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Agroecological management of Diseases originating in Soil for the Cultivation of Tomato (*Lycopersicum esculentum* Mill)

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Abstract

The tomato (Lycopersicon esculentum Mill) ranks first in the world in surface area and volume of production. In Mexico creates major currencies for the country as it generates a large economic value and high demand for labor. However, the lack of knowledge on the management of phytopathogens, has placed to the tomato as one of the crops that presents more risk of contamination by excessive use of agrochemicals to control fungal diseases mainly. The objective of this research was to conduct an agroecological tomato crop management for soil-borne diseases, using organic fertilizers and an antagonist under greenhouse conditions trough a random block design with five replications and nine treatments. The variables evaluated were stem diameter, plant height, leaf number, incidence of soil-borne disease, and yield. At 90 days, the best values were: for diameter (FC=1.35 cm), for height (FCTR =216.8 cm) and number of leaves (FC=23.3), occurring in all cases significant difference ($p \leq 0.05$) on the group control (TE). The disease incidence data exhibited statistically significant difference ($p \leq 0.05$) between treatments, the lowest values for soil-borne disease incidence were (FCTR=1.25%), yield (FC=93.08 ton/ ha) exceeded statistically ($p \leq 0.05$) at the treatments (TE =60.44 ton/ ha) and (LOFC =70.22 ton/ ha). Coconut fiber organic manure, presented the best results in varying yield and development of the tomato crop, being inoculated with Trichoderma, reduces the incidence of soil-borne disease, showing an alternative agroecological management of pathogens originating in soil.

Keywords: Organic fertilizer, tomato, agroecological management of disease, incidence of disease, suppressiveness, *Trichoderma* spp.

Introduction

The tomato (*Lycopersicon esculentum* Mill) is the most widely cultivated vegetable in the world, reaching 4.7 million hectares with a production of 159 million tonnes by 2011, ranking as the most important vegetable, take first place in both area and production[1]. Mexico is in eleventh place with 2,436 million tonnes with an average yield of 51.38 ton/ ha on 85 thousand hectares of tomato[2]. Growing tomatoes for marketing is a highly profitable business that generates significant income for the country, as they have entered Mexico on average per year, up dollars billion[3]. In Mexico, the tomato was placed in the number one position in export of agri-food products and is one of the most profitable investment opportunities and greater future, since it is a root vegetable that generate high economic value and a high demand labor due to its intensive use[3]. This activity generates 72,000 direct jobs and 10.7 million indirect jobs[4].

Susceptibility to high levels of humidity (80-100%), has placed the tomato as one of the crops that presents more risk of contamination due to overuse of agrochemicals, especially for pathogens control such as fungi, bacteria and viruses which cause disease, which affect the optimal development of cultivation[5 -7]. Among the major diseases, are caused by the fungal pathogens *Pythium* spp soil as *Phytophthora* spp, *Fusarium* spp , *Rizhoctoni*a spp among others, that attack the root and stem inducing different symptoms that can be easily observed, ranging from wilting rot, stunting, leaf spots and blights with affectations from 90% yield to complete loss of crop[7-9.]

The combat disease is mostly done with the use of chemical fungicides, but their indiscriminate use has caused contamination problems with the environmental persistence of toxic waste, negatively impacting production resources such as soil and water, also, in the same agro- biodiversity, causing instability to cause pathogen resistance and induce a higher incidence of disease in crops[10,11]. The indiscriminate use of agrochemicals in conventional agriculture fosters interest in the ecological control, which can be defined as any form of control that reduces the incidence or severity of disease, or increase crop production, even when there is not apparently an significant effect on the reduction in disease or inoculum, and its harmful impact on the environment is minimal or zero[7, 9-10].

Agroecosystems can be optimized through the use of two pillars: habitat manipulation via crop diversification and improving soil fertility[9,12].

For the specific case, the application of organic matter through organic fertilizers is the main nature reserve of potentially assimilable nutrients by plants, conservation and management of it is the most economical way to optimize nutrition and plant health, therefore, plays an important role in soil fertility, in addition to its potential to control pathogen populations originating in the soil[13-14]. It has been shown that species of beneficial fungi such as *Trichoderma* spp., *Penicillium* spp., and *actinomycetes* showed suppression against *Phytophthora* spp., *Rhizoctonia* spp., and *Fusarium* spp., such beneficial fungi colonize the organic material which depends on the composition of it during the maturation phase, for the case of *Trichoderma* spp colonize the rich organic material in lignocellulosic substances (wood waste and coir), while *Penicillium* spp colonizes the low organic cellulose material but high in sugars (food waste and vegetable)[15]. Given the advances in research at national and global level, you can not remain indifferent to the use of improper practices in the management of agroecosystems, as conventional disease control through the use of agrochemicals, such as pesticides and fertilizers minerals to optimize agricultural production, since these activities has led to the deterioration of the chemical, physical and biological soil characteristics, and has led to the susceptibility of plants to pests and diseases, causing major problems in most cases irreversible, drastically reducing production capacity, becoming unstable and unsustainable agro-ecosystems as a result of their high economic, ecological and social costs[7,9]. So, the purpose of this paper is to agroecological management of soil-borne diseases in the tomato crop under greenhouse conditions, to develop an alternative to practices to diseases conventional control, enabling the sustainable management of the agroecosystem in the cultivation of tomato and thus reduce the high economic, ecological, social costs.

Material and Methods

The research was carried out during the spring-summer season 2013 under greenhouse conditions in the community of Atempan, Puebla-Mexico. The factors studied were: soil of the region (as a witness), organic fertilizers; coconut fiber, bocashi, vermicompost from the pulp of coffee and walnut shell more the same organic manures inoculated with the antagonistic *Trichoderma* spp., (table 1).

The experimental design was random blocks with five replications and nine treatments (table 2). The experimental unit was 2.4 m^2 (1.2 m x 2.0 m) which includes two beds with double rows 0.4 m and a total of 16 plants (planting density of 5.8 plants m^2). Ground preparation began with the development of raised to a height of 30 cm beds, which were irrigated with 10 liters of water prior to the application of fertilizer, which is made with the following dose, vermicompost at the rate of 2.7 kg/m^2, coconut fiber 2.7 kg/m^2, Bocashi 2.7 kg/m^2, in the case of the vermicompost more coconut fiber mixture 50 + 50% at a rate of 1.35 kg for the first and 1.35 kg/m^2 for the second, the treatments which were inoculated with *Trichoderma* spp, the application rate was also 2.7 kg of manure by m^2, the inoculation of the antagonist was 9 g of *Trichoderma* spp., per 20 kg of organic fertilizer sprayed with 7 liters of water, all fertilizers were applied in a trench 30 cm wide by 20 cm deep, allowing the distribution of the fertilizer over the entire bed, later to cover the same ground. Organic fertilizers were obtained in advance; the bocashi was prepared a month and a half before planting. The vermicompost was made from the pulp of coffee and walnut shell. Coconut fiber used was the Cocoplus® trademark. The biofunguicida used was *Trichoderma* spp., trademark Tricofungi AFAO®.

The transplant took place on April 30, 2013 with seedling variety SUN 7705 (Nunhems USA Inc). Fertilization was realized with vermicompost extract, mixed 0.5 L in 19.5 L of water enriched with 20 g of fertilizer (13-40-13) during the first 60 days after transplanting, the rest of the cycle was applied 0.75 L vermicompost extract mixed in 19.25 L of water enriched with 40 g of fertilizer (13-40-13), irrigation was performed according to the needs of the crop and fertilization was performed in periods of 10 days during the same cycle applied manually to the base of the stem in a proportion of 100 ml per plant. Controlling pests (whiteflies, aphids and fleahopper) was performed based on plant extracts and traps. Control foliage disease was performed with mineral broths, plant extracts, and sodium bicarbonate.

Table-1
Properties of organic fertilizers used in the production of greenhouse Tomato in Atempan, Puebla-México

Treatment	pH	E.C. (dS/m)	OM %	N %	P %	K %	Ca %	Mg %	Na %	C/N
FC	6.6	2.35	60.00	2.80	2.60	3.00	3.10	2.10	-	-
BO	6.9	4.34	40.50	0.63	0.21	1.29	1.72	0.37	0.26	37.30
LO	5.6	0.51	79.50	1.75	0.04	0.15	0.98	0.17	0.04	26.30
EL	8.6	20.5	-	0.568	0.225	0.878	0.036	0.027	0.187	-

FC= Coconut fiber, BO= Bocashi, LO= Vermicompost; VE= Vermicompost extract, pH: Potential of hydrogen, E.C= Electrical conductivity and OM= Organic matter.

Table-2
Fertilizers organic for greenhouse tomato production in Atempan, Puebla-México

Treatment	Code	Organic substrates mixture				
T1	TE	(Soil of the region)				
T2	FC		Coconut fiber			
T3	BO			Bocashi		
T4	LO				Vermicompost	
T5	LOFC		Coconut fiber 50%		Vermicompost 50%	
T6	FCTR		Coconut fiber			*Trichoderma* spp
T7	BOTR			Bocashi		*Trichoderma* spp
T8	LOTR				Vermicompost	*Trichoderma* spp
T9	LOFCTR		Coconut fiber 50%		Vermicompost 50%	*Trichoderma* spp

T1= TE (Soil of the region), T2= Coconut fiber (FC), T3= Bocashi (BO), T4= Vermicompost (LO), T5= 50% + vermicompost + coconut fiber 50% (LOFC) T6= Coconut fiber + *Trichoderma* spp (FCTR), T7= Bocashi + *Trichoderma* spp (BOTR), T8= Vermicompost + *Trichoderma* spp (LOTR), T9= 50% Vermicompost + coconut fiber + 50% *Trichoderma* spp (LOFCTR).

The variables evaluated were: i. Diameter of plant stem (cm), measured with vernier hand at the base of the stem or base of the plant, 1 cm from the ground. ii. Plant height (cm), which was measured with measuring tape 5 m, whereas from the base of the stem or base of the plant to the tip of it. iii. Number of leaves per plant, having compound leaves from the stem base to apex. iv. Incidence of soil-borne disease (%), which was monitored every 15 days counting plants with symptoms of wilt, root rot or dead plant in relation to total plant from the experimental unit. v. Crop yield (kg). The yield was determined in each court, weighing the fruits harvested in each experimental unit. The data obtained were processed using Statgraphics version centurion 16.01.0002 for analysis of variance (ANOVA) test and subsequent Tukey multiple comparison ($p < 0.05$) was used to determine differences between treatments.

Results and Discussion

Stem diameter: In the first 60 days after transplantation excelled significantly (table 3) FC treatment (1.17 cm) and LOFCTR (1.14 cm), exceeding significantly to TE (0.97 cm). At 75 days after transplantation treatments highlights FC (1.27 cm), LOFCTR (1.25 cm) and BOTR (1.24 cm), which statistically outperformed the TE (1.07 cm). At 90 DAT highlights were significantly ($p \leq 0.05$) treatments FC (1.35 cm) , LOFCTR (1.33 cm), BOTR (1.32 cm), LO (1.31 cm), FCTR (1.31 cm) and LO (1.31 cm) by overcoming statistically TE (1.13 cm). Stem diameter is related to the crop yield, since more area means more reserve parenchyma similar that can be used in fruit growing, as well as increased xylem area allows greater transport of water and nutrients to the reproductive organs, so that a larger diameter increases the number of fruits and consequently yield crop[16-17]. In this trial, with most treatments values stem diameter statistically greater the witness were obtained, however, are low (1.26 to 1.35 cm at 90 days after transplantation) compared to those obtained by Ortega-Martínez *et al.*,[17] who reported values of stem diameter of 1.8 cm at 100 days after transplantation organic substrates sawdust-compost and 1.4 cm in substrate compost, thus also, Zarate[18] reports values of stem diameter in hydroponic production to the 13th week of 1.2 and 1.6 cm corresponding to the highest value to variety 7705 in coconut fiber substrate. These low values in stem diameter is largely due to the low radiation received during the crop cycle, as probably cloudy days occurred in most of the crop cycle, since the average temperature fluctuated around 15 °C and relative humidity was maintained around 90%, also lower luminosities are known to give rise to thin and weak stems with higher proportion of parenchymal tissue; that is, a larger area of parenchyma may involve larger pool of similar category, under stringent conditions, some form of stress such as high density or excessive leaf area may lead to that these reserves are partially remobilized to the fruits growing[16,17], this statement can be proven with the values reported in diameter Sánchez del Castillo *et al.*,[19] in hydroponic tomato with high densities, these values vary between 1.22 and 1.27 cm recorded at 90 days after transplantation, these being lower than those reported in this paper.

Plant height: In the first 60 days after transplantation, apparent significant difference between treatments (table 3) is not made. At 75 days showed significant difference ($p \leq 0.05$) treatments FC (189.5 cm) and FCTR (189.4 cm), exceeding significantly ($p \leq 0.05$) TE (164.9 cm). At 90 days the FCTR (216.8 cm) treatment showed significant difference ($p \leq 0.05$) TE (164.9 cm) surpassing statistically. With regard to plant height, taller consequently gives a greater number of leaves and clorofila[6]. The best height at 90 days after transplantation, which threw the FCTR (216.8 cm) above the treatment FC (212.4 cm) is possibly due to the *Trichoderma* spp., colonizes plant roots favoring radical development as both air and prevents the attack root pathogens also in some species of *Trichoderma* spp., noted its capacity as stimulator of growth in many vegetable crops and plants ornamentales[20]. The results obtained here agree with those reported by authors such as: Rodríguez-Dimas *et al.*,[21] who obtained values of plant height for two tomato genotypes produced in different organic fertilizers, height for Granitio genotype ranged from 158-206 cm and Romina genotype height was between 170 and 180 cm both at 90 days after transplantation. Also, Marquez- Hernandez *et a*l.,[22] reported values final plant height of tomato genotypes Bosky 174.8 to

202.8 cm and Big Beef with values of 148.1 to 235.7 cm, all obtained with different organic fertilizer sources. However, Ortega-Martinez *et al.*,[17] reported values greater height to those discussed above with the genotype Sun 7705 ranging between 280 and 380 cm to 100 days after transplantation, this difference may be due to the application of the nutrient solution fertilization system unlike fertilization with vermicompost extract used in this experiment. It is worth noting that although there are contrasts in tomato genotype with different authors, all common organic fertilizers applied as a substrate or as an amendment.

Number of leaves: The cultivation showed a homogeneous development within 75 days after transplantation, (table-3), however at 90 days after transplantation, treatment FC (23.3 leaves) showed statistically significant difference ($p \leq 0.05$) on LOFC treatments (20.2) and TE (20.3). Although the variable number of leaves is not used in several studies as an indicator of crop development, it is important according to the functions performed, example of this is that the leaves have the ability to assimilate nutrients by penetration, absorption and traslocación[6] also increased the number of sheets increases photosynthesis occurring, resulting in weight fruit gain and consequently yield[21]. For this research the nutritional contribution balanced organic fertilizer coir allowed to have as many leaves as the adequate supply of nutrients, especially nitrogen, is associated with adequate levels of chlorophyll, vegetative growth vigorous, high photosynthetic activity and synthesis of carbohydrates, which depends yield[6].

Means with the same letter within columns and sampling dates are equal according to the Tukey test at $p \leq 0.05$.

Incidence of soil-borne disease: Pathogenic *Fusarium* and *Phytophthora* spp showed statistically significant difference ($p \leq 0.05$) between treatments (table 4), the lowest values of incidence occurred in treatments FCTR value of 1.25%, 2.55% BOTR and FC with 3.75%, contrasting with the highest incidence values that corresponded to the TE, LO and LOFC whose values were 12.5%, 11.25% and 8.75% respectively. It is clear that the higher incidence of disease originating in soil was observed in TE (12.5 %), treatment will not apply any organic fertilizer. Lores *et al.*,[23] showed that, depending on the species of worm used and the organic source material, microbial communities originated after the vermicomposting process were different, which could lead to different capacities for disease suppression, so in this paper the ability of suppression of vermicompost used was low. In contrast, compost coir showed lower incidence of disease in the first place is significant attribute this property to the contents of ligno-cellulosic substances; this is because it has been demonstrated that beneficial fungi species as *Trichoderma* and *Penicillium* spp. showed suppression against *Phytophthora*, *Rhizoctonia* and *Fusarium* spp., such beneficial fungi colonize the organic materials depending on the composition of the organic material, for the case of *Trichoderma* spp colonize the rich organic material in ligno-cellulosic substances (coconut fiber), while *Penicillium* spp colonize organic material low in sugar but high in cellulose (vermicomposting and bokashi)[15]. Very importantly data, it has been shown that the properties of suppression diseases take more than three years with compost or organic materials with high content of cellulose and lignin (wood waste and coir), unlike those that are products high in sugar it takes between six and twelve months[15]. For all mentioned, in addition to the inoculation of *Trichoderma* spp to compost coir, made the treatment FCTR which presented lower incidence of disease in this research with a value of 1.25%. Likewise, the *Trichoderma* spp., as biocontrol agent of diseases originating from the ground, presents a strong aggression should face phytopathogenic fungi, and high efficiency in promoting plant growth and stimulating the defense mechanisms, also its ability to modify the rhizosphere, ability to survive under unfavorable conditions, high reproductive capacity, and efficient use of nutrients[24], this situation is reflected in the present work, since all the treatments inoculated with *Trichoderma* spp. , had lower disease incidence with respect to its corresponding uninoculated treatment. The results presented in this paper allows us to observe the effect that different organic fertilizers on the incidence of diseases originating in soil, as these also play an important role in fertility natural body function, generate a potential to control pathogen populations originating in the soil[13,14,] allowing assert, that the optimization of agroecosystems can be achieved by improving soil fertility[9,12]. Since the contribution of organic fertilizer increases organic matter and the conservation of soil biodiversity, ensuring the fertility and health of it, an alternative optimal agroecological management of pathogens originating from soil of the tomato agroecosystem becomes apparent.

Crop yield: The treatment FC scored the best yield in greenhouse tomato production (93.08 ton/ha) statistically outperformed the TE and LOFC treatments, with yields 60.44 ton/ha and 70.22 ton/ha respectively. Also, the treatments LOTR and FCTR obtained yields 86.72 ton/ha for the first and 83.82 ton/ha for the second statistically outperformed the TE (table 4). It is important to note, that the nutrimental characteristics different from organic fertilizers, caused different crop yield, and since manure of coconut fiber presented a better nutritional balance (table 1), therefore, presented the best values of the variables of development of cultivation and yield, outperformed witness for 35%. The high content of organic matter and nitrogen ratio better manure vermicompost (table 1), in addition to which the vermicompost improves the texture and structure of the soil allowing better nutrient retention, moisture and air for the better development of the crop[25,26], were the possible properties to overcome both variables of development of the crop value and yield on Bokashi and vermicompost-coconut fiber mix.

Table-3
Diameter, height and number leaves average of tomato plants in different organic fertilizers under greenhouse conditions in Atempan, Puebla-Mexico

Treatment	60 days			75 days			90 days		
	Diameter (cm)	Height (cm)	Num. leaves	Diameter (cm)	Height (cm)	Num. leaves	Diameter (cm)	Height (cm)	Num. leaves
TE	0.97 b	121.5 a	16.8 a	1.07 b	151.3 b	18.2 a	1.13 b	164.9 b	20.3 b
FC	1.17 a	146.0 a	18.1 a	1.27 a	189.5 a	20.8 a	1.35 a	212.4 ab	23.3 a
BO	1.09 ab	134.8 a	17.4 a	1.21 ab	170.8 ab	19.5 a	1.27 ab	191.6 ab	21.9 ab
LO	1.13 ab	142.7 a	18.2 a	1.24 ab	184.9 ab	20.7 a	1.31 a	206.5 ab	22.9 ab
LOFC	1.09 ab	130.6 a	16.5 a	1.18 ab	162.4 ab	18.7 a	1.26 ab	183.1 ab	20.2 b
FCTR	1.12 ab	144.5 a	18.1 a	1.24 ab	189.4 a	20.1 a	1.31 a	216.8 a	22.7 ab
BOTR	1.14 ab	138.9 a	18.0 a	1.24 a	175.7 ab	19.1 a	1.32 a	196.3 ab	22.8 ab
LOTR	1.11 ab	139.9 a	17.2 a	1.24 ab	177.1 ab	19.6 a	1.31 a	196.7 ab	22.0 ab
LOFCTR	1.14 a	145.2 a	17.7 a	1.25 a	181.6 ab	19.7 a	1.33 a	202.0 ab	22.4 ab

Table-4
Disease Incidence originating from soil, foliage incidence and average disease of tomato plants in different organic fertilizers under greenhouse conditions in Atempan, Puebla-México

Treatments	Incidence of disease originating from soil %	Yield crop ton/ha
TE	12.50 f	60.44 c
FC	3.75 b	93.08 a
BO	5.00 c	75.08 abc
LO	8.75 e	81.94 abc
LOFC	11.25 f	70.22 bc
FCTR	1.25 a	83.82 ab
BOTR	2.50 a	79.58 abc
LOTR	5.00 c	86.72ab
LOFCTR	6.25 d	81.46 abc

Means with the same letter within columns and sampling dates are equal according to the Tukey test at $p \leq 0.05$.

It was observed in all cases, except for the coconut fiber manure, the positive effect of the antagonist *Trichoderma* spp., on yield in inoculated treatments compared to treatments without inoculation. Effects demonstrated by Ousley *et al*.,[27] who found that some species of the genus *Trichoderma* are able to increase the growth of lettuce plants (*Latuca sativa* L); also Gravel *et al*.,[28] tested the ability of *Trichoderma* spp., to promote the growth of tomato plants. There is evidence from other studies, which reported higher yields compared to those obtained in this experiment, as in the case of Rodriguez-Dimas *et al*.,[21] who obtained yields of 179 to 222.2 ton/ha in a hydroponic system where used sand as substrate and nutrient solutions in organic tomato genotypes Granitio and Rominia. Also, Ortega-Martínez et al.,[17] reported yield values between 73 and 250 ton/ha using different organic substrates fertilized with nutrient solution Steiner genotype Sun 7705. Marquez-Hernandez *et al*.,[22] scored yield averages 116.41 and 136.7 ton/ha genotypes Big beef y Bosky, using bio-compost and sand as substrate and fertilized with nutrient solution Biomix (NPK). The high yields of the three aforementioned works argue for the continued provision of nutrients to plants in the hydroponic system; another job with similar characteristics but with the variant have used organic fertilizers and soil amendments and nutrient solution applied in fertigation Bioagro is Mendoza-Netzahual *et al*,.[29] who reported yields between 88.5 and 132.6 ton/ha DRW3410 genotype; by comparison with those reported in this trial of 93.08 ton/ha, are still being higher, this difference can be attributed to the effect of the application of the nutrient solution at each irrigation , unlike in the present work the application of fertilization with vermicompost extract was performed every 10 days throughout the growing season. Yield data reported by De la Cruz Lázaro *et al*.,[30] ranging between 40.499 and 57.375 ton/ha (lower than those obtained in this work) can confirm the aforementioned assertion, as these yields were obtained using mixtures as substrate vermicomposts and compost with sand, watered witness except only with water, so that the contribution of nutrients occurred only with organic substrates, thus proving the difference in yield, and that investigations were made under ambient conditions fully different.

Conclusion

Coconut fiber organic manure, yielded the best results from developmental variables and crop yield of tomato (93.08 ton/ha), which when inoculated with *Trichiderma* spp., reduced the incidence of soil-borne disease (1.25%), demonstrating an alternative optimal agroecological management of pathogens originating from the ground.

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