

Effect of chemical fertilization and worm leachate on tomato crop production

Hermenegildo-González, Santiago^{1*}; Mendoza-Pérez, Cándido¹; Rubiños-Panta, Juan E.^{1*}; Ramírez-Ayala, Carlos¹; Martínez-Ruiz, Antonio²; García Martínez, Perpetua¹

¹ Colegio de Postgraduados, Postgrado en Hidrociencias. Carretera México-Texcoco km 36.5, Montecillo, Estado de México. C.P. 56264.

² Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias CIRPAS-C.E. Valles Centrales, Santo Domingo Barrio Bajo, Villa de Etla, Oaxaca, C.P. 29140.

* Correspondence: jerpikie@colpos.mx

ABSTRACT

Objective: To evaluate the effect of organic and inorganic fertilization on the physiological and productive variables of tomato-mate crops grown under greenhouse conditions.

Design/methodology/approach: A completely randomized design was used with four treatments: T1 (100% worm leachate), T2 (65% worm leachate + 35% nutrient solution), T3 (50% worm leachate + 50% nutrient solution), and a control (100% nutrient solution). The response variables evaluated were plant growth, yield, and fruit size.

Results: Treatment T3 produced the highest yield at 171.6 t ha⁻¹, being significantly superior to the other treatments in fruit size and weight, while T1 showed nutritional limitations in growth and development.

Findings/conclusions: The combination of worm leachate and nutrient solution (T3) reduced the use of chemical fertilizers by 50%, promoting more sustainable agriculture while maintaining high productivity levels.

Keywords: *Solanum lycopersicum* L, organic fertilization, yield, sustainability.

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INTRODUCTION

The intensive production of tomato has led to a strong dependence on chemical fertilization due to its immediate effectiveness in supplying essential macro- and micronutrients. However, a significant proportion of these fertilizers is lost to the environment through leaching or runoff, reducing their availability to plants (Benbi, 2013). This excessive use can also compromise food safety and quality, for example, through nitrate accumulation in plant tissues (Ye *et al.*, 2020). In recent years, the rising costs of synthetic fertilizers and their adverse effects on soil health have renewed interest in organic alternatives. Likewise, the importance of preserving organic matter in agricultural systems has been increasingly recognized, prompting the search for more sustainable and economically viable inputs to meet crop nutritional needs. One promising option is the use of liquid organic materials, such as manure extracts or compost leachates (Preciado-Rangel *et al.*, 2011). In this context, organic agriculture has demonstrated its ability to produce high-quality food without compromising soil or environmental health, thus advancing toward more sustainable systems (Yadav *et al.*, 2013). Among these inputs, vermicompost stands out; its leachate contains bioactive compounds that enhance

economically viable inputs to meet crop nutritional needs. One promising option is the use of liquid organic materials, such as manure extracts or compost leachates (Preciado-Rangel *et al.*, 2011). In this context, organic agriculture has demonstrated its ability to produce high-quality food without compromising soil or environmental health, thus advancing toward more sustainable systems (Yadav *et al.*, 2013). Among these inputs, vermicompost stands out; its leachate contains bioactive compounds that enhance

nutrient availability, stimulate plant development during critical growth stages, and accelerate the formation of flower buds and fruits (Eyheraguibel *et al.*, 2008; Rodríguez-Fernández, 2017). However, organic fertilization alone is often associated with lower yields, making chemical fertilization still necessary to sustain significant production levels. In this regard, integrated nutrient management is proposed as a viable strategy not to eliminate the use of chemical fertilizers entirely, but to reduce their application by combining them with organic sources (Ye *et al.*, 2020). Based on this, the present study aims to evaluate the effect of the combined application of organic and inorganic fertilizers on physiological variables and fruit yield in tomato crops under greenhouse conditions.

MATERIALS AND METHODS

The experiment was conducted during the spring-summer 2023 cycle in the greenhouse of the Colegio de Postgraduados, Montecillo Campus, located in Texcoco, State of Mexico. The greenhouse is equipped with zenithal ventilation, a polycarbonate cover, and lateral walls with anti-aphid mesh. The saladette-type tomato variety ‘Cid F1’, of indeterminate growth, was used. Sowing took place on February 24, 2023, and transplanting on April 12, 2023, when seedlings had four to five true leaves. The substrate consisted of a 50% mix of sheep manure compost and 50% tezontle, placed in 12 L bags, one plant per bag, with drainage holes at the base. Irrigation was applied via a drip system with self-compensating drippers (8 L/h), controlled by a programmable digital timer with eight events. Nutrient management included two main sources. The first was Steiner’s nutrient solution (1984), applied at a concentration of -0.036 MPa during the initial phase and adjusted to -0.072 MPa during the vegetative and reproductive stages. The second source was worm leachate, applied at a rate of 2 L diluted in 20 L of water. An analysis of this fertilizer, conducted at the laboratory of the Universidad Autónoma Chapingo, indicated concentrations of $8,800$ mg L⁻¹ of potassium, 294.5 mg L⁻¹ of organic carbon, and 222.5 mg L⁻¹ of sodium as the main nutritional components. A completely randomized design (CRD) was used for this study, with four treatments consisting of different combinations of Steiner’s nutrient solution (1984) and worm leachate, applied to tomato crops in a hydroponic system. The planting density was three plants per square meter, arranged in a three-row pattern. The concentrations used in each treatment are detailed in Table 1.

Agronomic variables

Plant growth was evaluated using four randomly selected plants per treatment, which were marked and measured for height every eight days, from transplanting until the

Table 1. Specification of the combination of worm leachate with Steiner’s nutrient solution (1984).

Treatments	Nutrient solution combinations
T1	100% worm leachate
T2	65% worm leachate + 35% nutrient solution
T3	50% worm leachate + 50% nutrient solution
TES	100% nutrient solution

formation of the tenth cluster. Yield was also determined in four randomly selected and tagged plants per treatment, monitored throughout the crop cycle. Harvested fruits at maturity were weighed, and their equatorial and polar diameters were measured using a digital caliper. These measurements were conducted on all clusters, and at the end of the experiment, fruits were classified according to the Mexican standard NMX-FF-031-1997-SCFI. The data were subjected to analysis of variance (ANOVA), and means were compared using Tukey's test ($p \leq 0.05$), employing the R statistical software, version 4.3.2 (2023-10-31 ucrt).

RESULTS AND DISCUSSION

Growth and development

The growth and development of the crop followed an exponential pattern over the 108 days after transplanting (DAT), a behavior that was similar across the four treatments evaluated (Figure 1). Plant height exhibited a well-defined vegetative phase up to 65 DAT, after which a slight deceleration in growth was observed, associated with the onset of flowering. From that point forward, growth remained stable until 108 DAT, marking the end of the vegetative stage. No significant differences in height were found among treatments T2, T3, and the control; however, treatment T1 showed slower and significantly lower growth. This outcome is attributed to the fact that nutrition supplied solely by worm leachate was insufficient to meet the physiological demands of tomato cultivation under intensive conditions. These findings partially align with those reported by Reyes-Hernández *et al.* (2023), who observed no significant differences in plant growth at 90 DAT between those treated with organic fertilizers and those fertilized with Steiner's solution. In contrast, Torres *et al.* (2018) reported that organic fertilization favored vegetative development, with significantly greater plant heights compared to chemical fertilization. Such differences may

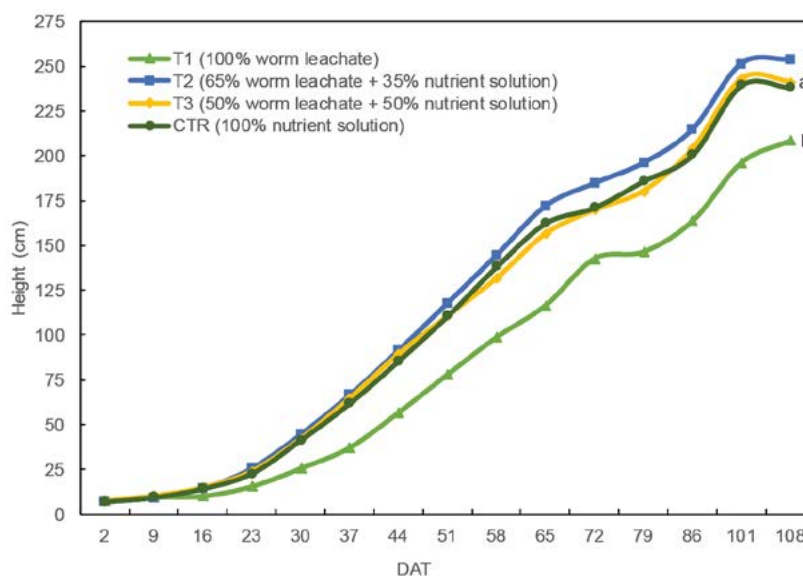


Figure 1. Average height of tomato plants (cv. Cid F1) under four organic and inorganic fertilization treatments over 108 days after transplanting.

be attributed to the capacity of certain organic fertilizers to more evenly meet the crop's nutritional requirements.

Yield

The effect of the treatments on yield is shown in Figure 2. Treatment T3 produced the highest yield, reaching 17.16 kg m^{-2} , a value significantly greater than those of the other treatments. In comparison, T3 surpassed T1, T2, and the control by 6.21 kg m^{-2} , 1.10 kg m^{-2} , and 2.76 kg m^{-2} , respectively. When extrapolated to a per-hectare basis, the yields were 109.5 , 160.0 , 171.6 , and 144.0 t ha^{-1} for T1, T2, T3, and the control, respectively. These values exceed those reported by Estrada-Arellano *et al.* (2023) and Cervantes-Vázquez *et al.* (2024), who achieved yields of 95.22 and 87.3 t ha^{-1} using bovine manure fertilization. However, the yield obtained with T3 was slightly lower than those reported by Mendoza-Pérez *et al.* (2020) and Ruelas-Islas *et al.* (2022), who recorded 19.65 and 19.98 kg m^{-2} , respectively, using chemical fertilization exclusively. These results suggest that the combination of worm leachate and nutrient solution may represent a viable and competitive alternative to the exclusive use of chemical fertilizers.

Fruit size

The classification of fruit size is shown in Figure 3. Treatment T3 achieved the best results, recording the highest percentage of medium and large fruits, meeting national and international standards for commercial distribution. Additionally, T3 had the lowest proportion of small and extra-small fruits compared to the other treatments. These differences were statistically significant, as indicated in Table 2. When comparing T2 with the control, no significant differences were found in the extra-small, medium, and large size categories; however, differences were observed in the small and extra-large sizes. In contrast, treatment T1 was significantly inferior across all size categories, with a high proportion of fruits classified as small. These results indicate that the combination of organic and inorganic fertilizers (T3) significantly improves the commercial size of

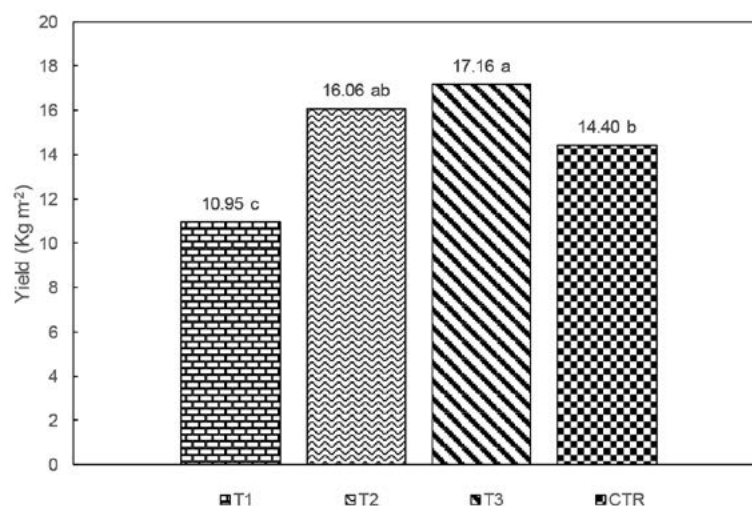


Figure 2. Average tomato yield (cv. Cid F1) under four fertilization treatments.

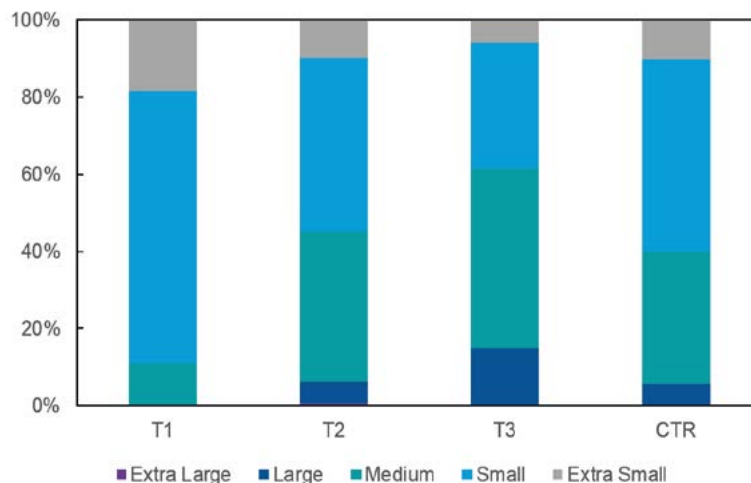


Figure 3. Percentage distribution of tomato fruits (cv. Cid F1) by commercial size under different fertilization treatments.

Table 2. Fruit size classification.

Treatments	Extra small (%)	Boy (%)	Medium (%)	Big (%)	Extra Large (%)
T1	18.40 a	70.52 a	10.85 c	0 c	0.24 b
T2	9.77 b	45.31 c	38.48 b	5.86 b	0.59 a
T3	5.70 c	32.70 d	46.84 a	14.56 a	0.21 b
TES	10.02 b	50.11 b	34.12 b	5.76 b	0 c

Means that do not share a letter are significantly different (Tukey $p \leq 0.05$).

the fruits by reducing the proportion of undesirable calibers. The findings surpass those reported by Martínez-Sías *et al.* (2020) and Estrada-Arellano *et al.* (2023), who used only organic fertilization in tomato cultivation.

CONCLUSIONS

The exclusive application of organic fertilizer (T1) did not result in significant improvements in the agronomic variables evaluated, leading to low yield. Therefore, it is concluded that worm leachate, used as the sole nutrient source, does not meet the nutritional requirements necessary for optimal tomato development. In contrast, the combination of organic and inorganic fertilization significantly improved agronomic variables, with treatment T3 standing out. This strategy allows for a reduction of up to 50% in the use of inorganic fertilizers when aiming to maximize yield, or up to 65% when seeking to maintain an acceptable yield under a more cost-effective approach. This reduction not only represents substantial savings in chemical inputs but also promotes more sustainable and balanced agricultural production in the long term.

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