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SHORT NOTE [NOTA CORTA]

BIOLOGICAL EFFICACY AND SELECTIVITY OF ACARICIDES IN PAPAYA (*Carica papaya* L.)

[EFECTIVIDAD Y SELECTIVIDAD BIOLÓGICA DE ACARICIDAS EN PAPAYO (*Carica papaya* L.)]

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SUMMARY

Mites are considered the second pest in importance in papaya (*Carica papaya* L.) in Veracruz, Mexico, caused by a general increment in pesticide use that might unbalance predatory populations. Efficacy of acaricides was evaluated against phytophagous mites, and their selectivity to predators in papaya cv. Maradol. A completely randomized block design with nine treatments and four replications was used. Significant differences (P = 0.005) were found in the number of phytophagous mites alive per leaf after the third weekly application. The lowest populations of pest mites per leaf (2.6, 3.9, 3.5 and 4.9) were observed in the following treatments: dicofol rotated with bifenthrin, paraffinic oil alone, sulphur powder alone and a weekly regime of fatty acid salts followed by paraffinic oil and azadirachtin 1.2%. Azadirachtin 1.2% alone had a lower efficacy than the previous group (5.8 mites per leaf), and the following pesticides were not significantly different (P > 0.05) than the control (17.4 mites per leaf): fatty acids sprayed alone (6.7), azadirachtin 4.5% alone (9.5) and drenched imidacloprid (7.6). No differences were found among treatments in the number of predatory mites, possibly due to the low mite densities found.

Key words: *Tetranychus merganser*, *Galendromus helveolus*, *Euseius hibisci*.

RESUMEN

Los ácaros son considerados la segunda plaga más importante en papayo (*Carica papaya* L.) en Veracruz, México, debido al incremento en el uso de plaguicidas que pueden alterar las poblaciones de sus depredadores. Se evaluó la efectividad de plaguicidas contra ácaros fitófagos y su selectividad a depredadores en papayo cv. Maradol. Se estableció un diseño experimental en bloques al azar con nueve tratamientos y cuatro repeticiones. Se presentaron diferencias significativas (P = 0.05) en el número de ácaros plaga vivos por hoja después de la tercera aplicación. Las menores poblaciones de ácaros por hoja (2.6, 3.9, 3.5 y 4.9) se obtuvieron con los tratamientos: dicofol en rotación con bifentrina, aceite parafínico de petróleo solo, azufre en polvo solo y el régimen que combina ácidos grasos, seguido de aceite parafínico de petróleo y azadiractina 1.2%. La azadiractina 1.2% sola tuvo menor efectividad que el grupo anterior (5.8 ácaros por hoja), y los siguientes plaguicidas no fueron diferentes (P > 0.05) al testigo (17.4 ácaros por hoja): ácidos grasos solos (6.7), azadiractina 4.5% sola (9.5) e imidacloprid al suelo (7.6). No hubo diferencias entre tratamientos en el número de ácaros depredadores, posiblemente debido a las bajas densidades encontradas.

Palabras clave: *Tetranychus merganser*, *Galendromus helveolus*, *Euseius hibisci*.

INTRODUCTION

Mites are considered a pest of the first importance in papaya (*Carica papaya* L.) orchards worldwide, due to the damages caused (Pantoja *et al*., 2002). In most cases, farmers will choose to control mites by applying pesticides, because they are easy to use, effective, and appealing business-wise. However, pesticides must be used with caution; they can cause pests to develop resistance to such chemicals; they can also pollute the environment as well, which limit their usefulness (Metcalf, 1990; Buttler *et al*. 1998). This is a reason to use low residual pesticides that are also selective to natural enemies (Lagunes-Tejeda and Villanueva-Jiménez, 1994).

Selective pesticides allow the survival and viability of natural enemies such as predators and parasitoids (Villanueva-Jiménez and Hoy, 2003). Collier *et al*. (2004) found the predatory mite *Neoseiulus idaeus* (Denmak and Muma) in papaya orchards in Brazil, after being subjected to continuous applications of pesticides. This mite is important to control the population of red spider *Tetranychus urticae* (Koch), which makes it a good candidate for integrated management programs. Two predatory mites, *Euseius hibisci* (Chant) and *Galendromus helveolus* (Chant), were found in commercial orchards of papaya in Veracruz, Mexico. However, their response to acaricides is still to be known. Integrated management of pests aims to assemble both biological and chemical control, in order to offer papaya farmers more sustainable choices. Thus, the objective of this study was to assess the biological efficacy of acaricides against pest mites and their selectivity to predators in papaya cv. Maradol roja.

MATERIALS AND METHODS

In June 2008, an experimental plot with papaya cv. Maradol roja was established in 4000 m^2 in the municipality of Manlio F. Altamirano, Veracruz, Mexico (19°06' NL, 96°20' WL). As part of the integrated management of papaya's ring spot virus (PRSV-p), at the moment of planting the experimental plot was surrounded with maize cv. CP-562. This was planted at a distance of 20 cm between plants, in a row separated 2.20 m from the rows of papaya, and removed three months later. The experiment was conducted using a completely randomized blocks design with four replications. The experimental unit included 16 plants of papaya (four rows with four plants each) at a distance of 1.80 m between rows and 1.30 m between plants. Treatments used are described in Table 1. These included chemical products alone and two regimens of applications with more than one pesticide. None of the chemicals used are highly persistent in crops.

Before the beginning of the experiment, weekly sampling took place in 20 plants located in a diagonal in the plot. The experimental applications began when one mite per leaf was found in the upper third of the plant, on average. Because of the high temperatures present at the beginning of the experiment (Figure 1), the initial action threshold was low, since it could have been two to five mites per leaf (Agnello *et al*., 2003), as it was the case for the following two applications. Before the application and from five to seven days after it, the number of pest mites and live predators per leaf were counted on the following sampling dates: 06/06/09, 11/06/09, 15/06/09, 25/06/09 and 02/07/09. Three applications took place (Table 1, Figure 1) on the following dates: 06/06/09, 11/06/09, and 26/06/09. The efficacy and selectivity of acaricides was assessed in one healthy leaf per plant in the upper layer of the four central plants in the experimental unit, which was marked before the application. During the sampling carried out after the applications, the leaves were visually inspected to check for damages caused by plant toxicity. No damage was found. Due to the low level of mite infestation, a non-parametric analysis was performed using the Friedman test and means comparison by Least Significant Difference test (LSD in SAS v. 9.1.3) (SAS, 2003).

RESULTS

Efficacy of acaricides

The infestation of pest mites (*Tetranychus merganser* Boudreaux) found in all the samples was low at the beginning and the means went up at the end of the experiment, with values of 1.5 to 17.4 pest mites per leaf on the five sampling dates (Table 2). Additionally, the presence of predatory mites was low but consistent (*G. helveolus* and *E. hibisci*) on all the sampling dates, with means from 0.2 to 1.3 predators per leaf in the control (Table 3). This result allows us to assume that the populations were subjected to certain level of natural control.

No significant differences were found (P = 0.86) among treatments before the first application of pesticides (Date 1). This indicates a similar distribution of densities all over the experimental plot. No significant differences were found either (P = 0.44) after the first application (Date 2). Despite important differences were observed among the means of pest mites populations in the second application (Dates 3 and 4, Table 2), these differences were marginal on Date 4 (P = 0.09), and none of the two was considered significant. After the third application (Date 5), significant differences were found (P = 0.005) among treatments on the number of pest mites (Figure 2), with a least significant difference of 2.8 pest mites per leaf. The unapplied control presented the highest mean of pest mites per leaf (17.4), as opposed to the treatment that simulates the applications used in the region (dicofol-bifenthrin), with 2.6 pest mites per leaf on average. Considering the LSD test, the most effective chemicals were dicofol rotated with bifenthrin, followed by paraffinic oil applied alone, sulphur powder alone and the regime of fatty acids followed by paraffinic oil and azadirachtin 1.2%, which yielded the lowest population of pest mites (2.6, 3.9, 3.5, and 4.9 mites per leaf).

Table 1. Description of treatments and pesticides used in the acaricides biological efficacy trial in papaya (*Carica papaya*) in Veracruz, Mexico.

Treatment	Brand name	Active ingredient (Concentration, toxicological group)	Dose ha^{-1}
Control with no application of pesticides	-----	-----	-----
Commercial control: dicofol – bifenthrin – dicofol, alternated weekly	AK-20® Talstar®	dicofol (18.5%, organochloride) bifenthrin (12.15%, pyrethroid)	0.45 L 0.50 L
Imidacloprid applied to the stem base, single application	Confidor®	imidacloprid (30.20%, neonicotinoid)	0.90 L
Oil, applied weekly	Safe-T-Side®	paraffinic oil (80%, oils)	9.00 L
Fatty acids salts with adherent[π], applied weekly	Peak Plus B[¶]	fatty acids salts (80%, soap)	2.00 kg
Sulphur, applied weekly	Sulphur powder	elemental sulphur (93%, inorganic)	50.0 kg
Azadirachtin 1.2%, applied weekly	Azadirect®	azadirachtin (1.2%, botanic)	3.00 L
Azadirachtin 4.5%, applied weekly	Neemix®	azadirachtin (4.5%, botanic)	0.45 L
Fatty acids salts with adherent[π] – paraffinic oil – azadirachtin 1.2%, alternated (fatty ac.-oil-aza 1.2)	Peak Plus – Safe-T-Side® – Azadirect®	fatty acids salts (80%) – paraffinic oil – azadirachtin (1.2%, botanic)	2.25 kg – 9.00 L – 3.00 L

*Applied to 400 L ha^{-1}. [π]Adherex®. [¶]Experimental agricultural soap (J. Concepción Rodríguez Maciel, Colegio de Postgraduados, Campus Montecillo, Mexico).

Table 2. Mean number of pest mites found in five samplings in papaya before and after applying acaricide trearments. Veracruz, Mexico.

Treatments	Date 1*	Date 2	Date 3	Date 4	Date 5
Control	1.5 a**	3.1 a	6.00 a	17.4 a	17.4 a
Dicofol-bifenthrin	0.4 a	0.2 a	0.19 a	3.8 a	2.6 e
Imidacloprid	0.3 a	0.9 a	2.94 a	5.3 a	7.6 ab
Paraffinic oil	0.5 a	1.4 a	0.44 a	4.9 a	3.9 de
Fatty acids salts	0.9 a	1.1 a	1.13 a	11.3 a	6.7 abc
Sulphur	1.4 a	0.4 a	1.44 a	12.6 a	3.5 cde
Azadirachtin 1.2%	0.7 a	0.7 a	1.25 a	12.1 a	5.8 bdc
Azadirachtin 4.5%	0.6 a	1.3 a	2.94 a	13.2 a	9.5 ab
Fatty acids – paraffinic oil – azadirachtin	1.3 a	2.0 a	3.94 a	13.5 a	4.9 bcde

*Applications performed on dates 1, 2 and 3 after sampling. **Means with the same letter are not significantly different.

Table 3. Mean number of predatory mites in five samplings in papaya before and after applying acaricide treatments. Veracruz, Mexico.

Treataments	Date 1*	Date 2	Date 3	Date 4	Date 5
Control	0.2 a**	0.3 a	0.44 a	0.6 a	1.3 a
Dicofol-bifenthrin	0.2 a	0.1 a	0.31 a	0.5 a	0.8 a
Imidacloprid	0.2 a	0.0 a	0.19 a	0.3 a	0.6 a
Paraffinic oil	0.1 a	0.3 a	0.00 a	0.6 a	0.9 a
Fatty acids salts	0.1 a	0.1 a	0.31 a	0.8 a	0.8 a
Sulphur	0.1 a	0.1 a	0.00 a	0.5 a	0.5 a
Azadirachtin 1.2 %	0.3 a	0.2 a	0.38 a	0.8 a	0.8 a
Azadirachtin 4.5 %	0.1 a	0.3 a	0.13 a	0.6 a	0.9 a
Fatty acids – paraffinic oil – azadirachtin	0.3 a	0.3 a	0.00 a	0.5 a	0.5 a

*Applications performed on dates 1, 2 and 3 after sampling. **Means with the same letter are not significantly different.

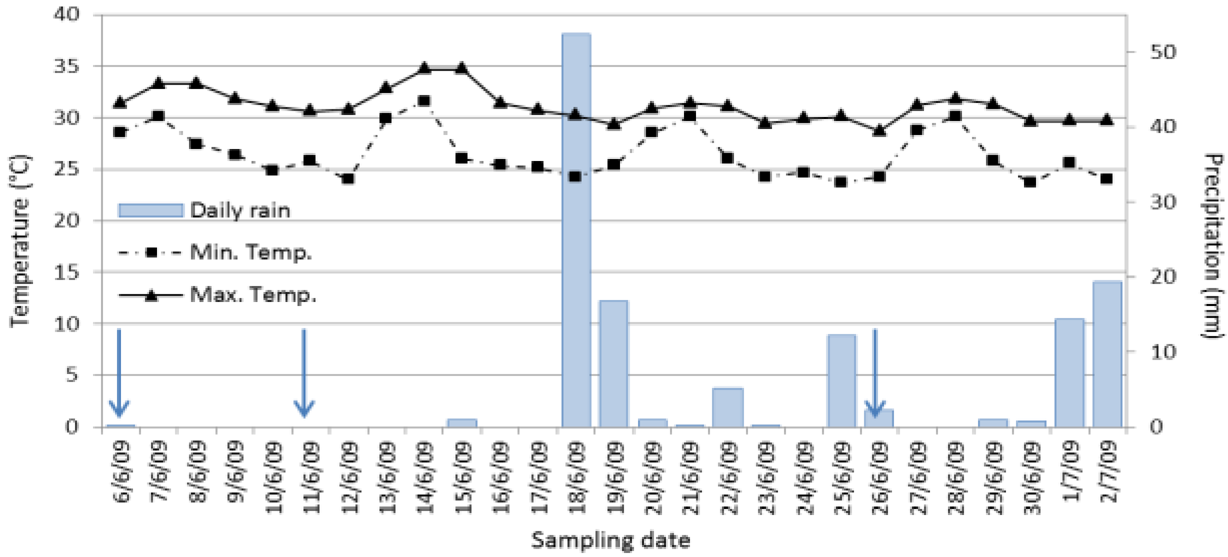

Figure 1. Environmental conditions for the papaya orchard in Manlio F. Altamirano, Veracruz, Mexico: daily precipitation (mm) and average daily temperature (°C). The arrows represent applications of acaricides.

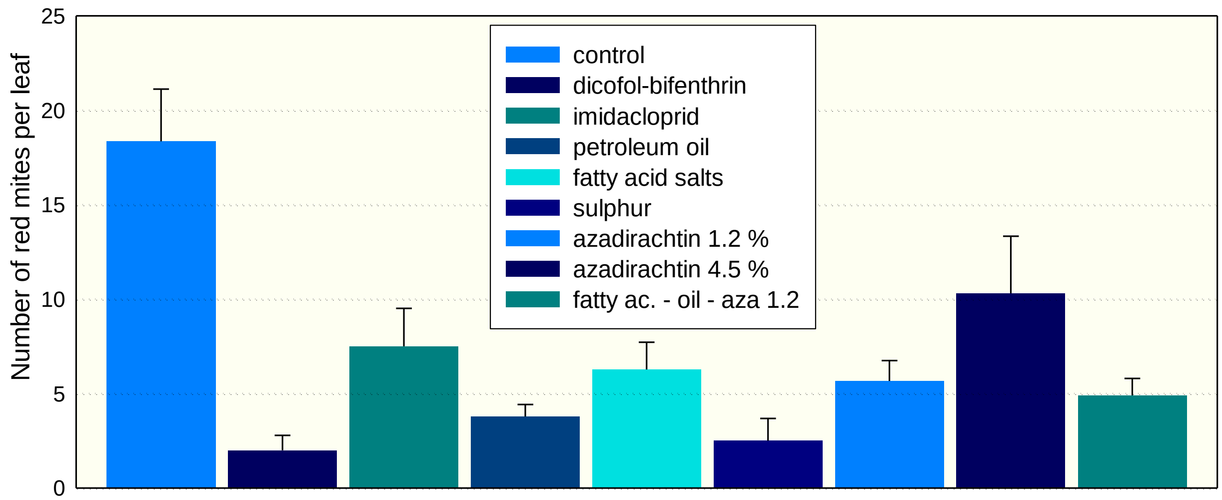

Figure 2. Means of pest mites per leaf, after the third application of different acaricides treatments in papaya in Manlio F. Altamirano, Veracruz, Mexico.

Selectivity of acaricides to predators

The presence of predatory mites was low but persistent in all samplings performed (Table 3). The population dynamics by treatment is presented in Figure 3. There was no significant difference between the different regimes of applications of acaricides in any sampling, even though several selective acaricides were visually as effective as dicofol (Table 2), and despite the highest number of phytoseids observed in the control on the last date. The ratio of predatory mites to pest mites present on average (1:5) is appropriate to keep the population of pest mites low. Additionally, most of the chemicals presented a certain degree of selectivity to predatory mites.

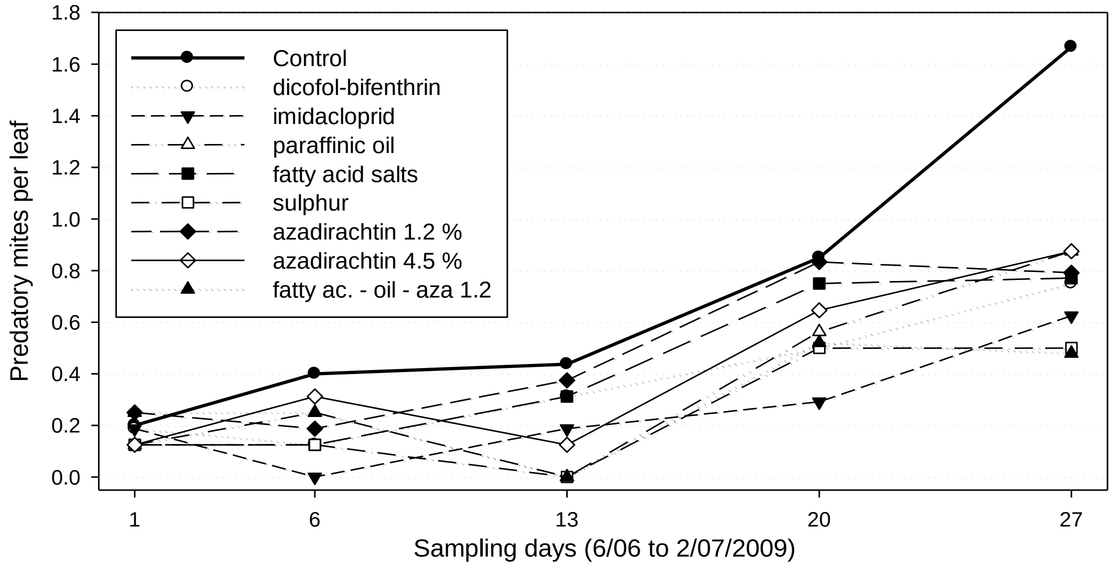

Figure 3. Population dynamics of predatory mites treated with acaricides, in a papaya orchard in Manlio F. Altamirano, Veracruz, Mexico.

DISCUSSION

The trial took place at the end of the dry season and the beginning of rains (Figure 1). This might be the right conditions for a high population of tetranychids. However, it was only after the beginning of rains and three applications of acaricides that the populations of both pest and predatory mites started to increase in all treatments. This was most notorious in the control, going beyond a high application threshold, such as five mites per leaf collected on the photosynthetic side of the papaya tree. Possibly, this was the result of high but appropriate temperatures for the development of mites. Something to be noticed was the survival of both pest mites and predators despite the applications, since at least three applications were needed to start noticing a fall in the population under treatment. Most likely, the number of surviving mites in all treatments had to do with the number of new eggs hatched, since samplings took place five to seven days after the application.

In relation to the efficacy of acaricides, Prokopy *et al.* (1980) consider dicofol a pesticide that is high to moderately toxic to predators, which also has an anti-reproductive effect in *A. fallacis*. Jones and Parella (1984) studied the residual effect of dicofol in citrus; they found that 66 days after its application the predator-day numbers of *Euseius stipulatus* Athias-Henriot (McGregor) was down by 72.4%, and caused a reduction in their predatory potential after 83 days. Stanyard *et al.* (1998) found that the population of *A. fallacis* in apple trees decreased sharply near to 0.2 mites per leaf over a period of two years, after using dicofol. Therefore, it is possible that the acaricides that were more effective are also selective to predatory mites present in the area of study. The dicofol-bifenthrin treatment includes an organochloride with higher residual activity, followed by a contact pyrethroid (Lagunes-Tejeda and Villanueva-Jiménez, 1994). It has been found that *Tetranychus cinnabarinus* Boisduval presented resistance to dicofol in China (Fengying *et al*., 1998), just as *T. urticae* did in Villa Guerrero, Mexico, on roses (Reséndiz, 1998) and in Guanajuato, Mexico, on strawberries (Cerna *et al*., 2005). Cerna *et al.* (2009) also found resistance of *T. urticae* to bifenthrin. This is the reason why the regime dicofol-bifenthrin would not be advisable to fight *Tetranychus*, since there are other chemicals that develop resistance more slowly and are less toxic to predators.

In this study, paraffinic oil was found to have a similar effect as dicofol to control *T. merganser*, with 3.9 mites per leaf. According to Beattie *et al.* (1995), Rae *et al.* (1997), and Villanueva-Jiménez *et al.* (2000), oils are considered to be pesticides with low toxicity to predators. Agnello *et al.* (1994) and Durán (2002), even consider that oils might "not generate resistance". Furthermore, it is known that oils pose a low risk for human health, that even the Food and Drug Administration (FDA) exempt them from tolerance requirements. Additionally, they have low prices (Agnello *et al*., 1994).

On the other hand, Hill and Foster (1998) found that Dormant Oil 435® at 2% allows the survival of *Amblyseius fallacis* (Garman) in apple orchards, while it is effective to control *Panonychus ulmi* (Koch). In a separate study, Stanyard *et al.* (1998) found low levels of infestation of *P. ulmi* (146 and 213 mites-day) when applying Safe-T-Side® and SunSprays 6E® oils.

These results were similar to the ones obtained with clofentezine, dicofol and propargite (6E), that also allowed the survival of predatory mites (9.2 and 9.9 mites-day, respectively). Agnello *et al*. (1994) were able to obtain effective control against *P. ulmi* with three applications of oil at 2 and 3% under a two to three week program. To control *T. urticae* (Koch) in roses, Nicetic *et al*. (2001) found that the applications of paraffinic oil (24 carbons, nC24), combined with the use of the predatory mite *Phytoseiulus persimilis* Athias-Henriot, was better than only using *P. persimilis*. In a three-year study on apple orchards, paraffinic oil was selective to natural enemies and its use was recommended for integrated management programs (Agnello *et al*., 2003). Therefore, this is one of the products that can be recommended for integrated management programs of mites in papaya.

Sulphur powder was also found to have a similar effect as dicofol-bifenthrin and paraffinic oil. Duran (2002) mentions that sulphur is an appropriate alternative to control pest mites since its toxicity is low to animals and humans, and moderate to phytoseids (Cranham and Helle, 1985). Likewise, the University of California (2000) recommends the use of sulphur powder to control pest mites, since it is selective to natural enemies. However, Barlett (1977) mentions that sulphur presents a detrimental effect in the long run, associated with the persistence of high and medium residual toxicity to species of the Phytoseiidae family. In this study, the presentation of sulphur in powder made its application difficult under the subhumid conditions in the area of study. The powder becomes too humid even before its application. Additionally, it cannot be applied immediately after using oils (University of California, 2000). Once all of these considerations are taken into account, sulphur can be recommended to control pest mites in papaya during the dry season.

The combined regime of applications including fatty acid salts (soaps) - paraffinic oil - and azadirachtin 1.2%, was in the first group of best treatments. This regime is based on chemicals that are selective to predators. The application of the combined regime was more effective than applying azadirachtin 1.2% alone or fatty acid salts alone. This makes it appropriate for integrated management programs of mites in papaya.

The second best effective group included only Azadirachtin 1.2%. The effectiveness of this acaricide was superior to the control, but not better than the treatments mentioned above. Azadirect® 1.2% is a pesticide of botanic origin that acts upon contact or ingestion. It is of ample spectrum and possesses trans-laminar action (Gowan Mexicana©, 2009). Castiglioni *et al*. (2002) found that neem oil 1% can cause 80% mortality in *T. urticae* females. However, the brand name Nimkol® at concentrations of 2.0, 1.0, and 0.5%, yielded lower mortality (51.5, 41.8 and 39.7%, respectively). Even though this chemical is not highly effective, it can help the management of pest mites when supported by the presence of predatory mites.

All other treatments were no different to the control (Table 2). In this group are fatty acid salts applied alone, imidacloprid applied to the soil, and azadirachtin 4.5% (Neemix 4.5%), with 6.7, 7.6, and 9.5 mites per leaf, respectively. This is not consistent with other studies. Stanyard *et al*. (1998) found that M-Pede®, a chemical based on fatty acid salts, was as effective as dicofol. Silva *et al*. (2005) found that 1 to 2 kg of iodized salt from suet (Peak) combined with 100 L of water can have a biological efficacy of 95.2% against *T. urticae* in roses. This result was similar to the application of clofentezin (Acaristo®) used as a regional control. In this study, however, the fatty acid salts find its usefulness in serial applications with other pesticides (Table 2).

Imidacloprid is widely used because of its ample spectrum and its low toxicity on *P. persimilis* and *Typhlodromus occidentalis* Nesbitt (Smith *et al*., 1997), even though it is considered a selective pesticide because it is systemic (Villanueva-Jiménez *et al*., 2000). However, there are reports by other authors that this chemical stimulates the surge of pest mites (Sclar *et al*., 1998; Raupp *et al*., 2004), and the increase in fecundity in *T. urticae* (James and Price, 2002). Moreover, Duso *et al*. (2008) found that *P. persimilis* diminished egg laying in average and the survival of females after a treatment with imidacloprid. Therefore, this chemical is not recommended to be used against pest mites in papaya applied directly on the foliage.

CONCLUSION

Dicofol in rotation with bifenthrin, paraffinic oil alone, sulphur powder alone, and the regime of fatty acid salts - paraffinic oil - azadirachtin 1.2%, achieved a better control for *Tetranychus merganser*, a pest mite in papaya in Veracruz, Mexico. Azadirachtin 1.2% had an intermediate effect in controlling the red spider. Predatory mites were alive and present in all treatments. This indicates a certain level of selectivity of these chemical products, which makes them appropriate to be used in integrated management programs of pest mites in papaya.

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