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Management of the Prickly Pear Mealy Bug, *Dactylopius opuntiae* Using Bio-Insecticide in Morocco

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Abstract

The cochineal, *Dactylopius opuntiae*, has recently become the main pest that damages the prickly cactus, *Opuntia ficus-indica,* plants in Morocco. The control methods in which pesticides are used and applied weekly, have generated phytotoxicity, poisoning and high residuality in fresh nopal, which also prevents its commercialization in international markets and the constant risk to human and animal health. Therefore, the use of less aggressive products with a low impact on the environment and is sustainable for the crop, has been introduced without an obvious strategy for gradual control of the insect. This study was conducted to evaluate the effects of *Beta vulgaris* subsp., *Eucalyptus torquata* and *Cedrus atlantica* plant extracts (*Eucalyptus* leaves, small pieces of beet and *Cedrus* leaves powdered and macerated in 100 ml of distilled water for 72 h) for controlling of *D. opuntiae* under laboratory and field conditions. The results show that these extracts constitute a viable alternative for the control of wild cochineal in the nopal. A gradual reduction of cochineal populations was obtained, until after the third application with these extracts, with biological effectiveness of up to 90%. The findings of our study indicate that *Beta vulgaris* subsp., plant extracts could be used in the development and implementation of a biological control program against *D. opuntiae* under field conditions.

Keywords

Cochineal, Control, Bio-Insecticidal, Nopal, Beet, *Eucalyptus*, *Opuntia*

1. Introduction

The list of arthropods associated with *O. ficus-indica* includes 167 species [1].

Among these insects, *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae) is a primary pest in Morocco, Mexico, Brazil, Spain, Turkey, and Israel [2] [3] [4] [5]. This pest has spread rapidly to several provinces, causing serious damage and leading to the death of many cacti [5]. *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) was described in Mexico in 1896 by Cockerell [6]. The body of females is covered by white filamentous wax. When females are crushed, they release a dark red dye called carmine. This is involved in the protection of the insect from natural enemies [7]. Females have four biological stages: egg, nymph (two stages) and adult. Males pupate before the adult stage. The metamorphosis of females is incomplete compared with that of males who show complete metamorphosis [6] [8]. Only females and nymphs feed on plants and cause damage by sucking sap from the cladode.

The fruits and cladodes of *Opuntia ficus-indica* (Caryophyllales: Cactaceae) are of better quality than those of other *Opuntia* species and they have fewer spines [9]. The *O. ficus-indica* species is native to Mexico, it has importance as food, fodder and industrial uses [9] [10]. In Morocco, Argentina, Bolivia, Chile, Spain, Italy, Peru and Israel, it is cultivated to obtain fruits [2] [4] [11], and in some countries of Africa and in Brazil extensive surfaces are cultivated for fodder [2] [12].

The mealybug is widely distributed in the country [5]. By sucking plant sap, this insect causes a local yellowing of the cladodes that results in a general weakening of the plant and even its loss when the attack is severe [13]. However, producers of this crop use different highly toxic insecticides to control the wild mealybug. This form of control generates pest resistance, intoxications and residuals in the fresh product destined for human and animal consumption [14].

The selection of these products by farmers is not based on formal tests of biological effectiveness, which increases the risks of using products whose effectiveness is unknown. For this reason, it is important to generate information on the effectiveness of different insecticides to serve as a reference in the future authorization of chemical products, in addition to promoting the use of less toxic substances in the cultivation of prickly pear cactus when the levels of insect damage warrant their use.

Vavrina *et al.* [15] propose the use of soaps against soft-bodied insects (aphids, whiteflies, psyllids and scales), since they cause obstruction of the respiratory spiracles and removal of the cuticular wax layer, producing severe dehydration that causes the death of the insect. Liu, T.-X., & Stansly, P. A. [16] consider that soaps can be used in Integrated Pest Management; Palacios-Mendoza *et al.* [17] mention that, in organic production systems, a concentration of up to 1% can be used to control various species of insect pests.

Plants may provide potential alternatives to currently used insect-control agents because they constitute a rich source of bioactive chemicals [18]. Since these are often active against a limited number of species including specific target insects, are often biodegradable to non-toxic products, and are potentially suitable for use in integrated pest agents. Much effort has, therefore, been focused on plant-derived materials for potentially useful product insects by using aromatic medicinal plants despite their excellent pharmacological actions [19] [20]. Plant-derived products are increasingly being used to combat crop pests because they are natural and are often assumed to be safe for the environment. Extracts of *Chenopodium ambrosioides* L., *Mentha piperita* L. and *Tagetes florida* L. are used as insecticides [21].

In Morocco, promising results have been achieved with d-limonene, mineral oil, and potassium salts of fatty acid [22] also the detergent black soap [23]. So, the main objective of this trial was to evaluate an alternative for control of wild mealybugs, with the application of doses and frequencies of the bioinsecticide (*Beta vulgaris* subsp., *Eucalyptus torquata* and *Cedrus atlantica* extracts).

2. Materials and Methods

The study was conducted in a plot of green nopal, located in the faculty of sciences Agadir (FSA), Morocco (30.410421N, −9.5444550W) (**Figure 1**). Phenology in production, vegetative growth at 10 years of age.

The bioinsecticide, made from plant extracts, is a product of natural origin, indicated as a bioinsecticide. It acts by contacting, destroying the cell membrane of insects and even dehydrating them, causing their death.

2.1. Preparation of Biologics Extracts

Eucalyptus leaves, small pieces of beet and *Cedrus* leaves powdered using an electric grinder, the powder obtained was kept in a room temperature. The aqueous extract was obtained by maceration of 60 g of powder in 100 ml of distilled water for 72 h, then the mixture was filtered under vacuum, the final solution

Figure 1. Plot of green nopal, located in faculty of sciences Agadir (FSA), Morocco.

was kept in a temperature of 4˚C.

2.2. Bioassay

Data was collected from 3 randomly sampled cladodes at ten days interval before spraying, and 24, 48 and 72 hrs after spraying. A total of three times of spray application was done. Cochineal populations during the period of study were recorded as indicator to the effectiveness of the applied treatments. The attached cochineal adults and nymphes were counted from the sampled cladode of cactus plant before and after treatment applications and expressed in mortality percentage rates and, then correlated to the damage levels. Applications were initiated when the pre-evaluation showed 50% or more mealybug infestation in all experimental plots. The bio-insecticides were applied via foliar, according to the established doses (**Table 1**). The application 60% of extracts had the greatest impact on mortality of *D. opuntiae* nymphs and adult females when applied at low to medium levels of *D. opuntiae* infestation [23].

2.3. Data Analysis

The total count data were subjected to mortality percentage rate and analyzed using GenStat 15th Edition statistical software.

3. Results and Discussion

After the 1st application, no differences were observed between treatments (**Figure 2**, **Figure 3**). At 24 hrs after spray, morality percentage of cochineal insects was none. However, after 48 and 72 hrs of spray, the number of cochineals had reduced. This means that at least three applications are needed to reduce mealybug populations. Botanical sprays have the greatest impact on cochineal mortality that was highly and progressively recorded at 48 and 72 hours count treated with beet extract followed by *Cedrus* extract then by *Eucalyptus* extract. After 72 h of contact, the beet extract caused almost total death of adult females and 90% of nymphs. For both *Eucalyptus* and *Cedrus* extracts, they caused the death of 65% of females and 50% of nymphal stages of *Dactylopius* spp.

The body of adult females was dehydrated, the external morphology and spiracles were destroyed (**Figure 4**), the nymphal stages were immobile after treatment and their color became pale yellow (**Figure 5**). Most of the parameters were statistically

Table 1. List of treatments with their code and rate of application used for mealybug control on green cactus in FSA, Agadir, Morocco.

Treatment code	Treatment name	Rate of application
Control	Control, only water	500 ml
BT	Beet extract 60%	500 ml
EC	*Eucalyptus* extract 60%	500 ml
CA	*Cedrus* extract 60%	500 ml

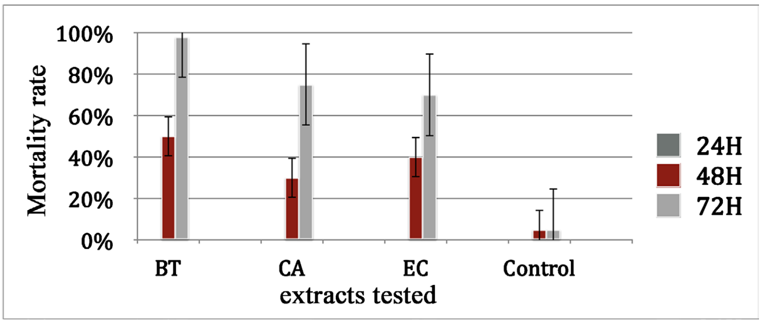

Figure 2. Effect of three extracts tested on adult of the cactus mealybug. BT: Beet; EC: *Eucalyptus*; CA: *Cedrus*.

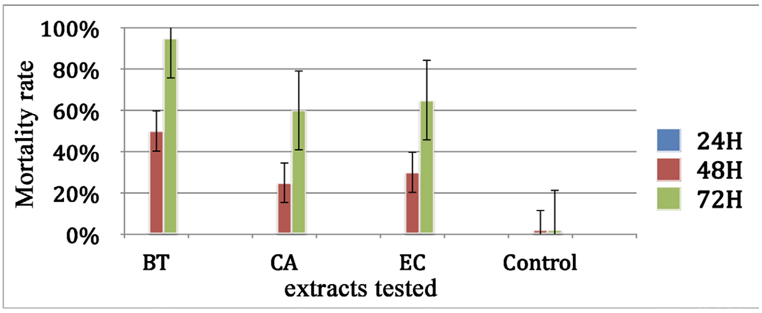

Figure 3. Effect of three extracts tested on nymphal stages of the cactus mealybug. BT: Beet; EC: *Eucalyptus*; CA: *Cedrus*.

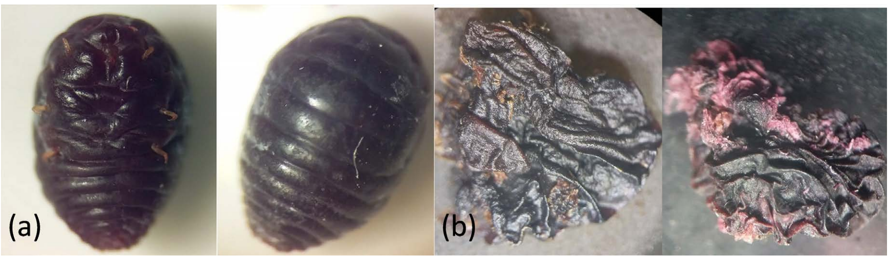

Figure 4. Effect on adult female of the cactus mealybug before (a) and after (b) traitement by *Beta vulgaris* subsp. extract (G×40).

Figure 5. Effect on nymphal stages before (a) and after (b) traitement by *Beta vulgaris* subsp. extract (G×40).

significant at 5% ($P < 0.05$) level of significance.

Cochineal insect has already become a serious pest spreading at a fastest rate and is highly damaging the cactus plants in the region with no effective solutions discovered yet. Our research findings could be promising enough in giving a relief to the farmers' community to tackle further spread and manage eventually. The experimental results showed a significant difference among treatments, and plots treated with Beet extract.

This treatment has highly and effectively reduced the number of cochineal insects at all sprays in the time intervals indicated. This indicates that botanical extracts such as Beet extract can be used to control insect pests such as cochineal and may replace the use of chemical application to reduce the side effects of synthetic chemicals on the environment.

Our results are slightly different from those observed by Ramdani *et al.* [23], they applied botanical extracts among them *Eucalyptus* extract which gave higher results, 78% mortality at a concentration of 10% after 72 h of treatment. They also used the black soap against the mealybug, this one gave a mortality of 100% of the adult females at a concentration of 30 g/l in 72 h, the same results were found by Yousef-Yousef, Meelad and Enrique Quesada-Moraga [24] but at a concentration of 6%, they also used a chemical treatment Chlorpyrifos-methyl, it gave a mortality rate of 91.5% of the adults [25] applied botanical extracts mixed with emulsifiers on the mealy bug, they found that the species *Chenopodium ambrosioides* L., *Mentha piperita* L., *Mentha viridis* L., *Tagetes erecta* L. and *Tagetes florida* L. mixed with tween 20 gave a higher mortality rate up to 99%, but no results were obtained by the same species mixed with other emulsifiers.

Botanical insecticides have been used for centuries for crop protection. Only with the development of synthetic insecticides in the mid-1990s, their use dropped as more effective products took their place. Within a relatively short time, problems arose with the synthetic products: environmental contamination, poisonings of nontarget species, and resistance, this led many to reconsider botanical formulations as natural alternatives because they are less toxic. However, these have always had varying degrees of success, and recently even their continued safe use has been questioned. Rotenone and pyrethrum, two of the most commonly applied by home gardeners and organic farmers, are being re-evaluated by the U.S. EPA-based o concerns regarding health effects from long-term exposure [26] [27].

4. Conclusion

The impact of *D. opuntiae* on *O. ficus-indica* was obviously catastrophic in Morocco where all the plants were completely destroyed. This impact affected negatively the socio-economic level of the farmers who depend on Barbary fig production to increase their incomes. The grave situation of the pest, thus, has to be reversed through a study looking for an environmentally sound and cost-effective control means. The research findings conducted under field conditions prove the fact that botanical pesticides like that Beet extract (*Beta vulgaris* subsp.) could be a promising candidate. It should be noted, however, that further research and in time because of the seriousness and the very damaging nature of the insect should be thought of for the botanicals to enhance their control efficacy over the pest.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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