

Use and abuse of fertigation. Modification of the soil in greenhouses in small-scale agriculture

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Abstract

Protected agriculture helps improve agricultural productivity, but if the management is not adequate, it will increase the risk of affecting the environment and the profitability of crops. Therefore, in the municipality of Tetela de Ocampo, Puebla, in 2021, the chemical environment of the soil in greenhouses in the region that use fertigation was evaluated. To identify the details of agricultural activities, a questionnaire prepared specifically was applied to cooperating farmers, collecting a composite soil sample (five subsamples) per unit of production evaluated and uncultivated lands were included as a reference of the initial condition. The analysis of the samples was based on the NOM-021-RECNAT-2000 (NOM). The average annual yield of tomato is $31 \pm 7.6 \text{ kg m}^{-2}$ and 87% of greenhouses have an area of less than $3\,000 \text{ m}^2$. They have technical assistance provided by companies and individuals, which include training courses and periodic soil analysis. In this study, excessive levels of all the chemical indicators established in the NOM were detected in the soil; nevertheless, the same fertilization program that has been carried out for several years in the region continues.

Keywords:

edaphic chemical environment, fertilizers, productivity, tomato.

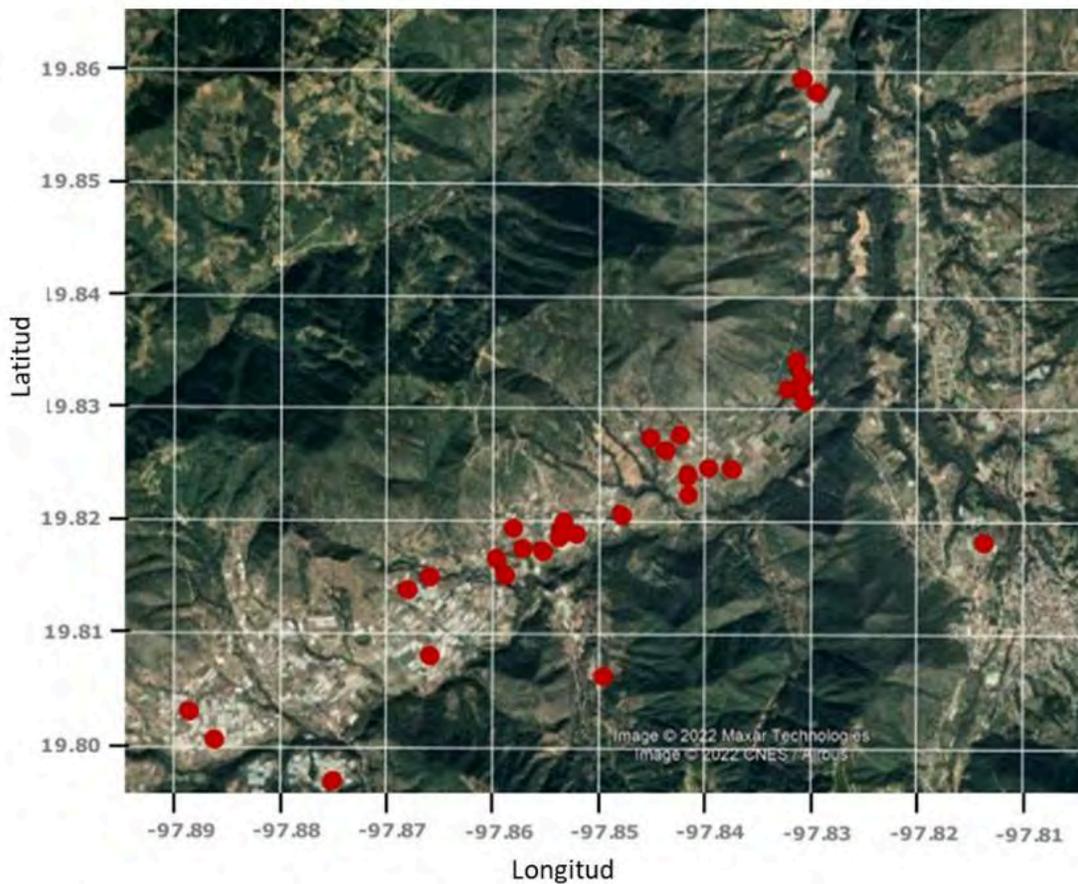


Greenhouse horticultural production is a technological alternative that can be successful even in small production units if properly conducted. For example, through fertigation it is possible to optimize the application of nutrients, but the excess increases the concentration of salts in the soil (Zörb *et al.*, 2019) and affects the environment (Yasuor *et al.*, 2020). Therefore, the objective of this work was to evaluate the effect of fertigation on soil fertility and tomato productivity under greenhouse in the small-scale agriculture in the municipality of Tetela de Ocampo, Puebla.

In the study area, the family is the central productive structure and due to its greater profitability, it has been engaged in protected agriculture for 16 years, replacing that of the extensive type. The region is humid temperate with rainfall of 600 to 1 600 mm per year, average annual temperature of 12 °C to 18 °C and Luvisol soils, which occupy 81% of the land of the region (INEGI, 2009). These soils are used to build the planting beds of each greenhouse.

The evaluation of the effect of fertigation management on soil fertility and tomato productivity was carried out based on the methodology proposed by Hernández-Mendoza and Galvis-Spinola (2017), that is: 1) tour the area to detect environmental conditions; 2) based on a survey, identify the problems of the region, applying to each farmer a questionnaire prepared specifically; 3) diagnose the current condition of the soil based on its analysis in the laboratory; and 4) relate agricultural management practices to regional information and soil evaluation. In this case, a sample of 30 farmers was used (Figure 1), equivalent to 10% of the total (95% confidence and 1% margin of error).

Figure 1. Location of greenhouses owned by cooperating farmers in the municipality of Tetela de Ocampo, Puebla. Satellite image taken from Google Earth Version 9.155.0.2.



The questionnaire consisted of 36 closed-ended and multiple-choice questions, which allowed knowing the area of each greenhouse, years of use, yield and quality of the crop, seasons per year, training, technical advice, non-nutritional disorders, inputs used, doses and times of application, irrigation management, use and frequency of soil analysis, correction of problems and management of amendments.

Soil sampling was done based on the NOM (2002), and in each greenhouse five subsamples were collected at 0-20 cm depth to form a composite sample, taken in the middle of the planting bed, and avoiding the drip line. Uncultivated lands were included as a reference of the original condition. The analyses were carried out in the laboratories of the Colegio de Postgraduados, Montecillo *Campus*, following the NOM (2002). The following were determined: pH, organic matter, inorganic nitrogen, electrical conductivity, nitrate, ammonium, texture, phosphorus, potassium, exchangeable bases and their respective soluble forms.

Information from the survey and laboratory analyses was evaluated based on the descriptive statistics mean and standard deviation, frequency distribution, correlation and simple regression. The area of the greenhouses varies from 1 000 to 11 000 m² (87% of them less than 3 000 m²) with a maximum of 16 years of use. Of the producers, 27% have been engaged # 4 years in protected agriculture and 40% > 8 years. Eighty-seven percent hire technical advice from companies (17%) or independent agronomists (70%), 53% receive training and do periodic analysis of their soils; however, technical decisions fall on advisors, because 63% of farmers admit to not knowing the inputs applied in their greenhouse.

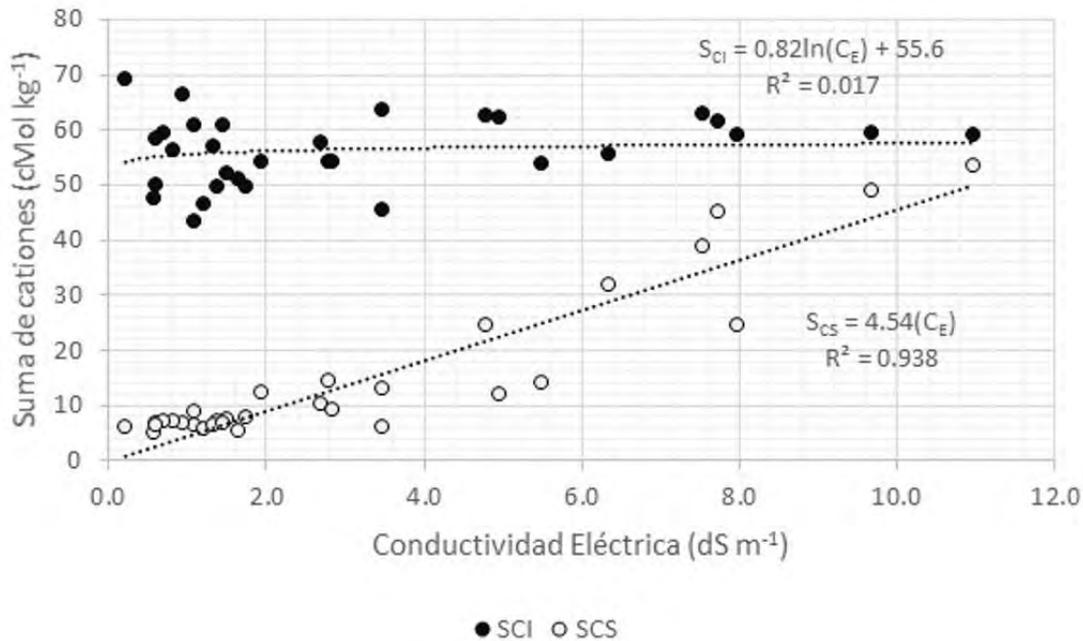
The tomato is grown in two cycles per year, with average annual yield of 31 ±7.6 kg m⁻². In 63%, productivity fluctuates from 14 to 16 kg m⁻² per cycle, which they attribute to some limiting factor that they have not yet identified, which is why in 90% of the units, amendments are applied as preventive measures to reverse this situation, even without knowing what they are trying to solve.

In 80% of the soils, the clayey fraction predominates. The native pH is 6.1 and coincides with 13% of greenhouses, because in 47% it is lower (pH from 4.2 to 5.9) and in 40% higher (pH from 6.3 to 7.8). This would be explained by what was reported by Barak *et al.* (1997), who assert that chemical disturbance is associated with the intensity, frequency and type of fertilizers used. There is 1.3% organic matter in uncultivated lands and in 87% of greenhouses it ranges from 2 to 6.5%, which is consistent with the continuous use of organic inputs in the area, which coincides with Mundo-Coxca *et al.* (2020) for the same region.

The electrical conductivity (C_E) in areas without agricultural activity is 0.2 dS m⁻¹, while in 53% of cultivated areas it varies from 0.5 to 2.5 dS m⁻¹ and in 47% it was higher than 3 dS m⁻¹, which, according to Sánchez-González *et al.* (2014), would already affect tomato productivity. Figure 2 shows the trend between C_E and base cations in their exchangeable and soluble forms.



Figure 2. Trend of electrical conductivity (C_E) with the sum of the base cations in their exchangeable (S_{CI}) and soluble (S_{CS}) forms, of the soils of greenhouses of Tetela de Ocampo, Puebla.



C_E is closely associated with ionic species in the soil solution, but not with exchangeable ones, a situation similar to that observed by Coitiño-López *et al.* (2015), who used these comparisons to characterize agroecological resources. In Table 1, C_E was correlated with the different ionic species to elucidate what influence they have on the use of inputs in the region.

Table 1. Significant Pearson correlation coefficients ($p < 0.05$) between electrical conductivity (C_E) and ionic species analyzed in soils in greenhouses of Tetela de Ocampo, Puebla

	Ca_E	Mg_E	K_E	Na_E	Ca_S	Mg_S	K_S	Na_S	**Ni	NO_3	NH_4	P
C_E	-0.51	ns	ns	0.82	0.9	0.88	0.5	0.91	0.94	0.96	ns	ns

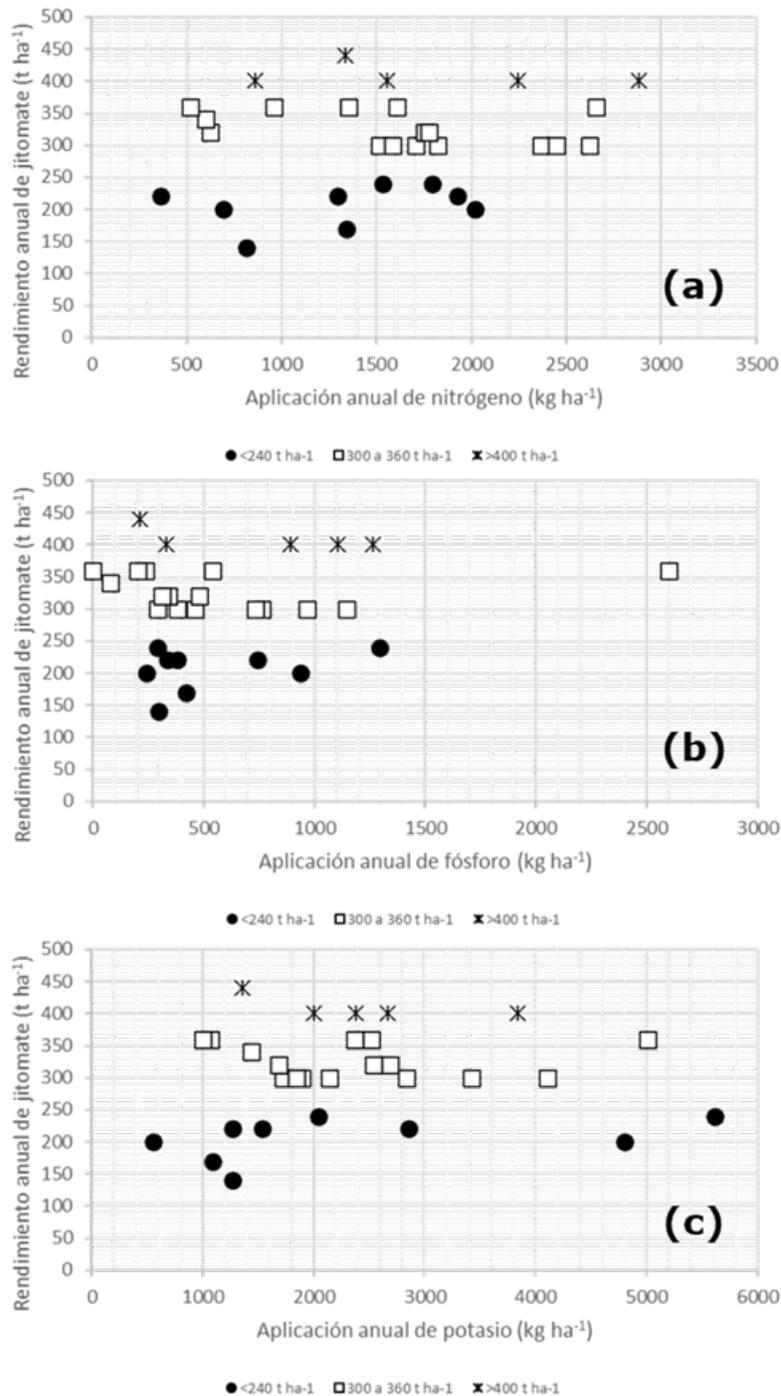
* = base cations, $cMol\ kg^{-1}$ (E= exchangeable; S= soluble). ** = in $mg\ kg^{-1}$; Ni= inorganic nitrogen; NO_3 = nitrate; NH_4 = ammonium; P= phosphorus (P); ns= not significant.

Phosphorus did not modify the concentration of salts in the soil solution, which is explained by the reaction between its ionic forms and the edaphic solid phase, which restrict its mobility and concentration in the aqueous medium (Barrow, 1978). In all cases, the 'high' limit of the base cations of the NOM (2002) was exceeded, which is attributed to the clayey nature of the soils. The correlation was significant ($p > 0.05$) between exchangeable and soluble species for potassium ($r = 0.9$) and sodium ($r = 0.92$).

The nutrients are applied daily through irrigation tape with chemical fertilizers plus organic inputs in 10% of cases. The following predominate: calcium nitrate (27%), potassium sulfate (17%), potassium nitrate (14%) and magnesium sulfate (13%) in average doses of 0.79, 0.51, 0.41 and 0.39 $kg\ m^{-2}$, respectively. The highest rate is 1.14 $kg\ m^{-2}\ d^{-1}$ during the period of cuts of marketable fruits. Fertilizer injection is 9 $kg\ m^{-2}$ per cycle and fluctuates from $\leq 8\ kg\ m^{-2}$ in 63% of

greenhouses to $\geq 20 \text{ kg m}^{-2}$ in 23% of them. Figure 3 shows the annual production of tomato and the dose of nitrogen, phosphorus and potassium applied per year, in each greenhouse evaluated in the study area.

Figure 3. Annual production of tomato and doses of nitrogen (a), phosphorus (b) and potassium (c) applied per year, in each greenhouse evaluated in Tetela de Ocampo, Puebla



Inorganic soil nitrogen was $<10 \text{ mg kg}^{-1}$ in 57% of cases, which may be due to its mobility and transformation in the soil (Cameron *et al.*, 2013). In greenhouses where soil samples are collected for periodic chemical analysis, excess calcium and magnesium are reported on a recurring basis. Despite this, calcium nitrate and magnesium sulfate are the preferred sources for farmers. Something similar happens for phosphorus and potassium, because they continue to be applied on a daily basis without favorable effect between the yield of the tomato and the amount of nutrients added.

The annual yield fluctuated between 14 and 44 kg m^{-2} , in 30% of the greenhouses #24 kg m^{-2} is obtained, in 53% 33 kg m^{-2} and in 17% $>40 \text{ kg m}^{-2}$. According to the federal government (SIAP, 2021), the region would rank 6th nationally in productivity. In this regard, according to the results shown in the figure under discussion, fertilization does not explain the variation in the amount of product harvested. Something similar to this situation occurred in China (Ju *et al.*, 2011), which is why those authors evaluated the efficiency of nitrogen use in greenhouse tomatoes, in which 18% of what was applied was recovered and the rest was leached, which would explain why the crop yield was not affected.

In this study, phosphorus fluctuated from 47 to 560 mg kg^{-1} and potassium from 429 to 2 291 mg kg^{-1} as a result of their continuous application and because the ionic forms of phosphorus (Barrow, 1978) and potassium (Griffioen, 2001) participate in reactions that promote their accumulation in the edaphic medium. Both cases exceed the highest levels of the NOM (2002), which is 11 mg kg^{-1} for phosphorus and 235 mg kg^{-1} for potassium.

Conclusions

The methodology used in the present study allowed detecting and characterizing the agricultural management that is carried out in the greenhouses in the small-scale agriculture of the municipality of Tetela de Ocampo, Puebla. The area of each production unit is less than 3 000 m^2 in 87% of the greenhouses studied, they have advice, periodic soil analysis and training for producers. The intensive use of inputs increased edaphic organic matter and favored the accumulation of soil nutrients, exceeding what is established in Mexican regulations (NOM, 2002). The average annual productivity of tomato remains unchanged at 31 kg m^{-2} , the same happens with the programming and use of fertilizers.

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