot caused by microbiological agents. Cracks and apical rots were considered commercially acceptable.

Data was statistically analyzed using Tukey test at 5 % significance level, using the statistical program SISVAR 5.6[16].

Results and Discussion

The replacement of mineral fertilization with 40 and 50 % of vermicompost resulted in the anticipation of the flowering and fruiting stages of plants (Table 2) and in the increase of the productivity of both evaluated tomato hybrids (Table 3). For the Absoluto hybrid, 48 days after transplanting the seedlings, the percentage of plants with inflorescence grew with the increase of the fertilization replacement with vermicompost. While only 10 % of the control plants (without vermicompost) presented flowers, the percentage of plants containing flowers increased 20 % in the treatments with the substitution of 10 and 20 % of the mineral fertilization by vermicompost, and 100 % in the treatments with the substitution of 40 or 50 % for vermicompost. Fruits were only observed in the treatments that received the highest concentrations of vermicompost (T4 and T5), where 10 % of the plants of each treatment already had green fruits in development.

A similar effect was observed in the Tinto hybrid 48 days after transplanting, where the control treatment presented 10% of plants with flowers and absence of fruits. Comparatively, the treatments referring to the use of 40 and 50 % of vermicompost presented 90 and 100 % of flowering plants, respectively. The treatment with the highest dose of vermicompost (T5) was the only one showing fruit presence, where 30 % of plants started fruiting.

Evaluations of the number of bunches and the number and diameter of green tomato fruits prior to harvest showed a significant increase in the number of bunches per plant, as well as in the mean values of total number and diameter of fruits present in treatments with 40 and 50 % of vermicompost when compared to control treatments, for both Tinto and Absoluto hybrids (Table 2).

The results obtained in this study may also be attributed to the presence of plant growth regulating substances (PGRS) in vermicompost, which act directly on the plants physiology, providing more significant growth and development. Earthworm intestine contains a wide range of microorganisms, enzymes, and hormones that are transferred to vermicompost during the organic waste degradations process[17]. These microorganisms can produce PGRS such as auxins, gibberellins, cytokinins, abscisic acid and ethylene in significant amounts[18][19]. These five classic hormones are known to modulate various stages of fruit development[20].

Table 2. Mean number of bunches and number, length/diameter of green fruits 71 days after transplanting tomato seedlings of Tinto and Absoluto hybrids. Mean of 10 repetitions.

Vermicompost concentrations	Tinto hybrid		Absoluto hybrid	
	Number of bunches	Number of fruits	Number of bunches	Number of fruits
0 %	0.86 bc*	1.14 bc	0.2 b	0.3 b
10 %	1.86 b	3.28 b	1.4 a	0.6 b
20 %	0.17 c	0.33 c	0.67 b	0.92 b
40 %	4.0 a	7.28 a	1.8 a	2.7 a
50 %	4.0 a	7.0 a	2.0 a	2.75 a
CV (%)**	36.20	38.18	29.75	31.18

*Means followed by the same letter in the columns do not differ from each other by the Tukey test at 5 % error probability.

**Coefficient of variation.

Among PGRS, the gibberellins are involved in flowering regulations and are essential for the development of fertile flowers in tomato(21). The presence of gibberellins, auxin and cytokinin activities were identified in *Eisenia Fetida* earthworm feces(22)(23). Thus, it is probable that the presence of these hormones, especially gibberellins, could explain the anticipation of flowering and fruiting stages, as well as the greater production of fruits in treatments with the highest doses of vermicompost. The presence of a great diversity of microorganisms in vermicompost facilitates nutrient assimilation in roots and promotes plant growth by producing hormones and enzymes(8). For this reason, vermicompost is considered a plant growth biostimulator and an excellent basis for the establishment of symbiotic and non-symbiotic beneficial microorganisms(24).

Even without evaluating tomato productivity, some studies have demonstrated the effect of vermicompost on the initial growth of seedlings. Tejada & Benítez(25) compared the effects of two vermicomposts of animal and vegetal origin on the growth of tomato seedlings. The authors observed that vermicomposts had a positive effect on plant growth, increasing the tomato seedling height, stem diameter, number of leaves per seedling and total dry matter. Atiyeh and others(26) evaluated some effects of humic acids on tomato and cucumber seedling growth, formed during the breakdown of organic wastes within the vermicomposting process (earthworms and microorganisms activity). Humic acids were extracted from the vermicomposts and mixed with a soilless container medium. Results showed that the incorporation of humic acids from vermicomposts increased tomato and cucumber plant growth significantly, in terms of height, leaf area, shoot, and root dry weight. These effects were attributed to the hormone-like activity of humic acids from vermicomposts that directly affect plant growth.

Soluble humic substances (fulvic and humic acids) may influence nutrient availability and plant growth(27). In soil solution, they can increase macro and micronutrient uptake due to H+-ATPase activation from plasmatic membrane(28). Assessing the effect of humic acids extracted from sanitary wastes sludge on plant growth, Rocha(11) observed several benefits such as growth, cellular elongation, stress tolerance, and an increase on membrane permeability and on oxidative stress enzymes activity. Therefore, it is probable that the presence of soluble humic substances in tomato crop substrate could have contributed to the increased productivity observed in treatments with 40 and 50% vermicompost (Table 3).

Mature fruits with higher mean values of fresh mass were obtained from both commercial tomato hybrids, in treatments with 40 and 50% vermicompost, differing significantly from the control treatment ($p = 0.05$) (Table 3). Values of mean fresh mass of Tinto hybrid fruits observed in this study are in agreement with the data obtained by Schwarz and others(29), who evaluated the productivity of different tomato hybrids and observed values of mean fresh mass of 86.0 g $fruit^{-1}$ for Tinto hybrid.

Considering the total productivity of fruits per plant, the treatment with the highest concentration of vermicompost was superior to the other treatments, producing a higher fresh mass total of mature harvested fruits per plant (Table 3).

Several researchers have studied the effect of the addition of organic material, whether associated or not to

Table 3. Mean fresh mass (MFM) and total fresh mass per plant (TFM) of mature tomato fruits for the Tinto and Absoluto hybrids. Weekly crops harvested from 01/07/2015 to 03/03/2015 in Santa Maria, RS, Brazil.

Vermicompost concentrations	Tinto hybrid		Absoluto hybrid	
	MFM* (g)	TFM (g)	MFM (g)	TFM (g)
0 %	74.57 c**	202.46 c	98.53 c	278.45 b
10 %	80.54 b	205.32 c	100.14 c	265.43 b
20 %	81.97 b	261.97 b	127.98 b	294.31 b
40 %	83.37 b	274.59 b	117.60 bc	289.18 b
50 %	90.06 a	323.77 a	143.08 a	325.72 a
CV (%)***	20.11	26.32	20.84	27.16

*Mean of 12 fruits per treatment.

**Means followed by the same letter in the columns do not differ from each other by the Tukey test at 5 % of error probability.

***Coefficient of variation.

mineral fertilization, on tomato production. Researchers in Croatia obtained a higher mean mass of fruits from plants supplied with an organic compound associated with mineral fertilizers(30). Ferreira and others(31) found that the addition of organic material to the soil increased the nitrogen required to obtain maximum productivity (total and commercial) of tomato fruit, when studying tomato fruit quality as a function of nitrogen concentrations and organic fertilization in tanned bovine manure. Mueller and others(32) obtained commercial yields for all concentrations of organic fertilizer (poultry litter) in association with mineral fertilization, not different from exclusive mineral fertilizer, showing that organic fertilizers meet the demand for primary macronutrients when associated with mineral fertilization supplementation.

Applying organic fertilizers on the soil has shown to raise productivity as a result of higher organic matter content(33). In this study, substitution of 50 % of mineral fertilization for vermicompost maximized the total productivity of the tomato hybrids studied, increasing total fresh mass of mature fruits for both tomato varieties (Table 3). All these results are related to the benefits of using vermicompost in plant production. Vermicompost benefits plant production due to the supply of nutrients as well as the set of physical and biological changes in the substrate that provides to root environment. Thus, there is a difference between using chemical formulations or organic compounds for plant fertilization: chemical formulations only meet the nutritional needs of plants. However, organic compounds, also improve soil structure and soil aggregation; increase porosity and water retention capacity; and provide enzymes, humic substances and plant hormones resulting from the biological activity of organisms and microorganisms that act in the degradation of fresh organic residues and in the formation of humified organic matter. According to Dinesh and others(34), the use of organic fertilizers may increase soil microbial activity by more than 16 % compared to inorganic fertilizers, and may also lead to increased enzyme activity due to the release of macronutrients essential to plants.

The ideal substrate for plant production should ensure mechanical maintenance of the root system and plant stability through its solid phase, supply water and nutrients through the liquid phase, and supply oxygen and transport carbon dioxide between the roots and the outer atmosphere through the gas phase(35). In this regard, vermicompost has an excellent nutrient status, good aeration, high porosity, water retention capacity and microbial activity(9) and factors that make it a biostimulator of plant growth(36). Besides these benefits, substances with similar effects on plant hormones also act as biostimulators. According to Zandonadi, Canellas & Façanha(37), humic substances with similar effects on auxin plant hormone are responsible for the elongation and turgescence of plant cells and for the growth of lateral roots, which directly reflects the ability of plants to resist water stress conditions.

Evidence shows that the presence of humic substances protects plants in situations of osmotic stress when toxic by-products are formed within plant cells during periods of water scarcity. In water stress situations, plants can accumulate solutes in the cytosol as a way to attract more water molecules into the cells, adjusting osmotically to soils with low water availability. These solutes are called compatible solutes and have an osmoprotective function. Also, they provide a source of carbon and nitrogen for the cell when the conditions of humidity or salinity return to normal[(3)]. Compatible solutes have already been isolated from bovine manure vermicompost[(10)], showing that the use of these organic compounds can protect the plant under conditions of hydric stress.

Compatible solutes are organic compounds that are non-toxic to plants, which raise cellular osmotic potential and prevent the entry of salts into the cytoplasm. The most common examples are proline, sorbitol and glycine betaine[(3)]. García[(10)] observed higher contents of proline in root cells of rice plants (*Oryza sativa* L.) that received a higher concentration of humic acids extracted from vermicompost. Aydin, Kant & Turan[(38)] applied humic acids to bean plants (*Phaseolus vulgaris* L.) under conditions of salt stress and also observed greater proline accumulation, inducing protective effects. Foliar application of fulvic acids in corn (*Zea mays* L.) stimulated the activity of antioxidative system enzymes and the accumulation of proline.

Therefore, more than just supplying nutritional demands in plant cultivation, the use of vermicompost can contribute to plant productivity by reducing the damage caused by stress conditions due to the presence of numerous organic substances with proven beneficial effects. According to Tao and others[(5)], combining inorganic and organic fertilization has been recommended to restore or preserve soil fertility and control soil diseases due to continuous monoculture. The results of the present study reveal economic advantages and the feasibility of using a combination of inorganic and organic fertilizers in tomato cultivation in a controlled environment.

Conclusions

Replacing 40 or 50 % of mineral fertilization with vermicompost promotes anticipation of flowering and fruiting stages of tomato and increases the values of fresh mass and productivity of fruits of Absoluto and Tinto hybrid varieties.

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Author's contribution

All the authors contributed equally to the content.

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