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Evaluation of Products for Pineapple (*Ananas comosus* MD-2) Symphylids Control

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A B S T R A C T

The symphylids, *Scutigerella* spp. and *Hanseniella* spp. are common soil pests in Costa Rican pineapple plantations. These arthropods feed on plant roots causing extensive crop damage which reduces water and nutrient uptake ending in yield reduction. Often, this problem is misdiagnosed since this pest may not be familiar to farmers and technicians. An experiment in a randomized complete block design with four repetitions was conducted to evaluate products for symphylids control. The treatments were: 1: untreated control, 2: commercial chemical treatment with Mocap® 72EC at 10 L ha^{-1}, 3: Thiamethoxam 1.5 kg ha^{-1}, 4: Acetamiprid 1.25 kg ha^{-1}, 5: *Steinernema carpocapsae* 1 kg ha^{-1}, 6: Spirotetramat 1 L ha^{-1}, 7: Inorganic fertilizer 4 L ha^{-1}, and 8: Biostimulant fertilizer 5 L ha^{-1} + Quillay extract 4 L ha^{-1}. All rates were applied with spray boom in 3800 L of water solution ha^{-1} 48 days after planting. The pre-treatment incidence of symphylids by 10 plants by repetition was similar (P= 0.3140) among treatments varying between 50 and 80% and the number of symphylids by plant differed (P= 0.0406) which varied between 1.0 and 3.6 by plant. When comparing the treatment effect, the average of the evaluations at 15, 30 and 45 days after product application, the lowest incidence was recorded in the plants applied with Mocap® with 17.5% which differed (P< 0.0001) from all those applied with the other products where it varied between 69.2 and 84.2%. The number of symphylids by plant was lower (P< 0.0001) in those applied with Mocap® with 0.4 differing from the other treatments where the population ranged between 1.9 and 3.0 per plant. When the product effect was compared, pre-application evaluation 0 days versus the average of 15, 30 and 45 days, only in the plants applied with Mocap® the incidence was reduced (P= 0.0084) from 57.5 to 17.5% and the number of symphylids by plant decreased (P= 0.0019) by 83%. Of the products evaluated only Mocap® gave satisfactory control.

Introduction

Abiotic and biotic factors affect the commercial production of pineapple for export. Abiotic factors include soil, climate, plantation management, fruit quality specifications for the market, etc. Among biotic factors, symphylids (*Scutigerella* spp. and *Hanseniella* spp.) are a soil pest in pineapple plantations in many producing countries including Australia (Waite, 1993), Colombia (Agredo *et al.,* 1988; Montes and Ossa, 2021), Mexico (Rebolledo *et al.,* 1998, 2011), Guadalupe (Soler *et al.,* 2011), Ivory Coast (Kéhé *et al.,* 1997), Brazil (Pinto da Cunha *et al.,* 1999) and Costa Rica (Jiménez, 1999; Araya, 2019). Symphylids are small (3-10 mm long), white, soft-bodied arthropods with 12 pairs of legs and a pair of antennae. They are sensitive to light and become very active when exposed to the sun.

In local pineapple plantations, symphylids are a common soil pest, which can affect the crop from the time of establishment to harvest (Rohrbach and Johnson, 2003). They are frequently found associated with plant debris, feeding on organic matter (Waite, 1993; Petty *et al.,* 2002; Rebolledo *et al.,* 2011), but in the presence of the crop, symphylids prefer to feed on their fine roots and root hairs (Py *et al.,* 1987; Waite, 1993; Petty *et al.,* 2002; Reyes *et al.,* 2005) which prevents its root system development and restrict the absorption of water and nutrients. In infested plantations, the time necessary to reach the appropriate plant weight for flower induction increases, the crop cycle is lengthened, and the weight and quality of the fruits is reduced. Injuries to the roots promote the entry of pathogens that accelerate their destruction. Agredo *et al.,* (1988) found that symphylids caused an average root loss in pineapple of 66% and yield losses in Colombia are estimated at more than 40%.

Before planting, good soil preparation (Soler *et al.,* 2011; Gerdeman and Diehl, 2022) reduces symphylids infestation at the time of planting. After planting, to avoid or reduce symphylids damage, the only management strategy currently available is the application of synthetic phytosanitary products, which growers consider economically viable. Among the recommended products, organophosphates are a feasible and economical option. Its applications are carried out when the incidence of the pest exceeds 20% or the established threshold of 1 symphylids per plant. However, markets continually demand to reduce the chemical load in the crop and certifications constantly push to reduce or eliminate organophosphate products in the crop. Therefore, the objective of the present experiment was to determine the symphylids control that offers products with toxicological profiles that are more friendly to users and the environment.

Materials and Methods

The experiment was developed within a long-term (more than 10 planting cycles) commercial pineapple plantation located at the Siquirres county, in the Limón province at an altitude of 120-130 meters above sea level, Costa Rica. The soil was cleaned free of plant residues and weeds, plowed twice to a depth of 40-50 cm, followed by two passes of disk harrowing and then ripped to 100 cm depth, in all cases following the direction of the block. The plantation layout was on terraces of 13 beds wide and 10-15 m long with about 1200 to 1500 plants. Beds were formed one month before planting. The soil had a sandy clay loam texture (52% sand, 25% silt and 23% clay), with an organic matter content of 1.8% and a pH of 4.65. The following concentrations of extractable bases were found using Mehlich 3 as extractant and reading with ICP-OES; Ca 1.3; Mg 0.3; K 0.32 cmol L^{-1} and P 2.0; Fe 55; Cu 1.7; Zn 1.3; Mn 73.0 and B 0.28 µg ml^{-1}.

The plantation had a system of primary, secondary and tertiary drainage channels to eliminate excess rainwater and avoid waterlogging conditions during heavy rains. Manual planting was carried out with suckers between 300-400 g of *Ananas comosus* cv. MD-2 at a planting density of 71000 plants ha^{-1}. The application of the treatments was carried out 48 days after planting when the incidence of the pest was greater than 20% and the population was equal to or greater than one symphylids per plant. The experimental period was between October and December 2024. The monthly precipitation was 241, 431 and 641 mm for the months of October, November and December 2024, respectively. The average daily maximum and minimum temperature varied between 25.7 and 34.8 °C and between 20.6 and 24.2 °C, respectively.

Following bed conformation, the pre-emergent solution: Cosmo-Aguas (pH regulating citrates + chelating edatates - CosmoAgro) 700 g, Diurex® 80WG (Diuron – Adama) 1.5 kg + Hexazinone (Velpar® 75WG – Duwest) 1 kg + Paraffinic oil (petroleum paraffinic oil - Brandt) 2.3 L, all in 1400 L ha) was applied to control weeds before planting and after sowing with a mixture of Diurex®, Ametrine 500SC (ametrine-Adama) and clethodim® 240EC (Cletodima-Agrospec) and sometimes manually. Fifteen days after planting and then every 15 days, a mixture of nutrients was foliar applied in 1800 or 2400 L of water with a spray boom at a rate adapted to the needs of the soil and the crop to complete 700 kg N, 117 kg P_2O_5, 800 kg K_2O, 100 kg MgO, 1 kg Cu and 2 kg Zn per hectare for the crop cycle.

The diseases were managed with applications of systemic and protective fungicides. These management practices (weed control, fungicide and fertilizer applications) were applied uniformly on all terraces.

Prior to the treatment application, no insecticides or insecticide-nematicide was applied. The treatments evaluated were: 1: untreated control, 2: commercial chemical treatment with Mocap® 72EC (ethoprophos-AMVAC) at 10 L ha^{-1}, 3: Act Up® 25WG (thiamethoxam-INTEROC) 1.5 kg ha^{-1}, 4: Acetazell® 20SP (Acetamiprid-Zell Chemie) 1.25 kg ha^{-1}, 5: Capsanem® (*Steinernema carpocapsae* - Koppert) 1 kg ha^{-1}, 6: Movento® 15OD (spirotetramat-Bayer) 1 L ha^{-1}, 7: Kontrol® (inorganic fertilizer 0.714% K_2O, 0.693% S – BCS Agrinput) 4 L ha^{-1}, and 8: Armorex® (liquid biostimulant fertilizer N 0.035%, P_2O_5 0.35%, K_2O 0.025%, amino acids 3.2%, botanical extracts 96.39% - Organic) 5 L ha^{-1} + Oasys® 89.8SL (non-ionic adjuvant Quillay extract 89.8% - Soil Technologies Corp) 4 L ha^{-1}.

All rates were applied using 3800 L of water solution ha^{-1}. The application was carried out with a spray boom with TeeJet 6508 nozzles with a discharge of 3.17 L per minute attached to a Case IH Maxxum 104/140m (KW/HP) tractor at a speed of 1 km per hour in first gear and at 1600 RPM. The treatment application order was: first biological products, then extracts, then fertilizers and lastly the chemicals. After the application of each product, the boom (tank and nozzles) was washed. The rectangular terraces (plots) were arranged in a Random Complete Block Design with 8 treatments and four repetitions.

To determine the products performance, pest sampling was carried out pre-application at 0 days and then 15, 30 and 45 days after the products were applied. Pest sampling was carried out in two plants of bed 3, 5, 7, 9 and 11 for a total of 10 plants per plot in each sampling. In each bed, the plants were removed and shaken onto a black plastic cover, and in each the soil and the plant were examined for the presence of symphylids. Once the plants were examined, they were planted again and marked with colored spray paint, so that in the next sampling, the plant evaluated was the neighbor and so on during the 4 sampling times. That is, in each evaluation there were 8 treatments (products) with 4 repetitions (4 terraces) and 10 plants on each terrace, for a total of 40 plants in each treatment and evaluation. Then, the incidence of symphylids per plant and terrace was determined and recorded.

The presence of one or more symphylids in any plant means incidence of the pest and non-detection of the pest in the plant indicates that there was no incidence. The percentage of incidence was calculated as follows: number of plants with the presence of the pest divided by the total number of plants evaluated per terrace (10) × 100.

The incidence and population of symphylids were subjected to ANOVA at evaluation 0; subsequently, the evaluations within each treatment were subjected to ANOVA and mean separation by LSD. To compare the treatment effect, the average of the evaluations at 15-30-45 days post-application was subjected to ANOVA and means separation by LSD. The product effect was determined by comparing the variables mean of the pre-application (evaluation= 0) in each treatment against the global mean after application, evaluations at 15-30-45 days after application.

Results and Discussion

The symphylids incidence pre-application was similar ($P= 0.3140$) among treatments and varied between 50 and 80% (Figure 1A). That is, of the 10 plants sampled in each repetition between 5 and 8 had at least one symphylids present.

The symphylids average population pre-application differed ($P= 0.0406$) among treatments and ranged between 1.0 (plants to be treated with Armorex® + Oasys®) and 3.6 (plants to be treated with Movento®) per plant (Figure 1B).

When the symphylids incidence was analyzed among evaluations (0, 15, 30 and 45 days) of each treatment, a significant reduction was observed in the plants applied with Mocap® ($P= 0.0043$) where it ranged between 57.5 and 2.5% (Figure 2A). In the plants of the other treatments, an increase in incidence was recorded, which was significant ($P= 0.0453$) in those applied with the Armorex® + Oasys® solution where it varied between 50 and 87.5%. A very similar behavior was found in the symphylids population by plant (Figure 2B). In the plants applied with Mocap® the population was reduced (P= 0.0002) from 2.4 pre-application to 0 (100%); 0.7 (73%) and 0.6 (76%) symphylids by plant at 15, 30 and 45 days after application.

In the plants of the other treatments, an increase in the number of symphylids of 186% (P= 0.0108) was found in the control plants and 154% (P= 0.0341) in those applied with the Armorex® + Oasys® solution (Figure 2B).

When comparing the treatment effect, average evaluations at 15, 30 and 45 days after application, differences (P< 0.0001) were observed among treatments (Figure 3A). The lowest incidence was recorded in the plants applied with Mocap® with 17.5%, which differed from all those applied with the other products where it varied between 69.2 and 84.2%.

The number of symphylids by plant was lower (P< 0.0001) in those applied with Mocap® with 0.4, differing from the other treatments where the population ranged between 1.9 and 3.0 per plant (Figure 3B).

When the product effect was compared, pre-application evaluation at 0 days versus the average of 15, 30 and 45 days, only in the plants applied with Mocap® the incidence was reduced (P= 0.0084) from 57.5 to 17.5% (Figure 4A). In all other treatments, an increase between 5 and 39% in symphylids incidence was observed. In symphylids number by plant, in those applied with Mocap® a reduction (P= 0.0019) of 83% was found (Figure 4B). Plants treated with Movento® and Capsanem® also showed a small decrease of 9 and 14%, respectively, in the symphylids number by plant. In the plants applied with the other products, increases between 0.4 and 88% of the population were recorded.

No difference in symphylids incidence was observed among treatments before treatment application, which means that any differences detected subsequently must be attributed to the treatment effect. The pre-application symphylids population differed among treatments, therefore, the treatment effect was analyzed considering the population after application, average of the evaluations at 15, 30 and 45 days after the products were applied. Additionally, the effect was verified for each product by comparing the pre-application incidence and population versus the average incidence and population of the post-application evaluations (average of 15-, 30- and 45-days post-application).

The highest symphylids population recorded was 27 by plant, and frequently 3 or more were recorded per plant, with symptoms of leaf yellowing, which corroborates what was indicated by Agredo *et al.,* (1988) and Nurfadhilah *et al.,* (2012), who found symptoms on pineapple foliage when infestations per plant were between 1.9 and 3 symphylids. As a result of the size of the experimental area and given the absence of control in most of the treatments, we were asked to complete the evaluations 45 days after application, given the foliage yellowing and the losses that would arise from the lack of control.

The application of the products was carried out starting at 1 pm in cloudy conditions, and at the end of the applications and after that, there was precipitation, which totaled 20 mm for that day and on subsequent days there was also precipitation, so it was discarded that the lack of control of some products, especially biological ones, was due to climatic conditions. The application of Mocap® reduced the symphylids incidence below the economic threshold of 20-30% and decreased the symphylids number below the economic threshold of two by plant (Rebolledo *et al.,* 1998, 2011) up to 45 days post application, time that the experiment lasted.

The observed control agrees with what was reported by Araya (2019), who under Costa Rican conditions found efficiencies in pineapple symphylids control between 67.5 and 100% with the application of Mocap® 72EC. It is also in parallel with what was reported from Australia in Pineapple News (1997) where Mocap® EC at 10 L ha^{-1} applied twice was the optimal treatment for symphylids control. Similarly, it is in line with what was found by Reyes *et al.,* (2005) and Aceves *et al.,* (2005) in Mexico, who recommended the application of 50-100 kg ha^{-1} of Mocap® 15G (ethoprophos), a granular formulation, and with the results of Py *et al.,* (1987), Pinto da Cunha *et al.,* (1999) and Petty *et al.,* (2002) who suggested that ethoprophos could be applied pre and post-planting to control pests in the crop.

Although good control was observed up to 45 days after application, Mocap® has a half-life in soil between 98 (Jordan *et al.,* 1986) and 120 days (Smelt and Leistra, 1992), so a longer control period would be expected. Accordingly, Soler *et al.,* (2011) recorded the absence of symphylids for up to four months after the edaphic application of ethoprophos at the time of planting. In none of the other products control expectations were observed.

Figure.1A-B. Percentage of symphylids incidence (A) and number of symphylids by pineapple (*Ananas comosus* MD-2) plant (B) 48 days after planting pre-application of the product treatments. Each bar is the mean ± standard error of 4 repetitions and in each repetition 10 plants were evaluated.

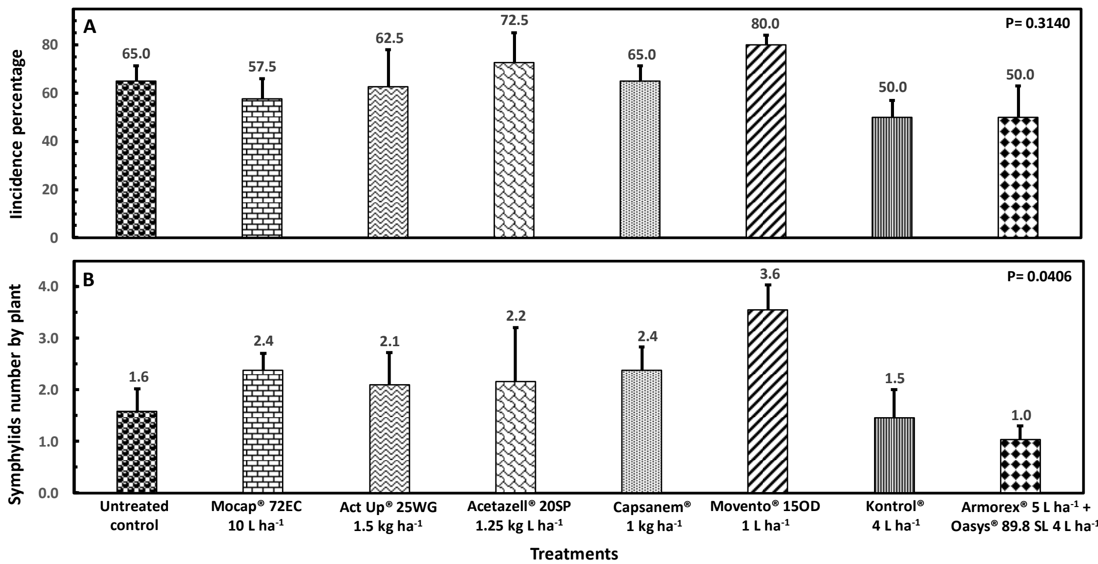


Figure.2A-B. Percentage of symphylids incidence (A) and number of symphylids by pineapple (*Ananas comosus* MD-2) plant (B) by evaluation (0, 15, 30 and 45 days after applying the products). Each bar is the mean ± standard error of 4 repetitions and in each repetition 10 plants were evaluated.

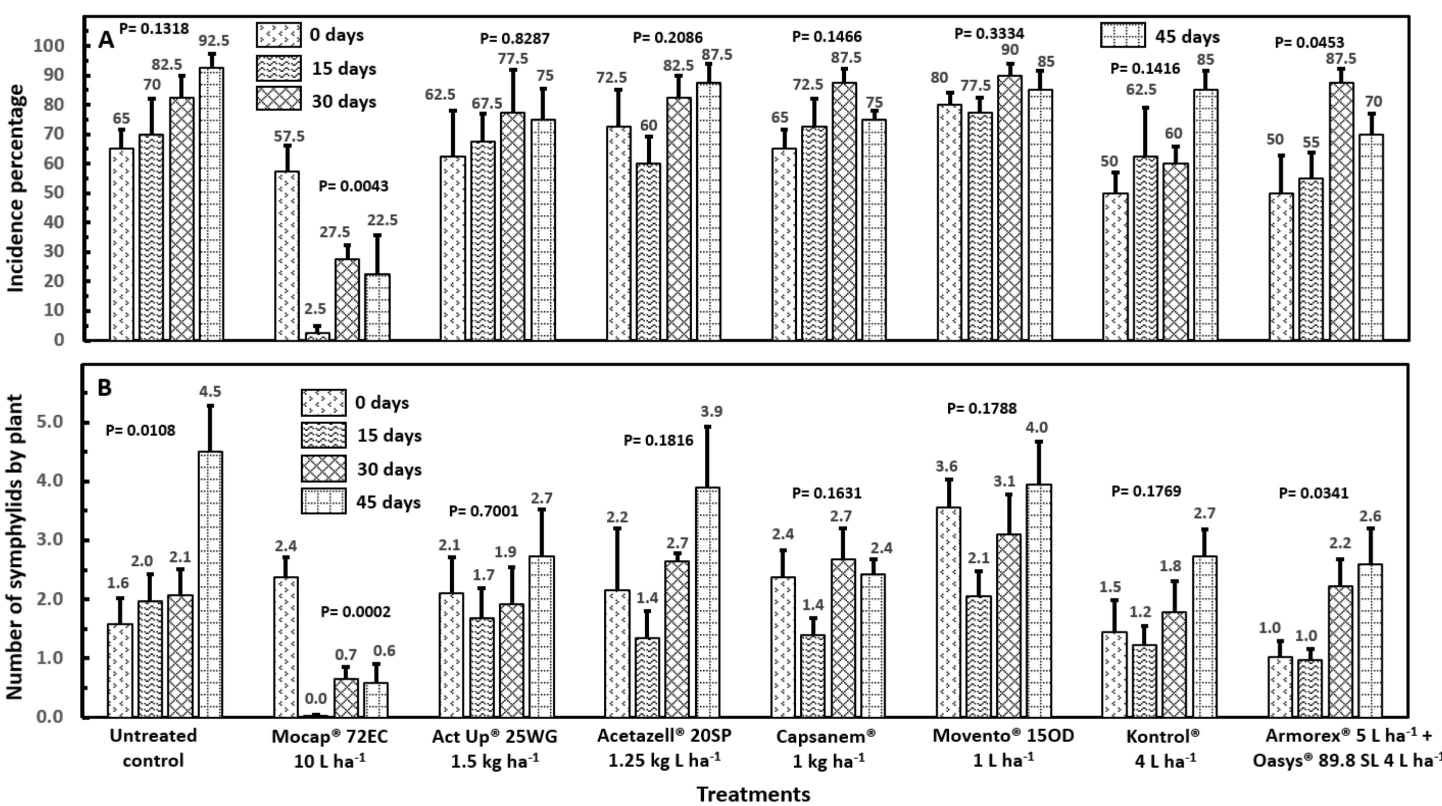


Figure.3A-B. Comparison of the treatments by the percentage of incidence (A) and number of symphylids by pineapple (*Ananas comosus* MD-2) plant (B) average of the evaluations at 15, 30 and 45 days after treatments were applied. Each bar is the mean ± standard error of 12 observations (three evaluations at 15, 30 and 45 days and in each evaluation 4 repetitions per treatment and in each repetition 10 plants were evaluated).

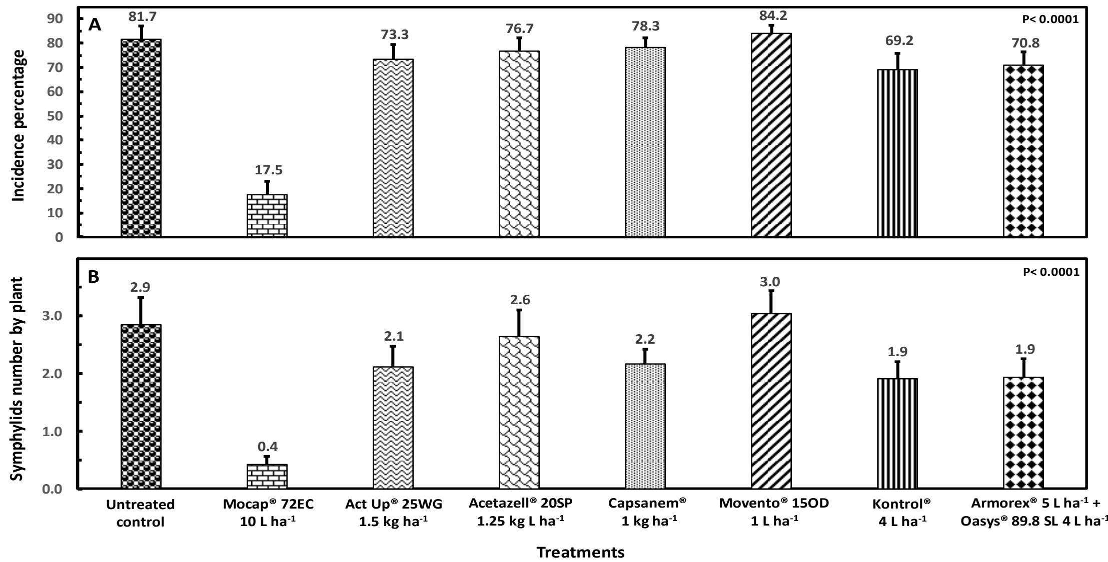
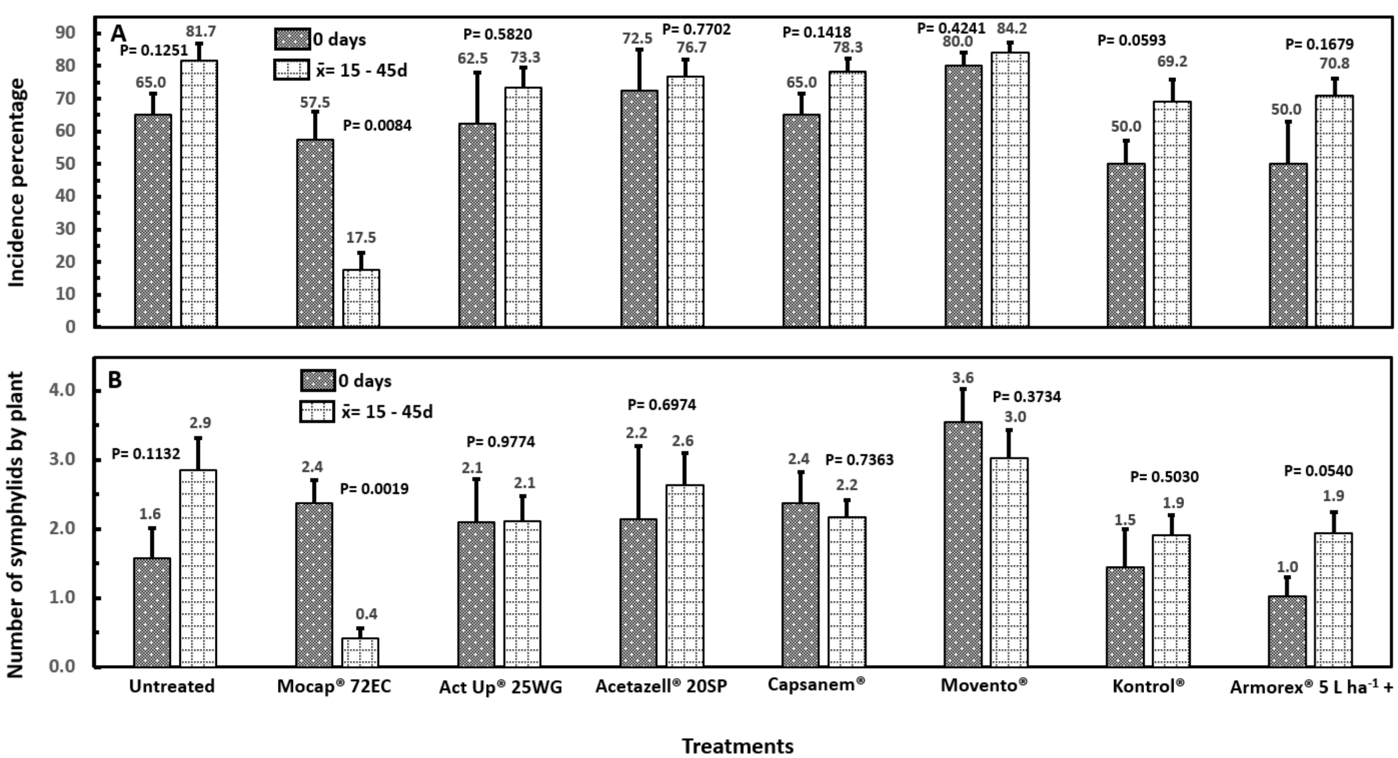


Figure.4A-B. Effect of the products, comparison of the pre-application evaluation versus the average of the evaluations at 15, 30 and 45 days after applying the products on the percentage of incidence (A) and number of symphylids by pineapple (*Ananas comosus* MD-2) plant (B). In the pre-application evaluation, each bar is the mean ± standard error of 4 repetitions and in each repetition 10 plants were evaluated and at x = 15 - 45 days each bar is the mean ± standard error of 12 observations (average of the evaluations at 15, 30 and 45 days after application and in each evaluation 4 repetitions, and in each repetition 10 plants were evaluated).



Mocap® is an insecticide-nematicide that belongs to the chemical group of organophosphates, which inhibits the nervous actions of acetylcholinesterase (Bunt, 1979; Devine *et al.,* 2008). Therefore, any organism in the animal kingdom with a nervous system can be threatened by the presence of the product. However, since the soil microflora is mainly composed of bacteria, actinomycetes, fungi and microalgae (Blaine, 1993), which lack a nervous system (Madigan *et al.,* 2012) they would not be affected by ethoprophos (Das *et al.,* 2003). Furthermore, free-living nematodes were not reduced after a nematicide application (Morales, 2006; Walker, 2007).

In this experiment, root mass measurements were not considered, however, symphylids control prevents root loss and its damage, which is the objective, since the roots of the pineapple plant do not regenerate once damaged by pests and diseases (Rohrbach and Apt, 1986; Petty *et al.,* 2002; Umble *et al.,* 2006). In Australia, when potted pineapple plants were infested with 12, 24 or 48 symphylids per plant, roots were reduced in 9 weeks, by 47.7; 61.7 and 92.8% respectively (Murray and Smith, 1983).

Regarding the response to symphylids control, in Martinique, Lacoeuilhe (1997) cited by Py *et al.,* (1987) found that the fruit weight increased in average from 0.72 to 1.27 kg, and the number of suckers by plant at the time of harvest, from 0.1 to 0.63.

In Ivory Coast, Kéhé (1979), also cited by Py *et al.,* (1987) reported an increase of 22% in the average fruit weight due to symphylids control. It is also mentioned that symphylids control reduces the number of small fruits.

Author Contributions

Cesar Guillén: Investigation, formal analysis, writing—original draft. Eduardo Corrales: Validation, methodology, writing—reviewing. Juan Delgado:—Resources, writing-review and editing. Oscar Cortes: Investigation, writing—reviewing. Mario Araya: Investigation, formal analysis, writing reviewing and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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