REVISTA de la FACULTAD de AGRONOMIA

Interaction between the incidence of *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) and management practices in tomato crops in Manabí, Ecuador

Interacción entre la incidencia de *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) y prácticas de manejo en cultivos de tomate en Manabí, Ecuador

Interacção entre a incidência de *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) e as práticas de gestão nas culturas de tomate em Manabí, Equador

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Rev. Fac. Agron. (LUZ). 2022, 39(4): e223950
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v39.n4.05

Received: 02-05-2022
Accepted: 08-10-2022
Published: 02-11-2022

Crop Production

Associate editor: Dra. Lilia Urdaneta
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Keywords:
Insect pest
Solanaceae
Infestation
Severity
Cultural practices

Abstract

The insect pest *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae), causes severe losses to the tomato crop in Ecuador, in the provinces of Manabí, Pichincha, Carchi, Cotopaxi, Azuay, and Chimborazo, where the main producing areas of this solanaceous crop in the country are located. The objective of this research was to study the interaction of the incidence of this pest with tomato crop management practices. The evaluations were carried out in twenty-five production units in different cantons of Manabí: in Bolívar (two), Portoviejo (eight), Rocafuerte (five), Santa Ana (one), Sucre (three) and Tosagua (six). Each unit had an area of 2500 m^2, where 25 plants were randomly marked and the number of healthy, infested and damaged shoots was recorded, as well as the number of healthy and damaged fruits. In addition, a survey was applied to growers to determine the management practices carried out during the crop cycle. Descriptive analysis, significance tests, hierarchical clustering and chi-square tests were carried out. It was determined that in the cantons of Portoviejo, Tosagua and Rocafuerte, infestations did not exceed 13 % and a severity of up to 15 %, reaching 25 % of damaged fruit in Tosagua. The agronomic practices applied were trellising, drip and gravity irrigation, collection of infested fruit and chemical insecticides. There was an interaction with *P. longifila* between infested fruit collection and trellising, which influenced its infestation and severity, respectively. These incidences were significantly high at harvest, where highly toxic insecticide applications were substantially increased indiscriminately.

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Resumen

La plaga insectil *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae), provoca severas pérdidas al cultivo de tomate en Ecuador, en las provincias de Manabí, Pichincha, Carchi, Cotopaxi, Azuay y Chimborazo, donde están las principales áreas productoras de esta solanácea en el país. El objetivo de esta investigación fue estudiar la interacción de la incidencia de esta plaga con las prácticas de manejo del cultivo de tomate. Las evaluaciones se efectuaron en veinticinco unidades productivas, en diferentes cantones de Manabí: en Bolívar (dos), Portoviejo (ocho), Rocafuerte (cinco), Santa Ana (uno), Sucre (tres) y Tosagua (seis). Cada unidad tuvo un área de 2500 m^2, en donde se marcaron aleatoriamente 25 plantas, y se registró número de brotes sanos, infestados y con daño; así como, números de frutos sanos y dañados. Además, se aplicó una encuesta a los productores para determinar las prácticas de manejo realizadas durante el ciclo del cultivo. Se efectuaron análisis descriptivos, pruebas de significación, conglomerados jerárquicos y chi cuadrado. Se determinó que en los cantones Portoviejo, Tosagua y Rocafuerte, presentaron infestaciones no superiores al 13 % y una severidad hasta el 15 %, alcanzando Tosagua el 25 % de frutos dañados. Las prácticas agronómicas aplicadas fueron, tutoreo-amarre, riego por goteo y gravedad, recolección de frutos infestados e insecticidas químicos. Entre la recolección de frutos infestados y tutoreo-amarre existió una interacción con *P. longifila,* que influyó en su infestación y severidad, respectivamente. Estas incidencias fueron significativamente altas en la cosecha, donde se incrementaron sustancialmente las aplicaciones de insecticidas altamente tóxicos en forma indiscriminada.

Palabras clave: Plaga insectil, solanácea, infestación, severidad, prácticas culturales.

Resumo

A praga *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae), causa graves perdas à cultura do tomate no Equador, nas províncias de Manabí, Pichincha, Carchi, Cotopaxi, Azuay e Chimborazo, onde se localizam as principais zonas produtoras desta cultura de solanáceas no país. O objectivo desta investigação foi o de estudar a interacção da incidência desta praga com as práticas de gestão das culturas de tomate. As avaliações foram realizadas em vinte e cinco unidades de produção em diferentes cantões de Manabí: em Bolívar (dois), Portoviejo (oito), Rocafuerte (cinco), Santa Ana (uma), Sucre (três) e Tosagua (seis). Cada unidade tinha uma área de 2500 m^2, onde 25 plantas foram marcadas aleatoriamente, e o número de rebentos saudáveis, infestados e danificados foi registado, bem como o número de frutos saudáveis e danificados. Além disso, foi aplicado um inquérito aos cultivadores para determinar as práticas de gestão levadas a cabo durante o ciclo de cultivo. Foram realizadas análises descritivas, testes de significância, agrupamento hierárquico e testes de qui-quadrado. Foi determinado que nos cantões de Portoviejo, Tosagua e Rocafuerte, as infestações não excederam 13 % e uma severidade até 15 %, chegando a Tosagua a 25 % dos frutos danificados. As práticas agronómicas aplicadas foram: aramação, irrigação por gotejamento e gravidade, colheita de frutos infestados e insecticidas químicos. Houve uma interacção entre a recolha de fruta infestada e a lavoura com *P. longifila,* o que influenciou a sua infestação e severidade, respectivamente. Estas incidências foram significativamente elevadas na colheita, onde as aplicações de insecticidas altamente tóxicos foram substancialmente aumentadas indiscriminadamente.

Palavras-chave: Praga de insectos, solanáceas, infestação, severidade, práticas culturais.

Introduction

Tomato (*Solanum lycopersicum* L.) is a vegetable in high demand, since its consumption is associated with its important nutritional properties (Arroyo *et al*., 2018), therefore its cultivation has increased worldwide (Trust Funds for Agricultural Development [FIRA], 2017). In Ecuador, 91 % of the production areas are located in the provinces of Imbabura, Manabí, Pichincha, Carchi, Cotopaxi, Azuay, and Chimborazo. In Manabí, in 2021, 35 ha were established with a production of 319 t and an average yield of 9.02 $t.ha^{-1}$ (Agricultural Public Information System [SIPA], 2021).

In Ecuador, *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) constitutes the main pest of economic importance of the tomato crops, limiting production and profitability of the crop, since the costs for its control represent up to 50 % of the total production cost (Cañarte *et al*., 2015; Polo, 2017).

The damage of *P. longifila* is caused by its larva in the first instars (Cardona *et al.,* 2010), with losses of up to 100 % of production (Cañarte *et al*., 2015). In the flower, it affects the epidermal cells of the ovary, pistils, and stamens (Peña and Mead, 2016). The female oviposits on the plant epidermis, without perforating the tissues, in protected areas such as closed buds, flower buds, and at the base of the fruits (Díaz, 2011), where upon hatching, the newly emerged larvae feed on these tender tissues, scraping the surface of the bundle, whose damage turns it blackish and in young fruits causes necrotic scars that deform the base, taking away its commercial value (Geraud *et al*., 2022).

The biological cycle of *P. longifila* is 11 to 24 days, distributed in three larval instars (2-3 days), pre-pupa (2-3 days), pupa (6-7 days) and adult (1-2 days), except for certain field or laboratory variations (Valarezo *et al*., 2003; Díaz, 2011; Geraud *et al*., 2022). It is a multivoltine species, which develops 18 to 22 generations per year, depending on environmental conditions of temperature, relative humidity and precipitation (Díaz, 2011).

The control of *P. longifila* is almost exclusively chemical, with extremely toxic insecticides, such as metamidophos (Valarezo *et al*., 2003; Polo, 2017; Chirinos *et al.,* 2020), triazophos (Fernández, 2016), benfucarb (Polo, 2017), methomyl (Polo, 2017; Chirinos *et al*., 2020) applied during the crop cycle, including the harvest stage. The use of this type of insecticides generates environmental pollution and ecological imbalance (Hernández *et al*., 2015), affecting human health (Lindao *et al.,* 2017), which affects the quality of life of the producer (Bravo *et al*., 2020).

In view of this situation, the implementation of sustainable integrated management programs should be considered, which include: 1) biological control through the action of predators, parasitoids and pathogens (Díaz, 2011; Cedano and Cubas, 2012), 2) genetic control with the use of cultivars that are harmless to the attack of *P. longifila* (Mena *et al*., 2014), 3) cultural control (Cañarte *et al*., 2015), 4) ethological (Camborda *et al*., 2015), in order to reduce or eliminate insecticide applications, which are responsible for the increased incidence of this species as a tomato pest, due to the elimination in the field of one of its natural biological controllers

(*Synopeas* sp.), which was reported by Geraud *et al*. (2022) parasitizing the larvae of *P. longifila* in the tomato crop in Ecuador.

Consequently, the objective of this research was to determine the interaction between the incidence of the pest and the agronomic and phytosanitary practices applied by producers in tomato crops in six cantons of the province of Manabí, Ecuador.

Materials and methods

This research was developed in crops established by tomato growers in open fields, where a single production cycle was evaluated between March 2019 and January 2020, in the cantons of Bolívar, Portoviejo, Rocafuerte, Santa Ana, Sucre, and Tosagua (figure 1). The province of Manabí is at coordinates 40°40’00 “S and 80°05’00 “W (National Geospatial-Intelligence Agency [NGA], 2022).

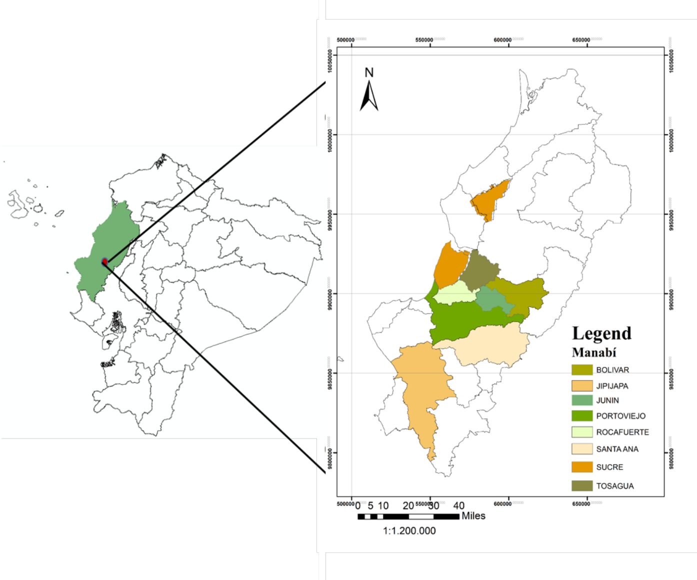

Figure 1. Location of the study area in cantons of the province of Manabí, Ecuador.

Implementation of the study

It was framed in two areas: an analysis of the infestation and severity of damage of *P. longifila*, for which 25 tomato production units were identified in the province of Manabí, considering the cantons: Bolívar (2), Portoviejo (8), Rocafuerte (5), Santa Ana (1), Sucre (3), and Tosagua (6). In each one, an observation area of 2500 m^2 was delimited, within which, a minimum of 25 tomato plants were randomly marked 10 days after being established in the field for statistical support (Badii *et al*., 2008). The varieties established in the province were Margot and Acerado, as well as the Zodiac, Prieto, and Revolución hybrids, all of which are cultivars genetically susceptible to *P. longifila.* The information required during the development of the crop (ni = 25) was evaluated in these materials. For this purpose, analysis of optimal sample size was not applied, since it is a finite population, where the variance of the qualitative characteristics is unknown (Bernal, 2006).

Additionally, the phytosanitary management program used by the producer to control the pest was considered. For this, the estimated universe of tomato producers in Manabí was assessed through an analysis of the planting area in the 24 cantons of the province of Manabí, which is 139 ha (SIPA, 2021). For the present study, six cantons with the highest production of this vegetable were delimited, with an approximate planting area of 60 ha, and the average size of the production units was 2 ha. These data allowed to estimate the population of growers (30). Badii *et al*. (2008), mentioned that for the statistical support of the survey data, the calculation of the optimal sample size [Formula 1], which estimated a total number of 25 growers to be surveyed, with a 95 % probability of success and a margin of error of 10 %, should be carried out.

Formula: [1]

$$n_{optimal} = \frac{N.Z^2_{\alpha/2}.p.q}{d^2(N-1)+Z^2_{\alpha/2}.p.q}$$

Where:
N= tomato producers (30)
Z = probability of making a mistake in the decision Z=1.96 for α=0.05)
p = hit = 0.05
q = not right = 0.95
d = maximum error accepted by the researcher (0.1)

Data recording

The incidence data of *P. longifila* and severity of damage caused by this pest on apical shoots, and fruits were taken from 25 tomato plants, in addition, cultural practices carried out on each crop were recorded. Field evaluations were performed every 15 days during the crop cycle. The variables evaluated were: the number of shoots (healthy, infested, and damaged) and the total number of healthy and damaged fruits by *P. longifila.*

With this information, the percentages of infestation and severity (shoot and fruit damage) were calculated by applying the formulas described by González *et al.* (1995):

Infestation (I%)

$$I\% = \frac{\text{N° of shoots with presence of } P.\ longifila \text{ larvae/plant}}{\text{N° total of shoots/plant}} (100)$$

Severity-damage (S%)

$$S\% = \frac{\text{N° of shoots with damage,with and sithout the present of } P.\ longifila \text{ larvae/plant}}{\text{N° total of shoots/plant}} (100)$$

Through a survey applied to the producers, the cultural practices carried out during the crop cycle (pruning, trellising, irrigation, and collection of infested fruits) and phytosanitary practices (applications of insecticide) were established.

Statistical analysis

The descriptive analysis was performed, and to establish significant differences in infestation and severity, the non-parametric Friedman test was used (Amat, 2018). To determine the similarities and differences between the agronomic practices applied in tomato crops in the six cantons, cluster analysis was performed. This is a multivariate statistical technique that seeks to group elements (or variables) trying to achieve maximum homogeneity in each group, and the greatest difference between groups (De la Fuente, 2011). The Euclidean distance was used to define similarity. Ward’s method was used for clustering and cophenetic correlation to determine the validity of the test. To demonstrate the level of relationship between agronomic practices, infestation, and severity, a contingency table was made, relying on the Chi-square statistic at 95 % confidence to know the significance level at 95 % (De la Fuente, 2016).

Results and discussion

Infestation (I%) of *Prodiplosis longifila*

The non-parametric Friedman test at 95 %, determined significance in the levels of infestation of *P. longifila* in the tomato crops of the six cantons. Rocafuerte, Tosagua, and Portoviejo showed similar significance, reaching up to 4 % infestation, differing from the other cantons which did not exceed 2 % (table 1). These percentages contrast with those reported in Portoviejo, and Santa Ana by Valarezo *et al.* (2003), whose infestation values ranged from 50.5 % and 45.6 % respectively, with an intensive insecticide application regime, highlighting that, in Santa Ana, without insecticide application, infestation reached 70.5 %.

In relation to the population dynamics of *P. longifila* according to the phenological stages of the crop, during the vegetative and flowering stages, no larvae were observed in the production units sampled, and the attack began during fruiting (0.8 %), which increased at harvest stage (7.78 %) (table 1). However, it is known that tomato emits abundant sprouting during its production cycle, which makes it vulnerable to attack by *P. longifila* (Díaz, 2011; Cañarte *et al*., 2015; Geraud *et al.,* 2022). During this research, low average infestations were recorded, which are possibly related to the high frequency of pesticide application (31 applications/average cycle), results that coincide with those of Valarezo *et al*. (2003) and Cardona *et al*. (2010), who recorded very similar infestations under very similar conditions.

Damage severity (%) of *Prodiplosis longifila*

Regarding the behavior of *P. longifila* by canton, the Friedman test at 95 %, determined significance in the severity levels of *P. longifila* in tomato crops in the six cantons. Portoviejo, Tosagua, and Rocafuerte showed similar damage to apical shoots up to 15 % (table 2). This percentage is lower than those reported by Valarezo *et al.* (2003), who indicated damage to apical shoots greater than 70 and 80 % in Portoviejo and Santa Ana, respectively, during the dry season in the flowering and fruiting stages. Regarding the severity of *P. longifila* in fruits per plant, Portoviejo, Tosagua, and Bolívar showed up to 25 % damage, in contrast to the other cantons that did not exceed 9 % in both variables.

Similarly, significant differences were established at 95 %, in the phenological stages, where the harvest reached an average damage of 31 %, and in the vegetative, flowering, and fruiting stages, affectation was recorded at 5 %. The average number of fruits damaged by *P. longifila* per plant was 14 % (table 2). These percentages are greater than those reported by Valarezo *et al*. (2003), who reported values of 11 % in fruits of tomato cultivars for industrial use, and those reported by Cardona *et al.* (2010), who established that 2.3 % of the total production was damaged by this insect. These results could be associated with the chemical management of the pest by growers, which is similar to the 30 applications reported by Cañarte *et al.* (2015), and which also contrasts with the 45 sprays recorded by Chirinos *et al*. (2020) during the crop cycle.

Through the survey carried out, it was possible to identify the agronomic practices applied in each of the tomato plantations evaluated. With the information recorded, a hierarchical cluster analysis (ACJ) was performed, which indicated that these practices were similar in the cantons of Tosagua, and Rocafuerte, approaching this group Portoviejo (figure 1).

Table 1. Infestation of *Prodiplosis longifila* in apical shoots by phenological stage and cantons, depending on insecticide applications, in Manabí, Ecuador.

Cantons	Infestation(%) / phenological stage					Application of insecticides
	Vegetative	Flowering	Fruiting	Harvest	x̄	x̄
Rocafuerte (n= 5)	0	0	1.6	11.4	4 **a**	**29**
Tosagua (n= 6)	0	0	0.33	12.17	3 **a**	**32**
Portoviejo (n= 8)	0	0	1.25	11.13	3 **a**	**29**
Sucre (n= 3)	0	0	0	7	2 **b**	**38**
Santa Ana (n= 1)	0	0	0	4	1 **b**	**24**
Bolívar (n= 2)	0	0	1.5	1	0.6**b**	**32**
Means x̄	0 **b**	0 **b**	0.8 **b**	7.78 **a**	2.23	31

P> 0.05 probability of 95 %.

Table 2. Severity of *Prodiplosis longifila* in apical shoots by phenological stages and in fruits, depending on insecticide applications in cantons of Manabí, Ecuador.

Cantons	Severity (%) / phenological stages					Damaged fruits/ plants(%)	Application of insecticides
	Vegetative	Flowering	Fruiting	Harvest	x̄	x̄	x̄
Portoviejo (n= 8)	1.1	2	11	44	15**a**	19 **a**	29
Tosagua (n= 6)	0.3	3	8	46	14**a**	25 a	32
Rocafuerte (n= 5)	0.2	3	9	39	13**a**	7,8 **b**	29
Sucre (n= 3)	0	0	1	34	9 **b**	8 **b**	38
Santa Ana(n= 1)	0	0	0	21	5 **b**	7 **b**	24
Bolívar (n= 2)	0	0	2	4	1 **b**	12 **a**	32
Means x̄	0.3 **b**	1 **b**	5 **b**	31 **a**	10	14	31

P> 0.05 probability of 95 %.

The similarity of the cultural activities carried out in Santa Ana and Sucre, places them in the same group, bringing Bolívar closer to this cluster (figure 1).

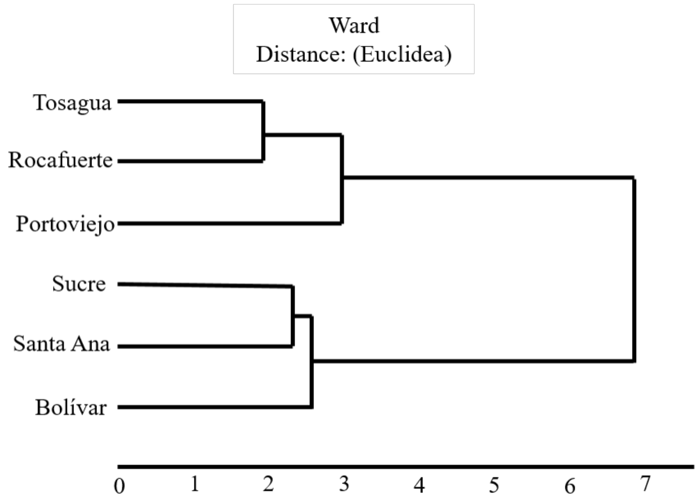

Figure 1. Similarity in the application of practices of pruning, trellising, drip irrigation, and collection of fruits infested by *Prodiplosis longifila* in tomato crop management in cantons of Manabí, Ecuador.

Diagnosis

According to the contingency matrix of categorical data and Pearson's Chi-squared statistic at 95 % probability, a relationship was established between the agronomic practices of collection of infested fruits, and trellising with the level of infestation and severity (high, medium, low) of *P. longifila*, respectively (table 3).

The practice of collecting infested fruits resulted in a low infestation of *P. longifila* in 36 % of the producers. This cultural practice contemplated within the MIP allows interrupting the biological cycle of the pest (Martínez, 2010), since, when collecting tomato fruits with fresh lesions and larvae, it reduces the population of *P. longifila* and minimizes its pupe stage (Díaz, 2011). Regarding trellising, 44 % of growers recorded low infestation, 28 % had a medium infestation and 8 % had a high infestation. This practice associated with pruning, allows the tomato crop to have greater light penetration and aeration, unfavorable conditions for the establishment of *P. longifila,* which needs a dark environment with little ventilation (Valarezo *et al*., 2003). This cultural practice, which is based on preventing pest attack, and reducing damage (Díaz, 2011), could have influenced the level of severity of *P. longifila.*

Table 4 shows the insecticides applied on the tomato crop. A total of 21 chemical groups and 37 active ingredients were used, predominantly phosphorous, neonicotinoids, and tetramic acids. Triazofos, pirimiphos-methyl, and spirotetramat were the most commonly applied in the phenological stages, particularly at harvest. There is the application of insecticides banned in Ecuador, such as methamidophos (Agrocalidad, 2020). Some of these insecticides are of extremely and highly toxic categories, being applied after transplanting, with a maximum of three controls/week in the vegetative stage and four sprays/week from flowering to harvest, without observing the toxicological deficiency of the products, which fluctuate in 8 to 21 days between the last application and harvest, as noted by Reinoso (2015).

These results indicate that tomato agroecosystems in Manabí are seriously disturbed, since the appearance of *P. longifila* in Manabí in 1988 (Valarezo *et al*., 2003), many producers indiscriminately use extremely toxic insecticides to combat it (Cañarte *et al*., 2015). According to Chirinos *et al*. (2020), this dependence on chemical

Table 3. Relationship between agronomic practices and the infestation and severity of *Prodiplosis longifila* in six cantons of Manabí, Ecuador.

Variables	Categories	Infestation			Total	Pearson's chi-squared test	Severity			Total	Pearson's chi-squared test
		Low	Medium	High			Low	Medium	High		
Collection of infested fruits	Yes	9	1	0	10		6	3	1	10	
	No	4	9	2	15	0.008*	6	5	4	15	0,508
Total		13	10	2	25		12	8	5	25	
Drip irragation	Yes	8	6	2	16		6	6	4	16	
	No	5	4	0	9	0.541	6	2	1	9	0,369
Total		13	10	2	25		12	8	5	25	
Gravity irrigation	Yes	6	4	0	10		7	2	1	10	
	No	7	6	2	15	0.463	5	6	4	15	0,196
Total		13	10	2	25		12	8	5	25	
Tresilling	Yes	11	7	2	20		11	7	2	20	
	No	2	3	0	5	0.523	1	1	3	5	0,043*
Total		13	10	2	25		12	8	5	25	
Pruning practices	Yes	10	7	2	19		10	7	2	19	
	No	3	3	0	6	0.659	2	1	3	6	0,106
Total		13	10	2	25		12	8	5	25	

P> 0.05 probability of 50 %.

Table 4. Insecticides applied to combat *Prodiplosis longifila* in tomato crop by phenological stages in six cantons of Manabí, Ecuador.

Chemical groups	i. a.	*Toxic level	Application of insecticides			
			Vegetative	Flowering	Fruiting	Harvest
Phosphorates	Triazofos	Ib	11	16	15	18
	Pirimiphos-methyl	III	12	11	12	15
	Methamidophos	Ib	6	7	6	6
	Malathion	III	2	5	6	5
	Profenofos	II	6	5	3	3
	Dimethoate	II	2	3	3	3
	Chlorpyrifos	II	1	2	1	
	Acephate	III				1
Neonicotinoids	Imidacloprid	III	7	4	8	8
	Acetamiprid	III	8	8	8	13
	Clothianidin	III		1	1	2
Tetramic Acids	Spirotetramat	III	11	14	12	13
Avermectin	Abamectin	II	6	3	10	9
	Emamectin + benzoate	III	1	2	4	4
Pyrethroid + Nitroguanidines	Lambdacyhalotrin+ Thiamethoxam	II	8	7	8	8
Naturalyte	Spinetoram-J-L	IV	5	7	4	8
	Spinosad A and D	IV			1	
Carbamates	Benfuracarb	II	2	5	4	5
	Methomyl	Ib	3	5	1	4
	Thiodicarb	II		1	2	4
	Carbosulfan	II		2	2	1

*Toxic level: Ib Extremely; II Highly; III Moderately; IV Slightly.

control in monoculture planting systems leads to a selection pressure of resistant insect populations, which causes an ecological imbalance between phytophagous and beneficial insects (Ortega *et al*., 2014). This situation, according to Geraud *et al*. (2022), is caused by the lack of knowledge that producers have about the bioecology of *P. longifila*, which makes its rational management impossible because the insecticides applied are also eliminating the populations of *Synopeas* sp. (Hymenoptera: Platygastridae) that are parasitoids of the larvae of *P. longifila* in the tomato crops evaluated. Hence, the importance of the integration of combat methods such as biological (Cedano and Cubas, 2012), genetic (Mena *et al*., 2014); and ethological, Camborda *et al*. (2015), which are environmentally friendly methods.

Conclusions

The levels of infestation and severity of *P. longifila* in the evaluated areas were significantly high only during harvest, where growers substantially increased the application of highly toxic insecticides indiscriminately.

The practices widely used by tomato growers in the study area are pruning, trellising, drip and gravity irrigation, collection of infested fruits, and the use of insecticides of various chemical groups.

There was a relationship between the agronomic practices of collecting infested fruits and trellising implemented by the growers with the infestation and severity of *P. longifila.*

Literature cited

Agrocalidad (2020). Plaguicidas prohibidos en el Ecuador. Coordinación General de Registro de Insumos Agropecuarios Dirección de Registro de Insumos Agrícolas. Agencia de Regulación y Control Fito y Zoosanitario. https://www.agrocalidad.gob.ec/wp-content/uploads/2020/05/Plaguicidas-prohibidos-en-Ecuador-1.pdf

Amat, J. (2018). Test de Friedman. h ttps://www.cienciadedatos.net/documentos/21_friedman_test

Arroyo, P., Mazquiaran, L., Rodríguez, P., Valero, T., Ruiz, E., Ávila, J. & Varela, G. (2018). Informe de estado situación sobre "frutas y hortalizas: nutrición y salud en la España del S. XXI". https://www.fen.org.es/storage/app/media/imgPublicaciones/informe_frutas_y_hortalizas_fen_2018-v1.pdf

Badii, M., Castillo J. & Guillen, A. (2008). Tamaño óptimo de la muestra (Optimum sample size). *InnOvaciOnes de NegOciOs, 5*(1): 53 - 65. https://www.researchgate.net/publication/315814025_Tamano_optimo_de_la_muestra_Tamano_optimo_de_la_muestra_Optimum_sample_size

Bernal, C. (2006). Metodología de la investigación. Para administración, economía, humanidades y ciencias sociales. Pearson Educación. México. p. 304.

Bravo, R., Villafuerte, A., Peñarrieta, S., Santana, F., Zambrano, F. & Fimia, R. (2020). Diagnóstico de uso e impactos de plaguicidas en el cultivo de tomate (*Solanum lycopersicum* L.) en la parroquia Rio Chico, cantón Portoviejo, provincia de Manabí, Ecuador. *El Biólogo, 18*(1),105-118. DOI: 10.24039/rtb2020181476

Camborda, F., Castillo, J. & Rodríguez, S. (2015). Trampas de luz con panel pegante para la captura de adultos de *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) en el cultivo de espárrago. https://revistas.lamolina.edu.pe/index.php/eau/article/view/90/89

Cañarte, E., Valarezo, O. & Navarrete, J. (2015). Manejo integrado de *Prodiplosis longifila* (Diptera: Cecidomyiidae) principal plaga de tomate en Ecuador. https://www.researchgate.net/publication/304346513_Manejo_integrado_de_Prodiplosis_longifila_Diptera_Cecidomyiidae_principal_plaga_del_tomate_en_Ecuador

Cardona, C., Yepes, F. & Cotes, J. (2010). *Evaluación de la rotación de plaguicidas químicos y biológicos sobre Prodiplosis longifila Gagné (Diptera: Cecidomyiidae) en tomate (Solanum lycopersicum L.). Revista Facultad De Ciencias Básicas, 6*(1):66-81. https://revistas.unimilitar.edu.co/index.php/rfcb/article/view/2116

Cedano, C. and Cubas, P. (2012). *Baeuveria bassiana (Bals)* Vuill y *Metarhizium anisioplae* (Metsch.) Sorokin para el control de pupas de *Prodiplosis longifila* Gagné en el cultivo de espárrago. *Scientia Agropecuaria, 3*(1), 29-34. https://www.redalyc.org/articulo.oa?id=357633701004

Chirinos, D., Castro, R., Cun, J., Castro, J., Peñarrieta, S., Solís, L. & Geraud, F. (2020). Los insecticidas y el control de plagas agrícolas: la magnitud de su uso en cultivos de algunas provincias de Manabí. *Ciencia y Tecnologías Agropecuarias, 21*(1): e1276. https://doi.org/10.21930/rcta.vol21_num1_art:1276

De la Fuente, S. (2011). Análisis de Conglomerados. Facultad de Ciencias Económicas y Empresariales. Universidad Autónoma de Madrid. https://www.fuenterrebollo.com/Economicas/ECONOMETRIA/SEGMENTACION/CONGLOMERADOS/conglomerados.pdf

De la Fuente, S. (2016). Aplicaciones de la Chi-cuadrado: Tabla de contingencia. Homogenidad. Dependencia e independencia. Gestión Aeronáutica: Estadística Teórica. Facultad de Ciencias Económicas y Empresariales. Departamento de Economía Aplicada. Universidad Autónoma de Madrid. https://www.fuenterrebollo.com/Aeronautica2016/contingencia.pdf

Díaz, F. (2011). Aspectos agroecológicos para el manejo integrado de *Prodiplosis longifila* Gagné en la irrigación de Chavimochic. https://www.academia.edu/15424714/Aspectos_Agroecol%C3%B3gicos_para_el_Manejo_Integrado_de_Prodiplosis_longifila_Gagn%C3%A9_en_la_Irrigaci%C3%B3n_Chavimochic

Fernández, E. (2016). Comparativo de insecticidas para el control de *Prodiplosis longifila* Gagné (Diptera: Cecidomyiidae) en el cultivo de papa (*Solanum tuberosum*) var. Canchán. https://repositorio.lamolina.edu.pe/handle/20.500.12996/2632

FIRA (Fideicomiso Instituido En Relación Con La Agricultura). (2017). Tomate rojo 2017. Panorama Agroalimentario. Dirección de Investigación y Evaluación Económica y Sectorial. https://www.fira.gob.mx/InfEspDtoXML/abrirArchivo.jsp?abreArc=65310

Geraud, F., Garces, A., Contreras, N. & Geraud, J. (2022). *Prodiplosis longifila* (Diptera: Cecidomyiidae), evolución como plaga y un método para evaluar sus poblaciones en tomate. *Revista Colombiana de Entomología*, *48* (1): e7807. https://doi.org/10.25100/socolen.v48i1.7807

González, C., Borges, M., Castellanos, A., González, N., Vázquez, L. & García, M. (1995). *Phyllocnistis citrella* Stainton. Minador de la hoja de los cítricos. In II taller nacional sobre el minador de la hoja de los cítricos *Phyllocnistis citrella* Stainton. *Phyllocnistis citrella* Stainton. (La Habana, CU). 35 p.

Hernández, L., Guzmán, C., Martínez, A., Manzano, M. & Sejvarj, J. (2015). The bud midge *Prodiplosis longifila*: Damage characteristics, potential distribution and presence on a new crop host in Colombia. *SpringerPlus 4*, 205. https://doi.org/10.1186/s40064-015-0987-6

Lindao, V., Jave J., Retuerto, M., Erazo, N. & Echeverría, M. (2017). Impacto en los niveles de colinesterasa en agricultores de tomate (*Solanum lycopersicum* L.) en la localidad de San Luis, Chimborazo por efecto del uso de insecticidas organofosforados y carbamatos. *Revista del Instituto de Investigación FIGMMG-UNMSM, 20*(40), 114-119. https://revistasinvestigacion.unmsm.edu.pe/index.php/iigeo/article/view/14400

Martínez, N. (2010). Manejo Integrado de Plagas: Una solución a la contaminación ambiental. *Comunidad y salud, 8*(1), 73-82. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1690-32932010000100010

Mena, Y., Mesa, N., Estrada, E. & García, Y. (2014). Evaluación de la resistencia a *Prodiplosis longifila* Gagné *(*Diptera: Cecidomyiidae) en genotipos de tomate cultivados y silvestres*. Acta Agronómica, 63*(2)*,*181-190*.* doi:DOI:10.15446/acag.v63n2.30210

NGA (National Geospatial-Intelligence Agency). (2022). Provincia de Manabí, Ecuador - Nombres Geográficos, mapa. Bethesda, MD, USA. https://geografiainfo.es/nombres_geograficos/name.php?uni=1376520&fid=1580&c=ecuador

Ortega, E., Sierra, C., Mayanga, A., Morey, G., Graterol, L., Dyer, P. & Mialhe, E. (2014). Identificación molecular de la mosquilla del brote *Prodiplosis* sp. Gagné en los cultivos de *Asparagus officinalis* L. por amplificación parcial del gen citocromo oxidasa I. *IDESIA* (Chile). *32* (4), 29-41. https://www.scielo.cl/pdf/idesia/v32n4/art05.pdf

Peña, J. y Mead, F. (2016). Citrus gall midge, *Prodiplosis longifila* Gagné (Insecta: Diptera: Cecidomyiidae). University of Florida. IFAS Extension EENY-035. http://ufdcimages.uflib.ufl.edu/IR/00/00/38/25/00001/IN16200.pdf

Polo, J. (2017). Estudio del control químico de *Prodiplosis longifila* Gagné en *Lycopersicum esculentum* Mill, en Huanchaco, La Libertad. Tesis. Escuela Académico Profesional de Agronomía. Universidad Nacional de Trujillo. Trujillo. Perú. 91 p. https://dspace.unitru.edu.pe/bitstream/handle/UNITRU/9932/POLO%20VALENCIA,%20JOEL%20ELIPIO.pdf?sequence=1&isAllowed=y

Reinoso, J. (2015). Diagnóstico del uso de plaguicidas en el cultivo de tomate riñón en el Cantón Paute. *MASKANA*, *6* (2),147-154. https://publicaciones.ucuenca.edu.ec/ojs/index.php/maskana/article/view/495/419

SIPA. (Sistema de Información Publica Agropecuaria). (2021). Cifras Agro productivas. MAG. http://sipa.agricultura.gob.ec/index.php/cifras-agroproductivas

Valarezo, O., Cañarte, E., Navarrete, J. & Arias, M. (2003). *Prodiplosis longifila* principal plaga de tomate en el Ecuador. Portoviejo, Ecuador: INIAP, Estación Experimental Portoviejo. Manual Nº 51. http://repositorio.iniap.gob.ec/handle/41000/1324

This scientific publication in digital format is a continuation of the Printed Review: Legal Deposit pp 196802ZU42, ISSN 0378-7818.