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ORIGINAL ARTICLE

Regionalization Of The Strawberry (*Fragaria X Ananassa* Duch) Production Areas of the Valley Of Zamora Michoacan, Mexico By Dry Wilt Incidence and Crop Technologies

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ABSTRACT
Because of its frequency and wide distribution, the dry wilt disease is a limitant of the strawberry crop. In order to regionalize strawberry growing areas with respect to the intensity of the disease and learn about the effect of the crop management, varieties, soil physicochemical and biological factors, 34 strawberry plantations spread over 8 locations of the Zamora Valley on Michoacan State, Mexico, were sampled. The variables using the Poisson function with the processor GENMOD SAS were analyzed. The dry wilt intensity was significantly lower (p<0.0001) in plots with plastic mulch and drip irrigation regard to plantations without padding and watered by gravity. The Aromas variety was more tolerant to the disease incidence than the Camarosa variety. The pH, compaction and soil texture, did not influence on the disease intensity. The dry wilt incidence was not influenced by the strawberry variety or organic matter content in the soil (p<0.0001), in any strawberry production system in the Zamora Valley. The number of Fusarium oxysporum colony forming units at the beginning plantation was correlated with a higher disease incidence in flowering (r = 0.70) and fructification (r = 0.65) stages.
***Keywords**: epidemics distribution, crop handling, strawberry*

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INTRODUCTION

Currently worldwide Mexico ranks 12th place in area planted with strawberry, and 8th place in strawberry volume produced. In 2007, 6154 acres were planted with this crop from which 176,000 tons of strawberries were obtained. In the same year, with a volume close to 67,000 tons exports Mexico ranked 3rd place among the major exporting countries of strawberry [1] Currently Michoacán state ranks first as producer of strawberry in Mexico, and the 19 municipalities of the state who sow strawberry, Zamora is the number one producer with 900 hectares planted [2].

The strawberry dry wilt is a severe illness in the Valley of Zamora, Michoacán, Mexico. During the 2004-2005 crop cycle, its incidence ranged between 15 and 30%, causing economic losses estimated at $ 4 million dollars. In Mexico, the research work conducted over recent decades, have been mainly focused on the control of the fungi complex, which affect the root. However, studies with regional focusing involving the analysis of technology of the agro-ecosystem and environmental components by means of multivariate methods and geographic information systems, are required [3, 4], which allow to develop a strategy of effective integrated management of disease for each region in particular. Therefore, strawberry production programs should consider those factors that favor the plant growth and the fruit production including selection of disease-tolerant varieties, since Strawberry is highly susceptible to root pathogens [5]. Of the pseudofungi (*Pythium aphanidermatum*, *Phytophthora* sp.) and the fungi (*Rhizoctonia fragariae*, *Fusarium oxysporum*) causing of the dry wilt plants in Michoacán state, Mexico [6], the latter is considered of greater importance, by further increase its impact on root and crown during flowering and fruiting. In addition, there is a direct relationship between inoculum concentration and the attack degree or disease speed [7]. Other factors that can contribute to the improvement of the health of the crop are the plastic padding and the organic matter incorporation because they stimulate physical or biological factors that protect the roots of the plant pathogens [8, 9, and 10]. In this context, this research was aimed to define distribution geographical areas of the disease to design an integrated precision management, incorporating factors of regional agronomic management, under the hypothesis that the crop, variety, climatic and edaphic conditions management, contribute to modify the disease regional distribution.

MATERIALS AND METHODS

The fieldwork was conducted in four irrigation areas of the District No. 088, Zamora, Michoacan, Mexico, which is located between parallels 19°54'49'' and 20°06'52'' N latitude and between the meridians 102°07'43'' and 102°23'68'' W longitude, at an average altitude of 1575 msnm. A global positioning system (GPS model 631026 A Thales Navigation) to record latitude, longitude and altitude in each of the sampled plots was used. In 34 strawberry plantations with contrasting agronomic characteristics and two strawberry varieties, 102 sampling during flowering, fruiting and the end of culture were performed; three sampling by plantations (Table 1).

Table 1. Variety, agronomic management and location of 34 strawberry plantations distributed in eight locations of the Valley of Zamora, Michoacán, Mexico

Locality / Plot No.	North Latitude	West Longitude	Altitude msnm	Strawberry variety	Management*
La Sauceda /1	20º 04´ 13´´	102º 21´ 23´´	1558	Camarosa	T
La Sauceda /2	20º 00´ 18´´	102º 20´ 57´´	1561	Camarosa	A + G
La Sauceda /3	20º 04´ 56´´	102º 22´ 23´´	1572	Aromas	A + G
La Sauceda /4	20º 04´ 56´´	102º 22´ 24´´	1572	Aromas	T
Atecucario /1	20º 02´ 24´´	102º 16´ 42´´	1573	Aromas	T
Atecucario /2	20º 02´ 42´´	102º 16´ 21´´	1563	Camarosa	T
Atecucario /3	20º 02´ 59´´	102º 16´ 10´´	1565	Aromas	T
Atecucario /4	20º 04´ 13´´	102º 21´ 22´´	1560	Camarosa	T
A. de Rayón /1	19º 59´ 55´´	102º 20´ 48´´	1566	Camarosa	A + G
A. de Rayón /2	19º 59´ 37´´	102º 20´ 33´´	1559	Aromas	T
A. de Rayón /3	20º 02´ 18´´	102º 20´ 25´´	1565	Aromas	T
A. de Rayón /4	20º 00´ 03´´	102º 19´ 20´´	1566	Camarosa	T
Villafuerte /1	19º 58´ 57´´	102º 20´ 02´´	1586	Aromas	A + G
Villafuerte /2	19º 59´ 21´´	102º 20´ 16´´	1567	Camarosa	T
Villafuerte /3	19º 59´ 36´´	102º 43´ 34´´	1583	Camarosa	T
Villafuerte /4	19º 59´ 21´´	102º 20´ 13´´	1575	Aromas	T
Zamora /1	20º 00´ 03´´	102º 19´ 28´´	1572	Camarosa	T
Zamora /2	19º 58´ 23´´	102º 17´ 49´´	1575	Aromas	T
Zamora /3	19º 59´ 26´´	102º 17´ 58´´	1564	Aromas	A + G
Zamora /4	19º 58´ 49´´	102º 17´ 59´´	1564	Camarosa	A + G
Jacona /1	19º 58´ 49´´	102º 18´ 00´´	1568	Camarosa	T
Jacona /2	19º 57´ 48´´	102º 17´ 37´´	1577	Aromas	T
Jacona /3	19º 58´ 00´´	102º 17´ 37´´	1582	Camarosa	A + G
Jacona /4	19º 57´ 48´´	102º 17´ 37´´	1574	Aromas	T
Jacona /5	19º 57´34´´	102º 17´ 05´´	1567	Camarosa	A + G
Jacona /6	19º 57´ 20´´	102º 17´ 09´´	1577	Camarosa	A + G
Ojo de Agua /1	20º 03´ 08´´	102º 15´ 39´´	1575	Camarosa	T
Ojo de Agua /2	20º 00´ 20´´	102º 12´ 03´´	1576	Aromas	T
Ojo de Agua /3	20º 08´ 15´´	102º 12´ 02´´	1584	Camarosa	T
Ojo de Agua /4	19º 59´ 59´´	102º 11´ 49´´	1591	Aromas	T
A. Serdán /1	20º 00´ 41´´	102º 14´ 18´´	1581	Camarosa	T
A. Serdán /2	20º 00´ 20´´	102º 12´ 03´´	1588	Camarosa	T
A. Serdán /3	20º 01´ 06´´	102º 13´ 07´´	1577	Aromas	T
A. Serdán /4	20º 02´ 16´´	102º 12´ 30´´	1575	Aromas	T

*Management: plastic mulching with drip irrigation (A + G), without padding and gravity irrigation (T).

Three samplings were carried out at 8 locations of the Zamora Valley, Michoacán, Mexico, during a crop cycle in the growth stages, flowering and fructification. The number of sampled plantations by locations was obtained by weighting, considering acreage parameters, variety and cropping system (Table 2), using the following equation [11]:

$$n_i = N\,[Sw_i \times Vw_i \times Mw_i] \;/ \sum_{i=1}^{4} [Sw_i \times Vw_i \times Mw_i]$$

Where: n_i = number of units (plots) to sampling by irrigation-i area, i = 1, ..., 4, N = total number of units that can be sampled in the laboratory (34), Sw_i = weighting the surface area-i, w = 2, ..., 3; Vw_i = weighing for the area-i variety, w = 1, ..., 2; Mw_i = weighing by the area-i management w = 1, ..., 2. The weighting higher values, indicates greater epidemic inductivity.

Table 2. Weighting factors and the number of sampled plantations in four irrigation areas of the District No. 088, Zamora, Michoacan, Mexico

Irrigation area	Surface (ha)	Stawberry Variety	Management	Factorial product	Plots number
I	500 (3) *	Camarosa (2)	A+G (1)	3x2x1=6	10
II	305 (2)	Aromas (1)	T (2)	2x1x2=4	8
III	309 (2)	Camarosa (2)	A+G (1)	2x2x1=4	8
IV	300 (2)	Aromas (1)	T (2)	2x1x2=4	8
Total	1414			18	34

*Weighting factors according to surface: 2 = 300-400, 3 > 400 ha; variety, 1 = camarosa, 2 = Aromas; Management, 1 = plastic mulching with drip irrigation (A + G), 2 = gravity irrigation (T).

Epidemiological Component Measurements

In 34 parcels of strawberry commercial production, the following variables were measured. Host: the effect on the strawberry damping off occurrence on the Aromas and Camarosa varieties was compared by measuring incidence. Disease: the disease incidence with a sample size of 128 plants in quadrants of 16 x 8 plants per plot was determined. Pathogen: Fusarium oxysporum and total fungi inoculum density, were quantified in five composite soil samples per plot, collected near the strawberry roots (rhizosphere) at a depth of 15 cm and were processed in a period no longer than a week [12]. Sampling was conducted at the beginning and end of the growing cycle. The colony count was estimated at 300 µL of a soil suspension of $1x10^{-2}$ in culture medium PDA + TS. Management: the damping off incidences in plantations with plastic mulch and drip irrigation, and without plastic mulch with gravity irrigation were contrasted.

Soil analysis

The soil texture was determined by the Bouyoucos hydrometer method; the soil pH in relation 1:2 with H_2O, 0.01M $CaCl_2$ and KCl 1.0N were measured; the soil organic matter was determined by the Walkley and Black method and the field compaction with the use of a cone penetrometer was determined.

Statistical Analysis

Analysis of qualitative variables (management type and variety) and quantitative ones (soil texture, compaction, pH, organic matter, incidence and colony forming units) were performed through of the Poisson function, using the SAS GENMOD statement prior to correlation analysis Proc CORR [13]. Geostatistical analysis of the incidence interpolation with respect to variables previously found significant with GENMOD was performed. The interpolation of the incidence variable was made by the method of inverse distance weighted [14]. The maps with the software ArcMap ® Version 5 were made.

RESULTS AND DISCUSSION

The Soils of the analyzed plots were of clayey texture, with values of average compaction of 12.5 kPa (10.20 - 15.98), and a moderately acidic pH (5.1 to 6.3). The organic matter contents on average were 1.0 to 2.8% (Table 3).

The dry wilt appeared with greater intensity in Atecucario, Aquiles Serdan and Ojo de Agua with average incidences of 15.2, 17.7 and 25.2% respectively. The least affected areas were Zamora (8.2%), Jacona (10.8%), Villafuerte (12.2%), Ario de Rayon (13.8%) and La Sauceda (13.8%) (Table 4).

Most dry wilt intensity observed by geostatistical maps, was recorded in plots located northeast of the strawberry region of Zamora Valley and cultivated under the traditional system (T). In contrast, plantations located in the Centre and southwest of the region, using plastic mulch and drip irrigation (A + G), recorded the lowest incidence ($p < 0.0001$) of the disease (Figure 1 and 2).

Regardless of the agronomic management, the Camarosa variety was more affected by dry wilt that the Aromas variety (p < 0.0001) (Table 4). This result confirms the latter as tolerant to root diseases, as well as the response of both cultivars was consistent with previous reports for the region [5, 15].

Table 3. Edaphic characteristics of 34 strawberry plantations distributed in eight locations in the Valley of Zamora, Michoacán, Mexico

Locality/ Plot No.	Ratio (%)			Texture	Compaction (kPa)*	$\bar{x}$	pH	Organic Matter (%)	$\bar{x}$
	Sand	Silt	Clay						
La Sauceda /1	6.54	20.00	73.46	Arcillosa	12.45		5.7	0.6	
La Sauceda /2	9.48	13.28	77.24	Arcillosa	11.86		5.3	1.9	
La Sauceda /3	4.54	14.00	81.46	Arcillosa	11.47	11.81	5.1	2.7	1.8
La Sauceda /4	4.54	14.00	81.46	Arcillosa	11.47		5.1	1.9	
Atecucario /1	4.54	14.00	81.46	Arcillosa	14.42		5.2	1.3	
Atecucario /2	17.48	13.28	69.24	Arcillosa	14.70		5.2	1.1	
Atecucario /3	17.48	13.28	69.24	Arcillosa	14.02	13.82	5.6	1.6	1.3
Atecucario /4	23.48	15.28	61.24	Arcillosa	12.16		5.4	1.1	
A. de Rayón /1	4.54	18.00	77.46	Arcillosa	12.45		5.9	1.2	
A. de Rayón /2	11.48	11.28	77.24	Arcillosa	14.02		5.7	2.6	
A. de Rayón /3	6.54	6.00	87.46	Arcillosa	13.14	12.94	5.7	3.9	2.3
A. de Rayón /4	11.48	15.28	73.24	Arcillosa	12.16		5.6	1.6	
Villafuerte /1	23.48	19.28	57.24	Arcillosa	12.16		5.1	3.1	
Villafuerte /2	17.48	35.28	47.24	Arcillosa	12.45		5.4	2.8	
Villafuerte /3	31.48	25.28	43.24	Arcillosa	15.98	13.26	5.6	2.9	2.8
Villafuerte /4	13.48	33.28	53.24	Arcillosa	12.45		5.3	2.2	
Zamora /1	13.28	21.48	65.24	Arcillosa	10.20		5.5	2.1	
Zamora /2	7.12	16.00	76.88	Arcillosa	10.20		5.7	2.3	
Zamora /3	15.48	23.28	61.24	Arcillosa	12.45	11.57	5.2	2.9	2.4
Zamora /4	16.54	10.00	73.46	Arcillosa	13.43		5.3	2.3	
Jacona /1	13.48	21.28	65.24	Arcillosa	14.71		5.2	1.2	
Jacona /2	23.28	15.24	61.48	Arcillosa	11.18		5.4	1.4	
Jacona /3	15.48	31.28	53.24	Arcillosa	10.59	11.88	5.3	2.5	1.9
Jacona /4	15.48	23.28	61.24	Arcillosa	12.16		5.3	2.2	
Jacona /5	21.48	11.28	67.24	Arcillosa	11.47		5.2	1.5	
Jacona /6	4.56	9.98	85.46	Arcillosa	11.18		5.4	2.3	
Ojo de Agua /1	11.48	17.28	71.24	Arcillosa	12.85		5.2	1.1	
Ojo de Agua /2	6.54	22.00	71.46	Arcillosa	11.18		5.3	0.9	
Ojo de Agua /3	6.54	20.00	73.46	Arcillosa	12.16	12.33	5.1	1.0	1.0
Ojo de Agua /4	15.48	23.28	61.24	Arcillosa	13.14		5.2	0.9	
A. Serdán /1	9.48	17.28	73.24	Arcillosa	11.18		5.9	1.6	
A. Serdán /2	4.56	15.98	79.46	Arcillosa	12.85		6.3	1.4	
A. Serdán /3	4.56	15.98	79.46	Arcillosa	12.45	12.16	5.0	1.3	1.2
A. Serdán /4	4.56	17.98	77.46	Arcillosa	12.16		5.9	0.7	

*kPa= kilopascal.

Table 4. Inoculum density and dry wilt incidence in 34 strawberry plantations distributed in eight locations in the Valley of Zamora, Michoacán, Mexico

Locality/plot No.	Variety	*Fusarium oxysporum*		Incidence (%)			$\bar{x}$
		Ufci	Ufcf*	Flower	Fruit	Final	
La Sauceda /1	Camarosa	200	475	5.4	17.9	31.2	
La Sauceda /2	Camarosa	25	150	0.8	3.9	7.8	
La Sauceda /3	Aromas	50	150	0.0	0.8	7.0	13.8
La Sauceda /4	Aromas	25	75	2.3	3.9	9.3	
Atecucario /1	Aromas	50	175	0.8	5.4	7.8	
Atecucario /2	Camarosa	150	375	5.4	18.7	28.1	
Atecucario /3	Aromas	100	275	2.3	7.8	10.9	15.2
Atecucario /4	Camarosa	100	350	3.1	7.0	14.0	
A. de Rayón /1	Camarosa	75	200	5.4	9.3	18.7	
A. de Rayón /2	Aromas	50	100	0.8	3.9	5.4	
A. de Rayón /3	Aromas	150	325	2.3	5.4	10.9	13.8
A. de Rayón /4	Camarosa	50	200	0.8	7.0	20.3	
Villafuerte /1	Aromas	50	100	2.3	3.1	9.3	
Villafuerte /2	Camarosa	100	125	3.1	9.3	16.4	
Villafuerte /3	Camarosa	50	325	3.1	10.9	16.4	12.2

Villafuerte /4	Aromas	50	100	0.8	2.3	7.0	
Zamora /1	Camarosa	25	150	2.3	5.4	13.2	
Zamora /2	Aromas	25	300	2.3	6.2	7.8	
Zamora /3	Aromas	25	50	0.8	0.8	6.2	8.2
Zamora /4	Camarosa	25	125	0.8	2.3	5.4	
Jacona /1	Camarosa	50	150	3.1	14.8	21.0	
Jacona /2	Aromas	25	150	0.8	3.1	7.8	
Jacona /3	Camarosa	50	125	2.3	3.1	9.3	
Jacona /4	Aromas	25	150	0.8	2.3	3.9	10.8
Jacona /5	Camarosa	50	350	2.3	3.1	10.1	
Jacona /6	Camarosa	50	175	3.1	7.0	13.2	
Ojo de Agua /1	Camarosa	125	175	3.9	14.8	25.0	
Ojo de Agua /2	Aromas	50	300	2.3	7.8	18.7	
Ojo de Agua /3	Camarosa	50	500	2.3	18.7	38.2	25.2
Ojo de Agua /4	Aromas	50	600	2.3	11.7	18.7	
A. Serdán /1	Camarosa	25	250	0.8	5.4	21.0	
A. Serdán /2	Camarosa	150	300	3.9	16.4	32.0	
A. Serdán /3	Aromas	50	275	2.3	3.9	10.9	17.7
A. Serdán /4	Aromas	50	250	0.8	5.4	7.0	

*Ufci and Ufcf= colony forming units / g of soil.

The organic matter contents ≥ 2% (Table 3) contributed to reduce the disease incidence ($p < 0.0001$) in both agronomic system and varieties (Table 4), this was observed mainly in the West (Ario de Rayon and Villafuerte), South (Jacona) and Center (Zamora) from the studied area. These organic matter levels can be promoted with farmyard manure treatments or vermicompost [16]. In soils with high organic matter content delayed the onset of epidemics (Xo) from the dry wilt, reduces the area under the curve of the disease progress (AUDPC) and significantly increases the strawberry yield obtained [17, 18]. This is because the organic matter induces the development of fungi and bacteria antagonistic to plant pathogens of root [19]. Similarly, it has been observed that organic amendments with Broccoli (Brassica oleraceae l.) plants inactivated propagules of *F. oxysporum*, *R. solani* and *V. dahliae* [20]. Texture, compaction and the soil pH did not influence the dry wilt incidence because they were similar in the study area (Table 3).
The *F. oxysporum* colony forming units estimated at the beginning (ufci) and at the end (ufcf) of the culture, exhibited significant differences in the strawberry dry wilt. A directly proportional correlation was found between ufci and ufcf with relation to the disease incidence (Table 5).

Table 5. Pearson correlation matrix and significance level of agronomic, edaphic and health variables measured at the regional level in eight localities of Zamora Valley, Mich., Mexico.

	MO	pH	UFCi	UFCf	C	I^1	I^2	I^3
MO	1.0000	-0.0407 0.8192	-0.1862. 0.2916	-0.4708 0.0050	-0.0443 0.8035	-0.3151 0.0695	-0.5180 0.0017	-0.5078 0.0022
pH		1.0000	0.3226 0.0628	0.1418 0.4239	-0.0383 0.8296	0.1866 0.2908	0.1938 0.2722	0.2060 0.2426
UFCi			1.0000	0.4152 0.0146	0.3459 0.0451	0.7003 <0.0001	0.6479 <0.0001	0.5743 0.0004
UFCf				1.0000	0.1765 0.3180	0.4037 0.0179	0.6014 0.0002	0.5899 0.0002
C					1.0000	0.2562 0.1437	0.4201 0.0134	0.2165 0.2189
I^1						1.0000	0.7441 <0.0001	0.65194 <0.0001
I^2							1.0000	0.9181 <0.0001
I^3								1.0000

*MO = Organic matter, Ufci and Ufcf = initial and final colony forming units, C = Compaction: resistance to penetration of the soil, I^1 = incidence in bloom, I^2 = incidence in fruiting and I^3 = final incidence.

However, the ufci correlation coefficient was greater in the flowering stage ($r = 0.70$), which is usually when the expression of the disease is initiated, and decreased at later growth stages. This result suggests the relative importance of *F. oxysporum* in the development and progression of the disease, since that behaves, as it would expect in an epidemic of monomolecular type, which depends on the initial inoculum, and its speed is greater in its initial stage. On the other hand, the reduction of the coefficient of correlation in subsequent phenological stages ($r = 0.65$ and $r = 0.57$), and considering that the incidence was used in the cumulative correlations, could indicate the involvement of inoculum of *R. fragariae, P. aphanidermatum* and *Phytophthora sp.* also involved in disease [6] but not quantified in this study. This

inoculum type could be expressing belatedly, which would confer upon these organisms a secondary character from the epidemic viewpoint.
The correlative nature of ufci and ufcf regarding the incidence may have different interpretations. In the first case the *F. oxysporum* inoculum acceptably explained the beginning of the epidemic while has been shown in other pathosystems that the inoculum efficiency is not 100% because, between other reasons, to the presence of non-pathogenic isolates [21]. Thus, it can tell that between 50 and 150 ufci *F. oxysporum* are necessary to induce around 6% of incidence of dry wilt in the phenological flowering stage (Figure 3A).
Opposite to the observed trend with ufci, in the second case the best correlation with ufcf in fruiting phenological stage (r = 0.60), and at the end of the crop (r = 0.59) was found (Table 5). This shows that this inoculum was produced during the epidemic and that the final incidence level estimated most likely the inoculum amount that an epidemic can produce. Although these significant correlations were not high, shows again that *F. oxysporum* is more important in the disease occurrence, but that the other involved organisms also contribute in the final incidence. Under this assumption, the incidence of 20% generated from 150 to 300 ufcf it can be assumed (Figure 4B). Similarly, the cfu of *F. oxysporum* rose throughout the production cycle by 358% relative to initial values (Figure 4A), which gives an idea of the inductive potential in epidemics developed in subsequent growing cycles.
Larger amounts of *F. oxysporum* ufcf generated in unpadded plantation with drip irrigation in the localities of Atecucario, Ojo de Agua and Aquiles Serdan were quantified (Table 4). In accordance with other research, the plastic mulch can improve crop health by protecting the roots of plant pathogens and weed [22, 23]. On the other hand, the mulch and drip irrigation reduces the spread of disease and consequently the aggregates size.

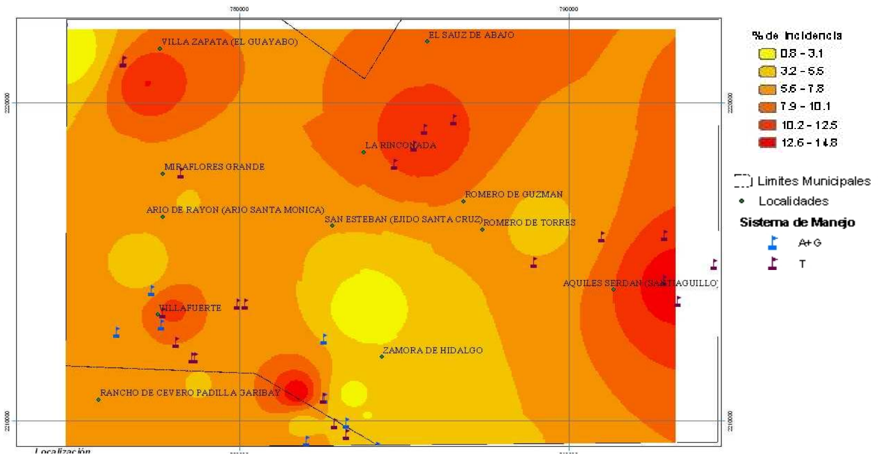


Figure 1. Map of strawberry dry wilt incidence in fruiting stage in plots with mulch and drip irrigation (A + G) and without padding and gravity irrigation (T) (p <0.0001), in the Valley of Zamora, Michoacán, Mexico.

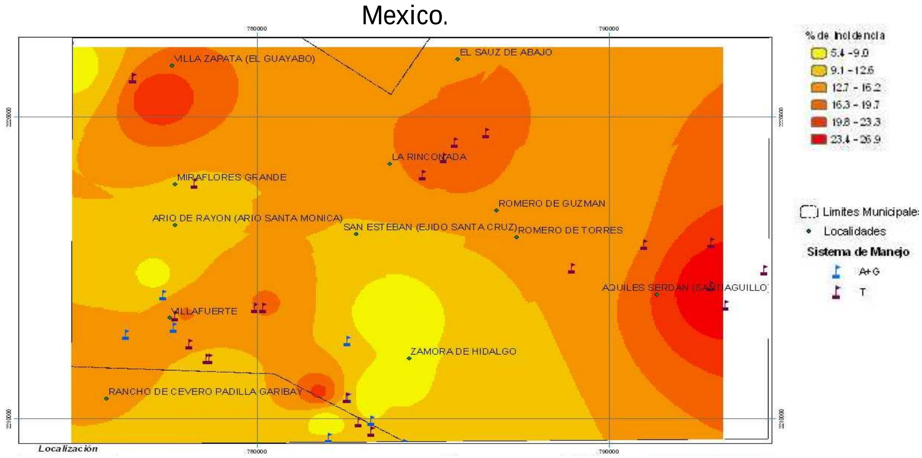


Figure 2. Map of strawberry dry wilt incidence at the end of the growing season in plots with mulch and drip irrigation (A + G) without padding and gravity irrigation (T) (p <0.0001), in the Valley of Zamora, Michoacán, Mexico

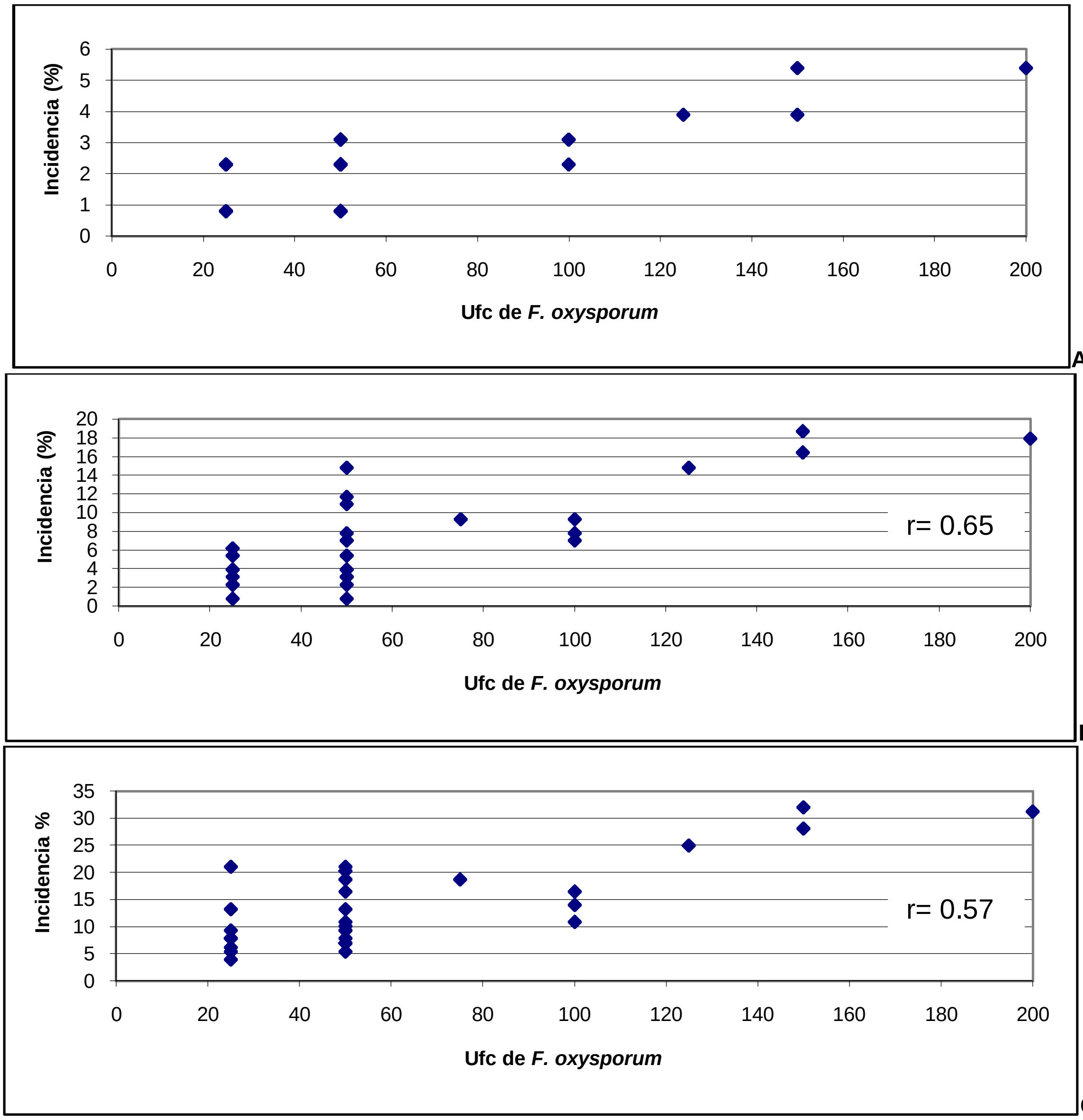
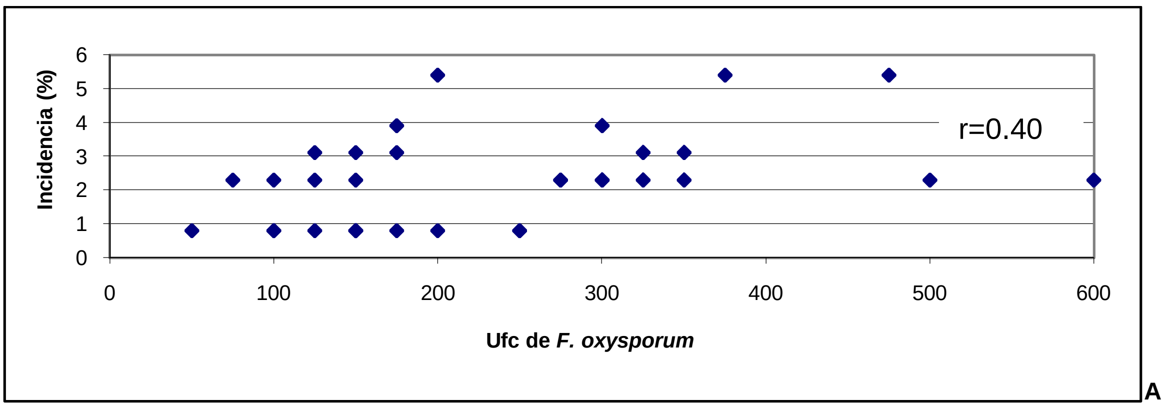


Figure 3. Relationship between colony forming units (ufci) of initial colony of *F. oxysporum* at the time of transplantation and incidence of dry wilt in 34 strawberry plots on the phenological stage of full flowering (A), fruiting (B), and at the end of the crop cycle (C) in the Valley of Zamora, Michoacán, Mexico



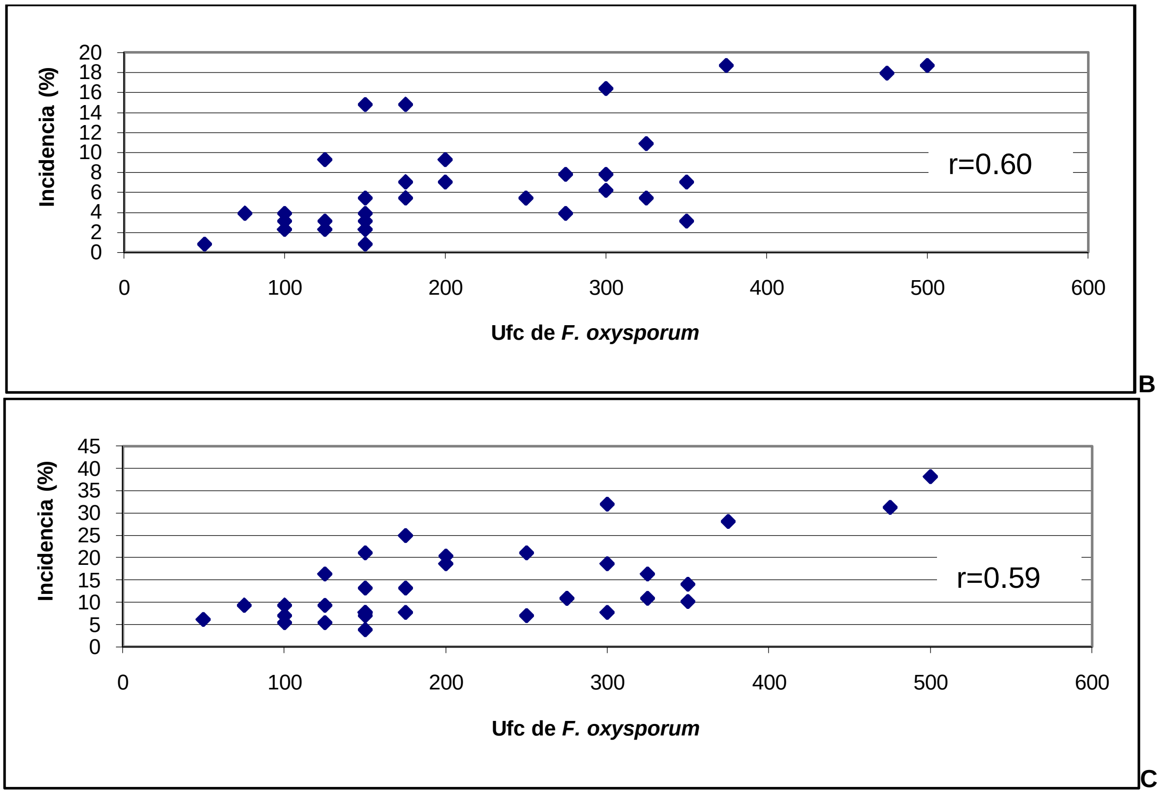


Figure 4. Relationship between final colony forming units (ufcf) of *F. oxysporum* at transplanting and incidence of dry wilt in 34 strawberry plots on the phenological stage of full flowering (A), fruiting (B) and at the end of the crop cycle (C) in the Valley of Zamora, Michoacan, Mexico

CONCLUSIONS

The strawberry crop areas with higher incidence of dry wilt were located in Atecucario (15.2%), Aquiles Serdan (17.7%) and Ojo de Agua (25.2%), northeast of the Valley of Zamora, Michoacán, Mexico. An intermediate incidence was registered in Villafuerte (12.2%), Ario de Rayon (13.8%) and Jacona (10.8%) in the southwest. Lower frequency of disease was observed in the area of Zamora (8.2%) in the central part of the Valley. The plastic mulch and the drip irrigation promoted lower incidence of the disease than plantations without padding and with irrigation by gravity ($p < 0.0001$). The strawberry crop with the Aromas variety was more tolerant to the dry wilt, than the crop with Camarosa variety ($p < 0.0001$), regardless of agronomic management and studied locality. Plantations with organic matter content (≥2%) were associated with lower dry wilt incidence ($p < 0.0001$). The initial amount of cfu (50-150) of *F. osyxporum* was related to the disease incidence in flowering ($r = 0.70$) and fruiting ($r = 0.65$). The initial inoculum of this species generated up to 6% incidence in the flowering phenological stage. 20% of incidence represented a value accumulated between 150 and 300 cfu of this pathogen and constituted potential inoculum for new production cycle.

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