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Agronomic and phytosanitary characterization of tomato production in the Comiteca-Tojolabal Plateau

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ABSTRACT

Objective: To characterize the agronomic and phytosanitary aspects of the tomato production units of the Comiteca-Tojolabal Plateau, Chiapas, Mexico.

Design/Methodology/Approach: A random sampling of n=76 tomato fields was performed; agronomic practice surveys were applied to their respective farmers, and the phytosanitary status of each site was evaluated.

Results: Tomatoes are grown in shade houses, in plots that mostly do not exceed 0.5 ha. The most common practices are crop rotation, one tomato cycle per year, incorporation of previous crop residues, and fertilization every 5-8 days. For phytosanitary management, foliar sprays are usually performed every 5-8 days. In order to prevent diseases and pests, 67% of producers pre-treat seedlings and 95% apply bactericides and fungicides to the roots during the first 45 days of the crop. The most important pests and diseases are whitefly, thrips, *Bactericera* sp., late blight, virosis, and wilt. The percentage of plants that suffer from root and vascular diseases ranges from 0-38%. However, low values were more frequent. The regional severity of wilting is low, since 90% of the plants evaluated did not present symptoms.

Study Limitations/Implications: This is the first work to describe the agronomic and phytosanitary aspects of tomato cultivation in this region. Additional research with this approach is required and this work will be the basis for further studies.

Findings/Conclusions: Most of the tomato farms have less than 0.5 ha and their farmers carry out intensive phytosanitary management with pesticides. In addition to chemical control, the cultural practices used may contribute to a low incidence and severity of soil-borne diseases. The most important crop diseases are late blight and virosis.

Keywords: pesticides, pest management, agronomic practices.

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INTRODUCTION

Tomato (*Solanum lycopersicum* Mill) is the most important horticultural species in the state of Chiapas, based on the cultivated area, the number of jobs it generates, its production, and its economic benefit (Garrido-Ramírez *et al.*, 2010). In 2021, this state ranked 14th at the national level for its production and 9th for the harvested area (SIAP, 2022a).

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The Chiapas tomato becomes relevant in southern-southeastern Mexico, due to its presence in the markets of Tabasco, Campeche, Yucatán, Mexico, Quintana Roo, and other Mexican States, as well as in parts of Central America, which enables its commercial self-sufficiency (Secretaría del Campo, 2014; quoted by InfoRural, 2014). Tomato production in Chiapas is mainly carried out (90%) in Comitán de Domínguez, La Trinitaria, La Independencia, and Las Margaritas, four of the seven municipalities that make up the Comiteca-Tojolabal Plateau Region (CTPR), where more than 1,300 hectares are cultivated using protected systems known as pabellones (SIAP, 2022b). Diseases in the CTPR have caused crop losses and have led some producers to abandon this crop. In addition, this seems to be the reason why yields are lower than in other producing regions in the same state (G. García, 2010). Along with the virosis and late blight problems, tomato wilt is one of the most frequent diseases (Gómez *et al.*, 2014).

The start and development of diseases in cultivated plant populations is the result of a combination of elements such as susceptible host plants, a virulent pathogen, and favorable environmental conditions. However, human intervention must also be taken into consideration, since human activities can contribute or stop the start and development of those diseases (Agrios, 2005).

In order to achieve a better understanding of the factors that influence the disease processes of a crop in a given area, a first approximation is the characterization of the production units in the region of interest. This characterization can help to identify potential relationships between economic, environmental, and social variables and indicators (Vargas and Sánchez, 2015), as well as their effects on biological processes. This measure would facilitate a dynamic interpretation of agroecosystems and the formulation of viable recommendations with a multidimensional approach (Coronel de Renolfi and Ortuño, 2005; Carrillo *et al.*, 2011). Based on the above, the phytosanitary and agronomical characteristics of the tomato production units (TPU) of the CTPR, in the state of Chiapas, were determined given the current lack of published research reports on the subject for this region.

MATERIALS AND METHODS

The research was carried out from 2021 to 2022, in the state of Chiapas. The study area was delimited to the municipalities of La Independencia (16° 15' 14" N, 92° 01' 24" W, 1,564 m.a.s.l.) and La Trinitaria (16° 07' 08" N, 92° 03' 01" W, 1,553 m.a.s.l.), both of which are part of the CTPR (INEGI, 2017). These two municipalities concentrated 80% of state production in 2021.

A random sampling of n=76 sites was performed. These production units were visited in order to apply surveys to producers and carry out field evaluations.

Information was collected on the following variables: location of the property (town, municipality, and UTM coordinates); cultivated variety; system (crop protection structure); irrigation type; years that tomato has been grown on the farm; crop rotation schedule (crop rotation, continuous management of tomato cycles, or rest period); fertilization (fertilization frequency and nutrients used); soil amendments (any soil amendment incorporated and amendment type); number of tomato crop cycles per year on the same farm; transplant date; and seedling origin (company that provides the seedlings to the producer). Along with general cultivation practices, phytosanitary control with the application of products directed at pest insects and diseases was characterized. In addition, the main phytosanitary problems and their levels of damage were evaluated.

The following variables were evaluated: frequency of applications for pest control and active ingredients used; management of foliar diseases (frequency of fungicide and bactericide foliar sprays and active ingredients used); type of treatment prior to transplantation, in order to prevent disease and pest attack; root disease management (frequency of root product applications and types of products used); record of root and vascular diseases in the two previous cycles; record of foliar diseases in the two previous cycles; incidence of dead plants due to root and vascular diseases (based on a 200-plant sampling); incidence of diseased plants due to root and vascular diseases (based on a 200-plant sampling), including plants killed by wilt and live plants with some level of damage, according to the wilting severity scale of Marlatt *et al.* (1996); wilting severity in the total number of plants sampled in the region (calculating the relative frequency for each severity level, based on the wilting severity scale proposed by Marlatt *et al.* (1996).

RESULTS AND DISCUSSION

Table 1 summarizes the variables evaluated and the values obtained. According to the survey data, the Ponny Express F1 variety is cultivated by 64% of the region's producers, followed by the Serengeti variety (20%). The remaining 16% use other varieties, such as Temible, Gabriela, Ángela, Atrevido, DT-22, and Cantil. Their postharvest quality is the main reason why the Ponny Express F1 and Serengeti varieties predominate in the region, since their firmness and shelf life are better than those of the other varieties. In addition, both varieties have been cultivated in the region for a longer period (13 years), which has resulted in greater knowledge about their requirements and behavior. The rest of the varieties have been introduced in the region in recent years and the particularities of their management are unknown.

A single supplier (Agrocima) supplies seedlings to 57% of the producers in the region; the rest is served by six companies: Pland-Bee (7%), Obed Rodríguez (9%), Plántulas Sta. Rita (9%), Biorquim (9%), Santagro (7%), and Hortamex (3%). Agrocima dominates the seedling market because it was the first to be established and its owners were the pioneers in tomato cultivation in the region. For a long time, it was the only company that supplied seedlings; currently, it has the largest organizational structure and has four branches in the region. Most of the other providers emerged in the last eight years.

Fifty-eight percent of the regional TPUs have less than a quarter of a hectare (ha), while 33% sow 0.25-0.5 ha; 7% have a 0.5-1 ha surface, and only 4% of the producers have farms larger than 1 ha. Nevertheless, none of the TPUs exceeds 2 ha. Tomato production in the CTPR is mainly carried out by small producers. Several reasons determine the presence of these small-scale TPUs, including the availability of farmland, lack of capital for larger-scale investment, lack of irrigation infrastructure, high input costs, and uncertainty in the sale of the harvested product. Most producers grow tomatoes and other important crops (*e.g.*, corn and beans) in small plots. Production costs are high, as a consequence of the

Table 1. Results of the agronomic and phytosanitary evaluation of the tomato production units in the Plateau Comiteca Tojolabal Region, Chiapas†.

Variable	Values (%)
1. Cultivated variety	Serengueti (20 %); Ponny Express F1 (64 %); Others (16 %)
2. Seedling provider	Agrocima (57 %); Pland-Bee (7 %); Obed Rdgz (9 %); Plántulas Sta Rita (9 %); Biorquim (9 %); Santagro (7 %); Hortamex (3 %)
3. Field size	0.1-0.25 ha (58 %); 0.26-0.5 ha (33 %); 0.51-1 ha (6.5 %); >1 ha (2.5 %)
4. Protection structure	Shadow house (96%); Greenhouse (4%)
5. Years of cultivation on the same field	1 (16 %); 2 (34 %); 3 (18 %); 4 (16 %); 5 (8 %); 6 (4 %); 10 (4 %)
6. Crop rotation scheme	Rest (7%); Rotation with corn (92%); Continuous Cycles (1%)
7. Fertilization frequency	Does not fertilize (0%); Every 15 days (8%); Every 10 days (20%); Every 5-8 days (72%)
8. Insecticide application frequency	Occasionally (12%); Every 15 days (5%); Every 10 days (11%); Every 5-8 days (72%)
9. Seedling pretreatment	No treatment (33%); With fungicide (11%); With antibiotic (0%); With fungicide + antibiotic (26%); With fungicide + antibiotic + insecticide (30%)
10. Foliar spray against diseases	Occasionally (4%); Every 15 days (1%); Every 10 days (1%); Every 5-8 days (94%)
11. Application of fungicides-bactericides to the roots	No applications (1%); Occasionally (3%); Every 20 days for 1.5 months (1%); Every 15 days for 1.5 months (45%); Every 10 days for 1.5 months (41%); Every 5-8 days for 1.5 months (9%)
12. Type of soil amendment	None (13%); Corn crop residues (79%); Manure or mature organic matter (8%)
13. Number of tomato crop cycles per year	1 (71%); 2 (21%); 3 (8%)
14. History of root and vascular diseases in the previous two cycles	None (6.5%); Damping off (10.5%): Vascular wilt (0%); Soft stem rot (1%); Symptom complex (82%)
15. Incidence of dead plants on the field*	0 (24%); 1-5 (59%); 6-10 (13%); 11-15 (0%); >15 (4%)
16. Incidence of diseased plants on the field**	0 (9%); 1-10 (55%); 11-20 (29%); 21-30 (4%); >30 (3%)
17. Wilt severity in the population	No symptoms (90%); Mild chlorosis and wilting (2%); Moderate chlorosis and stunting (3%); Severe chlorosis, wilting, and stunting (1%); Dead plant (4%)

† Results of 76 surveys and evaluations of the crops.
* Dead plants due to root diseases and vascular diseases.
** Diseased plants due to root diseases and vascular diseases.

management of high dependency of crops on agricultural inputs; therefore, producers lack the capacity to establish large surfaces.

Additionally, the commercialization of the product is decisive, given the significant fluctuation in the sale prices; sudden changes in them can lead to a risk of economic losses for the producers. Marketing is controlled mainly by intermediaries, who determine the price of the tomato. Finally, there have been cases of crop losses as a result of pests and diseases, which has led producers to be cautious when they establish a larger cultivation area.

In all cases, the tomato crops are protected with some kind of structure: 96% of them have a shade-house (*i.e.*, a wooden structure with anti-aphid meshes installed); and only 4% have a plastic greenhouse. The CTPR tomato market is mainly regional and the product quality it demands is met with the use of shade-houses. The use of protective covers is essential for tomato cultivation in the region, given the high presence of virus vector pests, including whitefly and thrips. The shade-house system has been more widely adopted than greenhouses, as a result of its lower cost and the fact that no specialized knowledge is required for its installation and management.

A drip irrigation system has been installed in 98.6% of the properties through the use of tapes. This technology is mainly used due to its efficient use of water and its crop fertilization capacity. In terms of time, the crop fields have been sown with tomatoes for 1-10 years, although the crop cycles are not continuous. In 50% of the cases, the producers have been cultivating tomatoes on the same property for 1-2 years, 42% for 3-5 years, and the remaining 8% have used the same property for 6-10 years. Tomato has been used as a crop option in Chiapas since 1960 (Gómez *et al.*, 2015); however, none of the current properties has been cultivated for more than 10 years. The productive actors are dynamic: on the one hand, some choose to abandon tomato cultivation for other activities or to cultivate other species; on the other hand, new producers start growing tomatoes.

Another reason why most of the properties do not exceed 5 years is the constant change to new farmlands. Productivity decreases after a tomato has been grown for a certain number of years in the same site, a phenomenon associated with loss of fertility and an increase in pest and disease populations.

Most of the farmers (92%) practice crop rotation, mainly with corn or with the corn-bean association, 7% let the land rest, and only 1% practice continuous tomato cultivation. Continuous tomato cycles on the same farm lead to a decrease in productivity, as well as an increase in the problems with pests and diseases. Tomato is rotated with corn and beans because these species are important for the producers, since they play a fundamental role in their diet. Additionally, rotation has a positive effect on maintaining productivity and lowering the occurrence of phytosanitary problems.

All producers fertilize the tomato crop: 72% every 5-8 days, 20% every 10 days, and only 8% every 15 days. All producers include sources of macro and microelements in the fertilization program and they also practice soil and foliar fertilization.

Soluble fertilizers (*e.g.*, potassium nitrate, calcium nitrate, potassium sulfate, magnesium sulfate, and magnesium nitrate) are mainly used for this purpose. Other sources are soluble fertilizer complexes that contain both macronutrients and micronutrients, and in some cases, humic, fulvic, and amino acids.

Regarding foliar fertilizers, a wide variety of brands with macro and micronutrient content are used. All the producers fertilize their crops, given its importance in the development of the crop and its proven impact on the yields and the quality of the harvested product. However, this practice is mainly based on the individual and shared experience of the producers and the recommendations of technicians who sell seedlings and agrochemicals in the region. In none of the cases, soil fertility analysis and/or foliar analysis of the crop were carried out. More frequent fertilization has been adopted as a consequence of the clear improvement in crop response to this management. Since crop nutrition is based on soluble fertilizers, a rapid effect has been observed after application; however, this effect does not last long, so frequent applications are required.

All producers apply insecticides: 72% (the majority) at intervals of 5-8 days; 11% every 10 days; 5% every 15 days, and 12% occasionally (as a response to an increase in the pest population). The active ingredients commonly used for pest control are: imidacloprid, thiamethoxam, tiociclam, cyantraniliprole, flonicamid, cypermethrin, abamectin, chlorantraniliprole, spirotetramat, spinetoram, and sulfoxaflor. The major pests are the whitefly, thrips, *Bactericera* sp., and the leaf miner. The control of pests in the crop is fundamentally based on the use of insecticides and anti-aphid mesh. High populations of the main tomato pests (whitefly, thrips, and *Bactericera*) have been observed in the CTPR. Additionally, one of the main limits to the production of tomatoes is the presence of virosis. The association of pests with viral diseases is known in the region. Whitefly and thrips species are widely reported as virus vectors (Fereres *et al.*, 2016). In places located in an area with a cooler climate in the municipality of La Trinitaria where insecticides are applied with less frequency, high populations of these pests are not observed. In TPUs with greenhouse technology, a lower frequency of insecticide was also reported. The use of a wide variety of active ingredients for pest control is a consequence of an increase in the populations of these insects. Additionally, as a result of their constant use, commonly used pesticides have been reported to lose their effectiveness. Therefore, the practice of rotating active ingredients has been adopted to reduce the rapid emergence of insecticide-resistant pest populations.

Seedling treatments prior to transplanting are aimed at protecting them against pests and diseases. Management is variable among producers: 33% do not apply any treatment; 11% immerse them in a solution with fungicide; 26% protect them with a mixture of fungicides plus bactericides; and 30% use a mixture of fungicides, bactericides, and insecticides. Commonly used active ingredients for seedling pretreatment are metalaxyl, propamocarb, fosetyl aluminum, azoxystrobin, gentamicin, streptomycin, and oxytetracycline. Disease problems are common during the seedling stage; therefore, most producers engage in pretreatment. In the cases in which no pretreatment was applied, producers indicated that no soil-borne diseases were observed in previous cycles or that the properties had been only recently used to grow tomatoes. Although root and vascular diseases have been observed in most of farms, the real cause of these symptoms is unknown, and the use of mixtures of products to ensure better control is a common solution.

Foliar applications for disease control take place at intervals of 5-8 days in most cases (93%); the rest apply this treatment every 10-15 days or only occasionally. For foliar applications against diseases, the following products are used: mancozeb, captan, chlorothalonil, copper, cymoxanil, prochloraz, azoxystrobin, propamocarb, dimethomorph, carbendazim, thiabendazole, benomyl, gentamicin, streptomycin, oxytetracycline, and kasugamycin. Late blight is the most important foliar disease, due to its difficult control and aggressiveness. The temperature and humidity conditions favor the infection and development of the pathogen that causes this disease. Other common foliar diseases are early blight and bacterial leaf spots. On the one hand, control products are constantly applied, justified by the losses (washing) caused by the frequent rains in the region and the constant presence of diseases. On the other hand, the control of pests and diseases of the tomato crop is based almost entirely on chemical control; therefore, guaranteeing plant health is highly dependent on the application of chemical products. The use of a wide variety of active ingredients for pest and disease control is also a result of the lack of restrictions on the use of pesticides. As this product is mainly aimed at the national market, producers are not governed by regulations regarding the use of pesticides on tomatoes.

Soil-borne diseases are managed through the direct applications of a mixture of fungicides and bactericides on the roots. These products are applied by 45% of the farmers, at 15-day intervals during a period of 1.5 months; 41% do it every 10 days during the same period; and 9% apply them every 5-8 days. A small percentage (1%) does not apply these products or only does it occasionally (3%). The following products are applied on the roots: metalaxyl, propamocarb, fosetyl aluminum, azoxystrobin, quintozene, thiram, fenamidone, TCMTB, MTC, gentamicin, streptomycin, oxytetracycline, and kasugamycin. The crop is commonly protected against root and vascular diseases during the first half of the crop cycle. If no control treatment is carried out, vascular wilting, damping off, and chlorosis problems are reported during this stage. Applications are less frequent 45 days after transplanting, given the lower incidence of root and stem problems at this stage.

Most tomato producers apply organic amendments to the soil: 79% incorporate residues from the previous crop, 8% apply manure or mature organic matter, and 13% does do not apply amendments. The use of amendments is common, mainly through the incorporation of residues from the previous crop. Most producers have been able to carry out this practice because crop rotation with corn or corn-bean association is a common practice, which does not involve any additional costs. Soil amendments with organic matter, biofertilizer, green manure, or lime to adjust the pH have multiple effects, including an improvement in plant immunity, suppression of pathogenic microorganisms, and the increase of the populations of beneficial microorganisms (Bonanomi *et al.*, 2018; Xue *et al.*, 2019). In addition, they directly provide certain levels of nutrients or the microbial activity altered by this practice modifies their availability (English and Mitchell, 1994).

Seventy-one percent of the producers carry out one crop cycle per year on the same property; 21% carry out two cycles, and only 3% carry out three cycles. Based on their own experience and the recommendations of third parties, one cycle per year has been adopted as a phytosanitary measure, since continuous cycles have been associated with a rapid increase in disease problems and the loss of soil fertility. These results match the findings of Shipton (1979), who indicates that the continuous planting of the same crop can cause the soil to be contaminated with phytopathogenic organisms.

Regarding the root and vascular diseases records, 82% of the producers have observed a complex of symptoms, including damping off, vascular wilting, soft stem rot, chlorosis, and reduced growth; 7% indicated that they had not observed any of those symptoms; 11% reported having observed only the damping off symptom; and only 1% observed soft stem rot. A wide group of pathogens has been identified as the cause of these symptoms, mainly fungi and bacteria found in the soil (Blancard, 2013; Rueda *et al.*, 2014). This suggests that the tomato wilt problem in the region is caused by soil-borne biotic agents.

Regarding foliar diseases, 97% of the producers reported that their crops had been affected by late blight and virosis in previous cycles, considering them as the most important foliar diseases.

According to field evaluations, the incidence of dead plants due to root disease or vascular infection ranged from 0-38%. In 59% of the properties, the incidence ranged from 1-5%. In 24% no incidence of dead plants was reported, and only 4% recorded a >15% incidence. The incidence of plants affected by wilt —which includes dead plants and plants with some level of disease— ranges from 0 to 49%. In 55% of the properties, the incidence of diseased plants ranged from 1 to 10%. In 29%, it ranged from 11 to 20%. At the extremes, 9% did not have wilting symptoms and greater than 30% incidence. The levels of incidence and the severity of wilting are generally low, considering that crop losses have been reported to reach up to 60-70% due to this disease (Ravindra *et al.*, 2015). A low incidence of dead and diseased plants in most of the sites can be explained by the widespread implementation of practices such as crop rotation, amendments, a high frequency of fertilization, one crop cycle per year, and frequent applications of pest and disease control products. As García (2010) mentions, these activities influence root diseases. These practices reduce the amount of inoculum in the soil, improve crop resistance to pathogen attacks, and reduce the number of successful pathogen infections through pesticide applications.

The genetic material is another factor that could be influencing these low disease levels, since the Ponny Express F1 variety has been reported to be resistant to the wilt caused by *Fusarium* sp, (one of the main pathogens associated with tomato wilt). Montiel *et al.* (2020) report the incidence of wilt by *Fusarium* sp. in nine commercial tomato genotypes, with the lowest incidence (0.03%) being reported for the Ponny Express F1 variety. This study recorded incidence levels higher than those reported by these authors for this variety. The occurrence of these differences is natural, since the resistance of crop varieties to pathogens does not remain fixed over time. In addition, under natural field conditions, the presence and interaction with a complex of pathogens and other microorganisms that could alter the resistance levels of the crop is a likely event.

Fernandez-Herrera *et al.* (2013) detected a higher incidence of wilting and a shorter incubation period when jointly inoculating *Phytophthora capsici*, *Rhizoctonia solani*, and *F. oxysporum*, compared to their individual inoculation in tomato plants.

Of the total number of plants sampled in the 76 sites, 90% showed no wilting symptoms, 2% had symptoms of mild chlorosis and wilting, and 3% presented moderate chlorosis and stunt. The rest recorded the highest severity levels: 1% of plants had symptoms of severe chlorosis, wilting, and stunt, and 4% were dead. Based on these data, the severity of the disease in the region is low. The adoption of new crop management practices is likely to have had an influence on these results. In addition to the abovementioned practices that help to reduce the impact of the disease, one of the common practices among producers is the constant change of cultivation land. Usually, after the property has been cultivated for a certain number (4-5 years), it is abandoned as an area for tomato cultivation and is used to plant other crops. The constant change of cultivation areas is a component that can explain a low incidence and severity of wilting in the evaluated properties. Those cultivation practices do not only reduce the amount of inoculum in the soil and give rise to greater physiological resistance in the crop; they also reduce the appearance of populations of more virulent and pesticide-resistant pathogens and decrease successful cases of infection by pathogens.

CONCLUSIONS

The tomato production units in the CTPR are mainly characterized by the use of shade-house structures. Ponny Express F1 is the predominant variety, mainly due to its firmness and long shelf life. The land properties do not exceed 2 ha and most have half a hectare or less. Crop management is intensive, with fertilizers and pesticides applied with great frequency to control pests and diseases. Most producers apply these products on a weekly basis. Practices such as the incorporation of crop residues, crop rotation, and the management of a single tomato cycle per year on the same farm are common among producers.

The level of incidence and severity of tomato wilt in the CTPR is generally low. This could be the result of the agronomic practices carried out by the producers, the variety of tomatoes cultivated, and the characteristics of the pathogens associated with this disease (*e.g.*, the genetic variability that exists in the populations, related to varied levels of virulence within the same species). In addition to tomato wilt, other regionally important diseases are virosis and late blight. Further studies should be carried out to better understand and manage these phytosanitary problems, given the relevance they have gained in the area and the importance of tomatoes as the major vegetable in the state of Chiapas.

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