Alternative products with insecticidal effect in the control of *Aulacaspis tubercularis*; Newstead, 1906 (Hemiptera: Diaspididae) in mango cultivation

Productos alternativos con efecto insecticida en el control de *Aulacaspis tubercularis*; Newstead, 1906 (Hemiptera: Diaspididae) en el cultivo de mango

Produtos alternativos com efeito inseticida no controle de *Aulacaspis tubercularis*; Newstead, 1906 (Hemiptera: Diaspididae) no cultivo de manga

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Abstract

The predominant microclimates of the coast and the inter-Andean valleys of Peru have favored the production and export of mango (*Mangifera indica* L.) to more than 30 countries in the years 2020 - 2021. In this process, phytosanitary support was of vital importance, however, the species *Aulacaspis tubercularis* Newstead, 1906 (Hemiptera: Diaspididae) is a pest that affects the resulting crop, increasing costs due to cleaning the fruits for marketing. Control with insecticides contaminates the environment; hence the objective of the study was to evaluate alternative products with insecticidal effect and low environmental impact. The use of mineral oil (7.5 $mL.L^{-1}$), azadirachtin (3.2 %, 5 $mL.L^{-1}$), commercial powder detergent (20 $g.L^{-1}$) and potassium soap (10 $mL.L^{-1}$) in the field and laboratory. In the field, 9 trees were sprayed per treatment, every seven days at an interval of 15 days and in the laboratory the individuals per bottle. The four evaluated products had a significant impact on the colonies in the field (95.31 %, 88.89 %, 77.38 % and 68.04 %, respectively) in the first three moments of application. In the laboratory, commercial detergent and 3.2 % azadirachtin exerted high mortality (100 %) on the third day post-application, followed by 100 % mineral oil on the fourth day. The four products evaluated are recommended for the management of *A. tubercularis*.

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Resumen

Los microclimas predominantes de la costa y los valles interandinos de Perú han favorecido la producción y la exportación de mango (*Mangifera indica* L.) a más de 30 países en los años 2020 – 2021, en este proceso el respaldo fitosanitario fue de vital importancia, sin embargo, la especie *Aulacaspis tubercularis* Newstead, 1906 (Hemiptera: Diaspididae) es una plaga que afecta el cultivo al incrementar los costos, debido a la limpieza de los frutos para la comercialización. El control con insecticidas contamina el ambiente; de allí que el objetivo del estudio fue evaluar productos alternativos con efecto insecticida y de bajo impacto ambiental. Se evaluó el uso de aceite mineral (7,5 $mL.L^{-1}$), azadiractina (3,2 %, 5 $mL.L^{-1}$), detergente comercial en polvo (20 $g.L^{-1}$) y jabón potásico (10 $mL.L^{-1}$) en campo y laboratorio. En campo se asperjó 9 árboles por tratamiento, cada siete días a intervalo de 15 días y en laboratorio los individuos por frasco. Los cuatro productos evaluados incidieron significativamente sobre las colonias en campo (95,31 %, 88,89 %, 77,38 % y 68,04 %, respectivamente) en los tres primeros momentos de aplicación. En laboratorio el detergente comercial y la azadiractina 3,2 %, ejercieron alta mortalidad (100 %) al tercer día pos-aplicación, seguido por aceite mineral con 100 % al cuarto día. Los cuatro productos evaluados son recomendables para el manejo de *A. tubercularis*.

Palabras clave: Impacto ambiental, frutales, plagas, eficacia.

Resumo

Os microclimas predominantes da costa e dos vales interandinos do Peru favoreceram a produção e exportação de manga (*Mangifera indica* L.) para mais de 30 países nos anos 2020 - 2021. Nesse processo, o apoio fitossanitário foi de vital importância , no entanto, a espécie *Aulacaspis tubercularis* Newstead, 1906 (Hemiptera: Diaspididae) é uma praga que afeta a cultura resultante, aumentando os custos devido à limpeza dos frutos para comercialização. O controle com inseticidas contamina o meio ambiente; portanto, o objetivo do estudo foi avaliar produtos alternativos com efeito inseticida e baixo impacto ambiental. A utilização de óleo mineral (7,5 $mL.L^{-1}$), azadiractina (3,2 %, 5 $mL.L^{-1}$), detergente em pó comercial (20 $g.L^{-1}$) e sabão de potássio (10 $mL.L^{-1}$) no campo e laboratório. No campo foram pulverizadas 9 árvores por tratamento, a cada sete dias com intervalo de 15 dias e no laboratório os indivíduos por frasco. Os quatro produtos avaliados tiveram impacto significativo nas colônias no campo (95,31 %, 88,89 %, 77,38 % e 68,04 %, respectivamente) nos três primeiros momentos de aplicação. Em laboratório, o detergente comercial e azadiractina 3,2 % exerceram alta mortalidade (100 %) no terceiro dia pós-aplicação, seguido do óleo mineral 100 % no quarto dia. Os quatro produtos avaliados são recomendados para o manejo de *A. tubercularis*.

Palavras-chave: Impacto ambiental, inseticidas, árvores frutíferas, pragas, eficácia.

Introduction

Peru allocates approximately 29 thousand hectares of land for the cultivation of mango (*Mangifera indica* L.). During the 2018 season, Peru was positioned in third place among exporting countries, and in the 2019-2020 season, it dropped to fifth place (International Trade Centre [ITC Trademap], 2021), with a production of approximately 535 thousand tons and 41.6 % for export as fresh fruit.

The decline in exports, for the most part, was subject to international export standards, which require phytosanitary quality of the fruit, without damage by agricultural pests (Food and Agricultural Organization, & World Health Organization [FAO-WHO], 2005).

Among the most frequent pests in the crop, the species *Ceratitis capitata***,** *Aulacaspis tubercularis*, the genus *Anastrepha*, mites and queresas stand out (Servicio Nacional de Sanidad Agraria [SENASA], 2018). The species *A. tubercularis* Newstead (Hemiptera: Diaspididae) whose common name is white mealybug, is the most important pest worldwide (Boyero *et al*., 2017; Del Pino *et al*., 2021; López-Guillen *et al*., 2018), is highly polyphagous on various fruit trees and wild vegetation, as well as on ornamental plants (Amún *et al*., 2012). *A. tubercularis* is an emerging pest, which has accelerated its infestations at an alarming rate and to date is of economic importance from a phytosanitary point of view (Guillén *et al*., 2017). Its peculiar behavior is the invasion of foliage and fruits (Abate and Dechassa, 2021; Noriega-Cantú *et al*., 2016; Walters, 2015) depreciating the commercial value (Del Pino *et al*., 2020), with higher incidence in summer seasons and in some cases present throughout the year and the overlapping of generations (Joubert *et al*., 2000) that causes losses of more than 50 %, by generating lesions with yellow spots of orange hue on the fruit peel (Juárez-Hernández, 2014). The nymph stage proves to be the most damaging as it feeds on the leaves and fruit of the crop, causing premature fruit drop (Chiguachi *et al*., 2020).

In Peru, the pest has positioned itself in all mango producing regions (SENASA, 2018) and controls are directed to the use of highly polluting chemicals, and with limited efficacy (Ayalew *et al*., 2015; Del Pino *et al*., 2020).

Taking into account the requirements of the official agency that regulates the sanitary aspects of exports, with emphasis on the use of chemical substances and pesticides (Ministry of Health [MINSA], 2023), it is necessary to search for new control alternatives. Although, there is scarce information, with significant effect, on the control of *A. tubercularis*, as well as environmentally friendly and beneficial entomofauna, there are the studies of López-Guillén *et al*. (2018), on the effect of phytosanitary pruning and the use of natural biological controllers in the reduction of *A. tubercularis* in *M. indica*, similarly Bienvenido *et al*. (2017), who determined the efficacy of eco-compatible active principles with the sex pheromones of the species *A. tubercularis*, considering them as active materials with low impact on beneficial entomofauna and reduced induction of resistance.

In Spain, among the products authorized by the phytosanitary registry for mealybug control are azadirachtin (3.2 %) and kerosene mineral oil (54.6 %) (Bienvenido *et al*., 2017; Chaudhary *et al*., 2017). The effect of citroline (mineral oil) has also been studied, at the rate of 50 $mL.L^{-1}$ and 75 $mL.L^{-1}$ with 91.3 % and 97.5 % mortality of *A. tubercularis* colonies, respectively; likewise, sprays of pyriproxyfen (0.3 $mL.L^{-1}$) and dimethoate (2 $mL.L^{-1}$) have been made with 100 % efficacy (Urías-López *et al*., 2013).

The objective of the present study was to evaluate the effectiveness of alternative products with insecticidal effect in the control of *A. tubercularis* in mango crop. It was considered to work with pesticides of low environmental impact and proven efficacy.

Materials and Methods

The experiment was carried out in the mango germplasm bank of the Centro de Investigación Frutícola y Olericola (CIFO) and in the Laboratorio de Fitopatología of the Escuela Profesional de Ingeniería

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The products used as insecticide were mineral oil (7.5 $mL.L^{-1}$), azadirachtin (3.2 %, 5 $mL.L^{-1}$), commercial detergent (Ariel®, 20 $g.L^{-1}$) and potassium soap (10 $mL.L^{-1}$), plus the absolute control, with three replicates per treatment under a randomized complete block design.

Nine trees of uniform size, five years old and with high infestations of *A. tubercularis* were selected as a sample for each treatment.

Field phase

Before applying the treatments, a blank test was carried out by determining 27 L of water to be sprayed per treatment.

The spraying was done manually with a 20 L sprayer (Jacto PJHA, Peru). The first three applications were made in July 2021, with a frequency every 7 days, followed by a rest interval of 15 days without application and then resuming the second stage of three applications. With a replication of the trial in August 2021.

Ten leaves per tree were randomly selected (8 leaves from the lower and middle third, and 2 leaves from the upper third). The samples infested with *A. tubercularis* were collected three days after each application, in airtight vials with sealing facility and taken to the Laboratorio de Fitopatología of the Universidad Hermilio Valdizán. Counting of colonies with live and dead individuals per leaf was done with a stereoscopic microscope. The colonies included females, males and immature stages of the species. A total of six evaluations were made during the trial, plus one in the 15-day rest interval between applications and two at the end of the treatment.

Laboratory phase

During the laboratory phase, 27 leaves infested with *A. tubercularis* were collected from the plants in the field, containing five colonies each, which were washed with sterile distilled water to remove dust and other particles. In the laboratory, 60 mL of each treatment was applied to the samples, with daily evaluations of efficacy for seven days.

Data analysis

Data were processed with InfoStat statistical software, version 2013 (Di-Rienzo *et al*., 2013) and the results subjected to analysis of variance and LSD Fisher mean comparison test ($p<0.05$). The formula of Henderson and Tilton (1955) and Abbot (1925) was used to calculate efficacy.

Results and discussion

Prior to the application of the field treatments, the density of *A. tubercularis* was eight individuals per leaf. When the products were applied, significant differences were found in the four evaluations ($p=0.0001$; <0.05), from that moment on, the populations of *A. tubercularis* remained at low densities without expressing any difference until the end of the trial, as shown in table 1.

The treatments with commercial detergent, mineral oil and azadirachtin 3.2 % exerted the greatest control in the first three moments of application, achieving an efficacy of 95.31 %, 88.89 % and 77.38 %, respectively. Potassium soap achieved an intermediate efficacy of 68.04 %.

In the second stage of intervention and evaluation, it was observed that the treatments of commercial detergent and mineral oil reached 100 % mortality at 37 days post-application, followed by azadirachtin 3.2 % with 99.24 %, while potassium soap was in the final position according to the order of importance.

Similar results were recorded by Urías-López *et al*. (2013), when evaluating the efficacy of insecticides, mineral oil and a readily available commercial detergent, as well as the mixture of these, in the control of white scale in the mango crop, where mineral oil caused 91.3 % mortality and the commercial detergent (Ariel®) 75.5 % mortality, while Fita *et al*. (2020), when evaluating the efficacy of *Azadirachta indica* seed extract in the management of *A. tubercularis*, recorded 59.17 % efficacy at 20 days post-application.

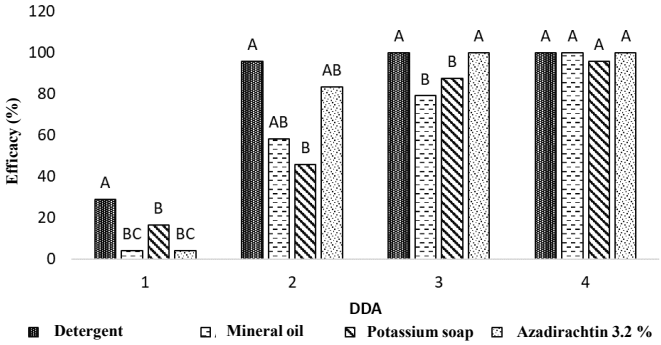

Figure 1. Estimated efficacy in percentage, in the control of *A. tubercularis* in the mango crop, at 7, 15, 22, 30, 37 and 45 days after application (Henderson and Tilton, 1955). Means with different letters indicate significant differences ($p<0.05$).

Table 2 shows the susceptibility data of the colonies to the treatments. The commercial detergent treatment and azadirachtin 3.2 % exerted the greatest control with 100 % on the third day after application of the product, followed by potassium soap with 87.5 %, and mineral oil (79.12 %) with the lowest percentage of efficacy; however, the latter reached 100 % efficacy on the fourth day after application. No mortality was observed in the absolute control. With some similarity, Mendoza-Montero *et al*. (2017), when evaluating the toxicity of insecticides recorded that propylene glycol monolaurate

Table 1. Mortality of *Aulacaspis tubercularis* after application under field conditions.

Treatments	Previous colonies per leaf	Days after application					
		7	15	22	30	37	45
		% Mort. Med. Sign.**					
Detergent	8.4 a	38.8±4.9 a	78.9±1.6 a	95.3±0.4 a	99.6±0.03 a	100±0.0 a	100±0.0 a
Mineral oil	8.67 a	21.5±8.0 b	55.6±4.2 a	88.8±2.3 a	94.9±1.1 a	100±0.0 a	100±0.0 a
Potassium soap	8.57 a	9.5±7.3 bc	39.7±4.7 b	68.0±3.2 b	84.8±1.4 ab	91.1±0.9 a	91.1±0.9 a
Azadirachtin 3.2 %.	8.63 a	1.9±6.4 c	46.1±3.5 a	77.3±1.1 a	87.8±0.4 a	99.2±0.3 a	99.7±0.08 a

**Percentage mortality adjusted by the Henderson and Tilton (1955) formula and the average number of previous colonies per leaf. Means with different letters are statistically different, LSD Fisher ($p<0.05$).

and mineral oil had 100 % and 98 %, respectively, of efficacy in the mortality of adult females of *A. tubercularis*. Gursha *et al*. (2021), studying the efficacy of *Azadirachta indica* L. in the control of *A. tubercularis*, recorded a significant reduction in infestations and 89.06 % mortality of the insect with the third application.

Table 2. Mortality of *A. tubercularis* under laboratory conditions.

Treatments	Previous colonies	Days after application			
		1	2	3	4
		% Mortality**			
Detergent	8.00 a	29.10± 5.6 a	95.8±0.3 a	100±0.0 a	100±0.0 a
Mineral oil	8.00 a	4.1±7.6 bc	58.3±3.3 ab	79.1±1.6 b	100±0.0 a
Potassium soap	8.00 a	16.6±6.6 b	45.8±4.3 b	87.5±1.0 ab	95.8±0.3 a
Azadirachtin 3.2 %.	8.00 a	4.13±7.6 bc	83.3±1.3 ab	100±0.0 a	100±0.0 a

**Percent colony mortality adjusted by Abbott's formula (1925) and the average number of colonies per leaf. Means with different letters are statistically different, LSD Fisher ($p<0.05$).

Conclusions

The present investigation allowed concluding that mineral oil, commercial detergent and azadirachtin 3.2 %, have potential effect on the control of *A. tubercularis*, so its use as an alternative product of low environmental impact can be frequent in the phytosanitary management of the crop. Potassium soap in the medium and long term reduces populations, a characteristic that makes it a useful strategy in integrated management programs.

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