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Thiamethoxam in Papaya (*Carica papaya* Linnaeus) Agroecosystems

Megchún-García Juan Valente[1], Rodríguez-Lagunes Daniel Arturo[1], Castañeda-Chávez María del Refugio[2*] Murguía-González Joaquín[1], Lango-Reynoso Fabiola[2*], Leyva-Ovalle Otto Raúl[1,].

[1]Universidad Veracruzana Campus Córdoba; Faculty of Biological and Agricultural Sciences, Región Orizaba-Córdoba. Camino Peñuela-Amatlán s/n Peñuela, Municipio de Amatlán de los Reyes, Veracruz. México. C. P. 94945. Teléfonos: +52 271 716 6410; +52 271 716 6129 ext. 3751.

[2]Tecnologico Nacional de México/Instituto Tecnológico de Boca del Río. Km 12 carretera Veracruz-Córdoba, Boca del Río, Veracruz. México. C.P. 94290. Tel (01 229) 6905010.

Abstract— *Papaya (Carica papaya L.) is a profitable fruit of economic and food importance in Mexico and Central America. Veracruz is the state in Mexico with the highest cultivable area, eventhough its production presents numerous phytosanitary problems, which are being faced with the use of the pesticide thiamethoxam. The aim of this study was to make a diagnosis of the use and management of thiamethoxam in papaya agroecosystems in the municipality of Cotaxtla, Veracruz. Two surveys were applied, one to a 30% of the total number of producers organized by an association dedicated to papaya culture, and the other survey was through key informants, both surveys were designed using the snowball sampling, a non-probability sampling technique. The results indicate that 6% of papaya producers use mainly the pesticide thiamethoxam, which belongs to the chemical group of neonicotinoids. It was found out that for five years there have been records of thiamethoxam use in vertisoils. During the cycle of papaya cultivation the producers use a maximum dose of 3 L/ha and a minimum dose of 250 ml/ha per crop cycle. One hundred per cent of those who apply thiamethoxam are not aware of its use and efficient management, nor of the damage they are doing or have caused to agroecosystems.*

Keywords— Thiamethoxam, Carica papaya L., neonicotinoids.

I. INTRODUCTION

Tropical agroecosystems are ecological systems modified by man that have the job of generating a good or service, and are obtained from the processes of agricultural production, with the purpose of satisfying the needs of the population, such as economic, moral, social or spiritual type [22]. *Carica papaya* L. agroecosystem, is a dynamic production system integrated by short cycle crops that allow having an income several times a year, unfortunately affected by the economic loss that is generated by the pests and diseases that occur in the crops. Papaya is a profitable fruit tree in Mexico and Central America, its cultivation is carried out with a minimum investment of one hundred thousand Mexican pesos per hectare [25], most of this investment is focused in the acquisition of agrochemicals to combat pests and diseases. In 2015, Veracruz became the main papaya producer state with a cultivated area of 18% of the total area of papaya established in Mexico, and the municipality of Cotaxtla contributes with 19% of the total agricultural land of papaya in Veracruz [24]. Aphids are the most economically important pests in Mexico, among them the red spider (*Tetranychus cinnabarinus*) and the white mite (*Polyphagotarsonemus latus*) stand out; a characteristic of these aphids is that they damage the foliage of papaya plants. Another important pest in Mexico and in other countries like India is the mealybug (*Planococcus sp*.) that acts as a vector of viral diseases. Of the minor pests are the parakeet (*Acanophora projecta*) and the papaya fly (*Toxotrypana curvicauda*). For that reason cultural management in the control of pests is fundamental to obtain fruit of commercial quality. It is necessary to respond to the sustainable development policies of the General Assembly of the United Nations (UN), where the use of organic products, entomopathogenic fungi and plant barriers is recommended to minimize the damage caused by pests and at the same time maintain an ecological balance of biodiversity [14, 28]. This effort to use organic products does not respond to the demands and requirements of the agricultural sector, therefore producers use pesticides massively in papaya crops. Training is also considered necessary for proper management culture of chemical waste that is the result of pesticides used at plot level. This chemical waste is one of the major factors in soil and groundwater contamination through leaching, percolation and entrainment of chemical molecules towards the aquifer. Currently, farmers use organophosphorus products for the management of the "Maradol" papaya crop, one of the disadvantages of handling pesticides such as parathion, diazinon and malathion, is the harm caused in humans by intoxication known as cholinergic syndrome. However,

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this chemical group is not the only one that has caused damage, there are also the neonicotinoids, which are a chemical group that causes ecological damages, such as death of birds that eat tropical fruits [7, 9 and 8], mainly in the flowering stage until reaching the production one that begins three or four months after flowering [4]. The use of chemicals in pest control is of global interest due to its motility ability within plant organs, besides having the capacity to accumulate in certain specific organs [27]. Currently of the authorized agrochemicals in Mexico, the group of neonicotinoids such as imidacloprid, acetamiprid, nitenpyram, thiamethoxam, thiacloprid, clothianidim and dinotefuram [26] are highly required by producers for their effectiveness in the control of sucking insects. From this chemical group, thiamethoxam is used in the control of Spodoptera frugiperda, *Bemisia tabaci*, aphids and triocides, sucking insects that transmit diseases in papaya crops [5]. Thiamethoxam is a systemic neonicotinoid pesticide that is characterized by its rapid effect, active by ingestion and contact, besides being an inactivator of the nicotinic receptors of the acetylcholine of the insects nervous system, causing paralysis and then death, these pesticides are effective in controlling lepidoptera [10, 11, 2]. Thiamethoxam can last 3 years in soil, it is soluble in water and its use in crops can cause bee hives collapsing at concentrations of 0.1 to 0.5 µg/hive [15], whereby the Environmental Protection Agency (EPA) and the European Food Safety Authority (EFSA) set the maximum permissible limits in fruit trees of 0.4 and 0.05 πg/L. In addition, the damage caused to ecology and human health is innumerable. Therefore the aim of this study was to make a diagnosis of the use and management of thiamethoxam in a papaya agroecosystem, in the municipality of Cotaxtla, Veracruz in Mexico.

II. MATERIALS AND METHODS

The municipality of Cotaxtla, Veracruz México is located at the geographical coordinates 18° 44'-18° 59' north latitude and 96° 11'- 96° 32' longitude west at an altitude of 10 to 200 meters above the sea level and is formed by papaya producers of 216 localities (Figure 1), among the most important are La Tinaja, La Capilla, Cotaxtla, Colonia Ejidal and Mata tejón. The municipality of Cotaxtla has a population of 18, 821 inhabitants.

Fig.1: Location of the study area in the municipality of Cotaxtla, Veracruz México. [INEGI, 2005].

This study was carried out by means of a design and application of two surveys, one applied first to 30% of the total of papaya producers of the localities of Las Lomitas, Mata Espino, Mata Tambor, Loma de los Hoyos, Los Bajos del Tlachiconal and the municipal seat of Cotaxtla. This group of producers is constituted in an organized manner by an "Agricultural Grouping" which facilitated to carry out the surveys. The first survey was applied with an open-ended questionnaire in order to know: which groups of agrochemicals are currently used for the management of papaya crops; which are the main phytosanitary problems that they have during crops. And also if there is, as a consequence of these, a low yield of the crops that generates a negative impact to the agroecosystem. A second survey was conducted to determine the use and management of the systemic pesticide thiamethoxam. It was designed through the non-probabilistic qualitative snowball sampling technique, and the interview was applied to key informants in order to obtain the following information: 1. If they knew the chemical characteristics of the thiamethoxam. 2. Who the main leading papaya producers are. 3. To have knowledge about thiamethoxam's distribution and sale in a papaya

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agricultural area. 4. Locate the major suppliers of thiamethoxam.

As a study strategy, the main commercial centers for agrochemicals in the municipality of Cotaxtla and Piedras Negras in the municipality of Tlalixcoyan, Veracruz, were identified; and key informants were interviewed (Figure 1). The data obtained were analyzed with the program statistica version 7, along with a nonparametric and parametric analysis of Kruskal Wallis.

III. RESULTS AND DISCUSSION

In this research the key informants were interviewed, of which 56% of them used to grow papaya "Maradol". Among pests present in papaya crops, the producers mention that the main pest species that cause severe damage to papaya plantations are the red spider 44%, mites 33% and aphids 11% (Table 1). For producers to learn to know main species, their classification and control, it is necessary to transfer technology on integrated management of pests and diseases. It is important to consider that the producers that are devoted to this activity are among 30 to 70 years old [16], so it is necessary to anticipate and train groups of young producers with attitude and aptitude for food production between 18 to 30 years old. And in doing so, to identify and form innovative leaders in the agricultural sector. Currently, 35% of agricultural producers are using organophosphorus pesticides in their crops, in order to achieve control of mites; 23% use those of the macrocyclic lactate chemical group; 12% use pyrethroids, and 6% use those of the chemical group neonicotinoids. Of the latter group 6% of the producers apply the pesticide thiamethoxam (Table 1). The massive use of pesticides in crops, mainly thiamethoxam due to its high solubility chemical characteristics, is causing an impact on the ecosystem. Aquatic systems by runoff are being affected, besides its use also represents a potential risk for productive activities that use water as a resource. Aquaculture is a productive activity in the Gulf of Mexico that is being negatively impacted by the presence of this pesticide in surface and groundwater. In addition, it is important to consider that the presence of these chemicals affects public health and provoke damages to the environment [19,24].

Table.1: Chemical groups and active ingredients most used by producers in papaya agroecosystems and main pests that attack the crops.

Chemical Groups	Producers who use it (%)	Active Ingredient	Producers who use it (%)	Pests	Population (%)
Nitroguanidines	6	Clotianidin	6	Nematodes	6
Carbamates	6	Oxamyl	6	Red spider	44
Macrocyclic lactone	23	Abamectin	23	Mites	33
Organophosphates	35	Parathion	11	Wire worm	6
Pyrethrins	12	Cypermethrin	12	Aphids	11
Neonicotinoids	6	Dimethoate	12		
Chloronicotinyls	6	Methamidophos	6		
Saccharopolyspora spinosa	6	Thiamethoxam	6		
		Imidacloprid	6		
		Malathion	6		
		Spinosad	6		

Nowadays, it has become a must the use and management of new pesticides in agriculture to combat pests and diseases in crops of commercial importance. This has favored the use of the systemic pesticide thiamethoxam, which can be persistent in soil for 90 days, in addition it degrades and percola itself settling in groundwater in which it is highly soluble (4.95 X 10^{-11} ha 25° C). Its hydrolytic degradation is in a range of pH of 5 to 9, reason why it is necessary to carry out studies of dissipation and motility in water, as well as learning how to handle and apply it in papaya crops, since producers use it due to its systemic and contact activity, that becomes suitable for an efficient control of sucking insects such as aphids [21, 13]. Producers from the study area of the municipality of Cotaxtla, have mentioned that mite has caused severe damage to papaya agroecosystems (Table 1). The main species present in papaya crops is the white mite (*Polyphagotarsonemus latus*), this causes reduction and deformation of young leaves, buds, flowers and fruits. It presents a symptomatology called “monkey

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hand", which is associated with the presence of the Papaya Annular Blight Virus (PRSV-P), this is due to the fact that the adoption of technology has been limited by the producer himself and the presence of hoarders generates that papaya producers look for alternatives for the control of pests. In addition, it is considered that the crop requires sufficient inputs for the integral management of papaya crops, the leading producers seek to share their tacit knowledge to other adoptive producers in order to improve their production systems [1 and 6].

The distribution of thiamethoxam is currently carried out in the town of Piedras Negras in the municipality of Tlalixcoya, Veracruz, under the trade name Engeo (Thiamethoxam + Lambda cyalotrina) and Actara 25WG (thiamethoxam) distributed in the municipality of Cotaxtla, Veracruz, with the name Unikum (thiamethoxam), this means that there is a probability of a trend towards the use of thiamethoxam in the agricultural area of the municipality of Cotaxtla, mainly for the cultivation of papaya and main vegetables in the region (Table 2).

Rotation and association of papaya crops with watermelon cultivation and the proximity of papaya crops to farms where watermelon and tomato are planted or, where appropriate, the location with old papaya orchards has caused crops to be affected negatively by the presence of the virus. This phenomenon is associated with migration of major insect vectors to new papaya plantations [23].

Table.2: Characteristics of thiamethoxam distribution in the main papaya production areas in the center of the state of Veracruz, México

Variables	Municipalty of Tlalixcoyan	Municipality of Cotaxtla	Commercial brand of thiamethoxam	Sale percentage (%)	Pests controlled (%)
Thiamethoxam suppliers (%)	67	33	Engeo	60	36 Whitefly
Thiamethoxam sale (L/year)	140	6	Actara	20	18 Trips
Use of thiamethoxam in crops	Papaya, vegetables, sugar cane	Papaya, lemon, watermelon	Unikum	20	45 Aphids

The survey showed that 45% of the producers are dedicated to the production of papaya and watermelon, 27% are only cultivating papaya, while the rest is focused on other types of crops (Table 3). There are records of the use of thiamethoxam for 5 years in crops with vertisol soils, the maximum dose used is 3 L/ha^{-1} during papaya cultivation cycle on sandy loam soils (Table 4). According to studies carried out with other pesticides, thiamethoxam could become an important non-point source of groundwater contamination, due to its high soil motility [3].

Studies reported in Venezuela show that thiamethoxam applications have been made in clay-loam and clay soils, which predominate at the foot of high savannas that are vulnerable to intermittent flooding [32]. Land losses caused by conventional farming practices are considered to cause severe ecological damage, it is estimated that worldwide soil erosion is 3 million hectares and 2 million hectares are desertified on agricultural land [20], this degradation will contribute to the vulnerability of surface water and groundwater by the presence of the pesticide. Among these pesticides of the chemical group of the neonicotinoids, thiamethoxam due to its systemic characteristics and high motility, is highly effective in papaya cultivation, mainly in the combat of sucking insects that transmit diseases. Its efficacy can be observed 7 days after its application [12]. Although damage to the agroecosystem could be a high risk, it has been reported that thiamethoxam in concentrations of 1 to 100 ppb in flowers and fruit plants causes death in bees; 10 ppb in water causes death in aquatic species, and also 10 ppb in agricultural layer damages macrofauna and soil microflora [31].

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Table.3: Predominant cultures in papaya agroecosystems and its relation to thiamethoxam.

Crops	Presence in agroecosystem (%)	Thiamethoxam use (Years)
Papaya-Vegetables	9	4
Papaya-Corn-Watermelon	9	0
Papaya	27	2
Papaya-Corn	9	0
Papaya-Watermelon	45	2.5

Table.4: Applications of thiamethoxam in different types of soil and crop cycle in the municipality of Cotaxtla Veracruz, México.

Soil types	Application of thiamethoxam (Years)	During the growing cycle (ml/ha)
Clay	3.8	700
Sandy-clay	1.5	250
Sandy	0	0
Loamy sand	2	3000
Vertisol	5	600

In the locality of Loma de los Hoyos Cotaxtla the maximum dose used in crops is 3 L/ha, unlike the producers of the locality of Lomitas who mentioned that they do not use thiamethoxam in papaya crops. The group of producers of Los Bajos de Tlachiconal used a dose lower than 500 ml/ha in the cycle of papaya cultivation, which represents a significant difference with respect to the group of producers of the locality of Mata Espino, who apply a dose of 1 l/ha (Figure 2). Currently in countries like India, in relation to the control of *Paracoccus marginatus* in papaya cultivation, they found out that profenophos 50 EC (0.05%) and acephate 75 SP (0.075%), are more efficient in 90% and 80% with reference to 78% of the mortality index of the pesticide thiamethoxam, although papaya producers are using biopesticides to control this pest [18, 12]. Thiamethoxam is efficient in the control of *Empoasca fabae* Harris with a protection of 31 to 38 days on the crop and of *Bemisia* spp. as a major vector of papaya ringspot virus, reducing the adult population to 97% after 14 days of foliar treatment [2]. In addition, it controls the pests of the coleopteran, hemiptera and lepidoctera families, mainly to *Tagosodes orizicolus* in a period of 21 days, these species may be responsible for the presence of papaya virus [32]. An alternative for the control of aphids in papaya cultivation is the use of reflective and black plastic mulch, these plastic covers reduce insect-pest populations and contribute to reduce the presence of virus, it is also important to consider the use of biodegradable plastics since it provides better development of plants [30; 29]. Biological control may be an alternative for tropical papaya agroecosystems that are negatively impacted by the excessive use of pesticides, although the management of neonicotinoids such as thiamethoxam has regained importance because of its nicotine-like effect by blocking acetylcholine receptors of the central nervous system of the insect. The use of organic products and live barriers such as Maize can be an alternative for the control of pests and diseases of the crop, as well as for the production of innocuous foods [10, 23].

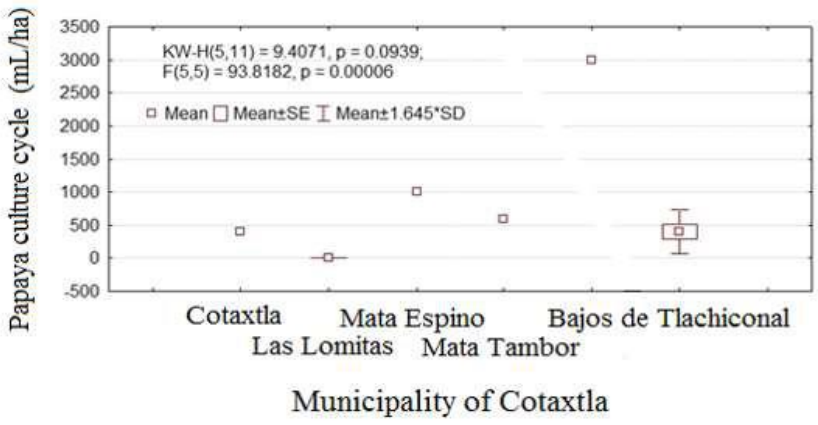

Fig.2: Thiamethoxam use in papaya culture cycle in the municipality of Cotaxtla Veracruz, México.

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IV. CONCLUSIONS

Producers prefer ENGEO® (Thiamethoxam + Lambda-cyhalothrin), which is most frequently used in papaya cultivation. One hundred per cent of those applying this product are unaware of its use and efficient handling, and damage that may cause to agroecosystems. It is necessary to carry out scientific research to know the concentrations of thiamethoxam in soil, water and plant and to know if it does not exceed the permissible limits established by EPA and EFSA. Thiamethoxam tends to be used more by papaya producers because of its efficiency in combating crop pests, but it is necessary to validate the product in the field to use the effective dose in crops and it is also important to evaluate it with organic insecticides and chemical products recommended for each crop.

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