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Basalt powder "Farina di Basalto® "Application for the Sustainable Management of *Dactylopius opuntiae* in Cactus Pear

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ABSTRACT
The cactus mealybug (*Dactylopius opuntiae*) is a significant pest that threatens *Opuntia* species in Tunisia and other arid regions, often causing severe damage to crops. This study aims to evaluate a sustainable pest control approach through the use of micronized basalt flour (Farina di Basalto® type XF). Applied at 3% and 5%, alone or mixed with 1% mineral oil, the treatments were evaluated in the field at two infested sites in Tunisia (Kalâa Soghra, Sousse Governorate and Ennadhour, Zaghouan Governorate). For comparison, conventional chemical control (chlorpyrifos-ethyl) and untreated plots were also included. The treatments were applied by foliar spraying every 14 days. Observations were made two days before treatment, on the day of treatment, and 24, 72, and 168 hours afterwar. The most effective result was obtained with the combination of 3% basalt flour with 1% mineral oil, which achieved mortality rates of 89.29% and 100% at Kalâa Soghra and Ennadhour, respectively. This treatment also reduced significantly the appearance of new individuals (98%), indicating a strong repellent effect. Chlorpyrifos-ethyl achieved 100% mortality and total inhibition of new individuals, but it caused considerable damage to the plants. In contrast, the basalt-based solution proved to be a safe, effective, and environmentally responsible alternative, highlighting its potential as part of a sustainable pest management strategy for cactus crops.
Keywords: Basalt flour, *Dactylopius opuntiae*, Biological control.

1 INTRODUCTION

The cactus pear (*Opuntia ficus-indica* L.) is a strategic crop in arid and semi-arid regions due to its tolerance to drought and poor soils, as well as its multiple uses in food, fodder, cosmetics, and soil conservation (Nefzaoui, 2019). Tunisia ranks among the leading countries in cactus pear cultivation, with about 600,000 hectares cultivated mainly for fruit production and as forage in marginal areas (FAO and ICARDA, 2018).

However, the sustainability of this crop has been severely threatened by the invasive mealybug *Dactylopius opuntiae* (Cockerell), which has emerged as a key pest causing serious damage to cactus plantations in many countries, including Tunisia. Since its first detection, the pest has rapidly spread to several regions across the country, resulting in the destruction of thousands of hectares of cactus plantations (FAO, 2022). The pest feeds on plant sap, causing chlorosis, deformation, and, eventually, plant death, with devastating consequences for local ecosystems and rural economies (Ramírez-Cruz et al., 2020; Matos et al., 2021; Méndez-Gallegos et al., 2022).

Currently, the most widely used control measures include chemical insecticides and, more recently, biological control using the predatory beetle *Cryptolaemus montrouzieri*. However, these approaches have limitations (Bouharroud et al., 2018; El-Aalaoui et al., 2019). Chemical control, while effective in the short term, poses risks to the environment, non-target organisms, and human health, especially in areas where cactus is used for forage or human consumption (Lopes et al., 2021). Biological control requires a well-balanced ecosystem and careful monitoring, and its effectiveness varies depending on climatic and ecological conditions (Wyckhuys et al., 2024). Therefore, there is an urgent need to explore and validate alternative, sustainable pest management strategies that are both effective and compatible with agroecological principles.

In this context, the use of rock dusts such as basalt flour has attracted interest as a promising pest control method. Rock dusts are finely ground minerals applied to plants to improve soil fertility and health but have also shown insecticidal properties by acting as desiccants, damaging insect cuticles, and disrupting feeding behavior (Elimem et al., 2020; Richardson, 2024). Basalt flour, in particular, is rich in silica and other minerals that may contribute to both plant defense and pest deterrence. Although its use in pest control is relatively recent, several studies suggest that rock powders can reduce populations of sap-feeding insects, including aphids and mealybugs, under certain conditions (Faraone et al., 2020).

The present study aims to evaluate the efficacy of basalt flour in controlling *D. opuntiae* under natural conditions in Tunisia. Specifically, we assess its effects on insect mortality and damage reduction compared to untreated control plants. This work contributes to developing an environmentally friendly approach to managing the cactus mealybug and sustaining cactus pear cultivation in Tunisia and similar agroecosystems.

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2 MATERIALS AND METHODS

2.1. Experimental site and field bioassay

The field experiment was conducted in two regions of Tunisia—Kalâa Soghra (Sousse Governorate) and Ennadhour (Zaghouan Governorate), both characterized by moderate to severe infestations of *D. opuntiae*. These locations were strategically selected based on their representative pest pressure, making them appropriate for evaluating the efficacy of various control strategies.

The study followed a randomized complete block design (RCBD) with three replicates per treatment. Within each replicate plot, ten cladodes were randomly selected and tagged for monitoring. Treatments encompassed a range of management options, including conventional chemical and biological approaches, as well as untreated controls for comparison. At each experimental site, plots were delineated and individual experimental units were marked with color-coded tags at 15-meter intervals to facilitate identification and data collection.

2.2. Product Description

Basalt powder, or "Farina di Basalto®", was obtained from Basalti Orvieto from Italy. Micronized Farina di Basalto® type XF is produced through mechanical grinding of pure basaltic rock using ceramic tools, without the use of ventilation processes. No additional minerals, substances, or process water containing flocculants commonly considered undesirable or potentially harmful in agriculture are introduced during its production. This micronized basalt flour is intended to enhance the fertility of agricultural soils, particularly those degraded or exhausted by intensive farming practices. It contributes to both mineral and organic soil enrichment and supports the restoration of beneficial microbial communities. Silicon, primarily in the form of silicon dioxide (SiO_2), is the dominant component, comprising 45–49% of the product (Elimem et al. 2020; Rouz et al. 2020; Elimem et al. 2023). The detailed elemental composition is presented in Table 1.

Table 1. Chemical characteristics of basalt powder (Anonymous 2019)

Percentage	Component
SiO_2	49.0%
Al_2O_3	20.5%
K_2O	8.0%
Fe_2O_3	7.5%
CaO	7.2%
MgO	2.8%
Na_2O	2.5%

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2.3 Field bioassay

Before starting the treatments, the study area was marked, and initial insect counts were taken. Treatments were applied twice, with a 14-day gap between applications. Observations were made two days before treatment, on the day of treatment, and 24, 72, and 168 hours afterward.
Basalt flour was tested at 3% and 5% concentrations, as well as at 3% combined with 1% mineral oil, to evaluate treatment efficacy. A chemical insecticide (chlorpyrifos-ethyl) and an untreated control were included for comparison. All treatments were applied using a backpack sprayer to ten randomly selected mature cladodes per plot. Mortality rates of different treatments were estimated and corrected using the Abbott's formula (Abbott, 1925).

2.4. Statistical analysis

The study was conducted using a Complete Randomized Design (CRD) on 20 m lines per treatment with three replicates (n=3 experimental units/treatment) with 10 cladodes per experimental unit. Statistical analyses were performed using IBM SPSS Statistics for Windows (version 25.0, IBM Corp., Armonk, NY, USA), applying a significance level (α) of 0.05. Deviations from the arithmetic mean were calculated as standard errors. Normality and homogeneity of variance of the data sets were tested using the Kolmogorov-Smirnov and Levene tests, respectively. General linear models (GLMs) were used to compare treatments. When normality or homogeneity of variance was not achieved after transformations (using the $\sqrt{x}$, $1/x$ or $\ln(x)$ functions), data sets were analyzed using generalized linear models (GLZ) (Ng and Cribbie, 2017). When significant differences were observed for a given treatment, data were subjected to analysis of variance using a non-parametric Kruskal-Wallis H test or a Mann-Whitney U test (Steel et al., 1997).

3 RESULTS

3.1. Population dynamics of *Dactylopius opuntiae*

The data analysis of *D. opuntiae* population dynamics revealed significant differences among the tested treatments across all exposure durations at both study sites (Figure 1A, B). Compared to the untreated control, the application of basalt 3% in combination with mineral oil 1% notably reduced the emergence of new individuals, with observable effects as early as 24 hours after the initial treatment. This early suppression could be attributed to the repellent or deterrent properties of the basalt-oil mixture (Figure 1 A, B).
A pronounced decline in the emergence of new adult females was observed by the end of the trial. At the Kalâa Soghra site, the greatest reduction (100%) occurred following treatment with chlorpyrifos-ethyl, likely due to its phytotoxic effects leading to cladode deterioration. This was closely followed by the basalt flour treatment at 3% combined with 1% mineral oil and basalt 3% alone, both achieving approximately 98%. The 5% basalt treatment resulted in a slightly lower reduction of about 85%. This near-complete suppression of new individuals may be attributed to the repellent or deterrent effects of the basalt-oil formulation, which likely interferes with pest settlement and oviposition behavior.

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At Ennadhour site, as observed at the Kalâa Soghra site, new adult females continued to emerge on untreated cladodes. However, none of the treated plots showed the emergence of new individuals following the third round of applications, indicating the high efficacy of all tested treatments in suppressing population emergence.

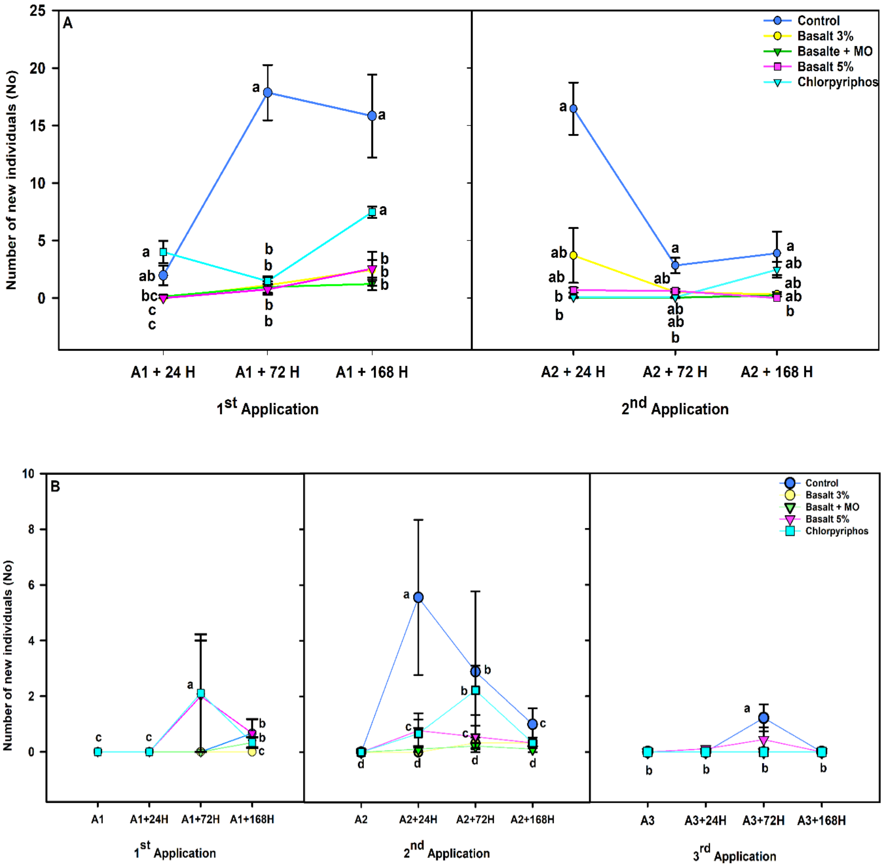

Figure 1. Effect of different treatments applied on the population dynamics of *D. opuntiae* at El Kalâa Soghra (A) and Nadhour (B). Values are means ± standard error (n = 3). Different letters indicate significant differences between treatments (Mann-Whitney U test, P < 0.05).

3.2. Insecticidal effects of different treatments on *D. opuntiae*

The mortality of mealybug adult females and the treatment efficacy differed significantly depending on the treatment type and exposure duration (Mann–Whitney U test, $P < 0.05$), as presented in Figures 2 and 3.

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At the El Kalâa Soghra site, treatment with Farina di Basalto® type XF at 3% combined with 1% mineral oil showed in the highest final corrected mortality rate after the second application (89.29%), followed by chlorpyrifos-ethyl (76.54%) and FdB type XF 3% alone (71.44%). This combination also showed the highest efficacy rate (84.46%), surpassing chlorpyrifos-ethyl (78.62%) (Figures 2A and 3A). At the Ennadhour site, the highest final corrected mortality rate was recorded after the third application of Farina di Basalto® type XF 3% mixed with mineral oil 1%, reaching 100%, followed by 95% for FdB type XF 3% alone. These treatments also demonstrated the highest efficacy rates (Figures 2B and 3B).

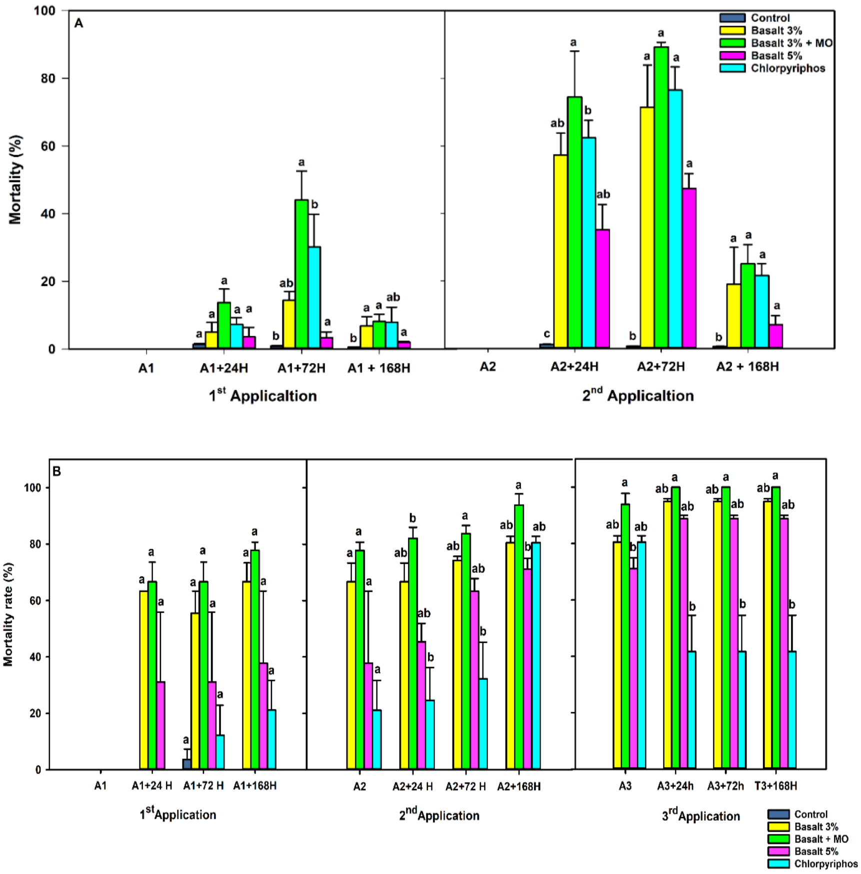

Figure 2. Effect of different treatments applied on the corrected mortality rate of *D. opuntiae* at El Kalâa Soghra (A) and Ennadhour (B). Values are means ± standard error (n = 3). Different letters indicate significant differences between treatments (Mann-Whitney U test, P < 0.05).

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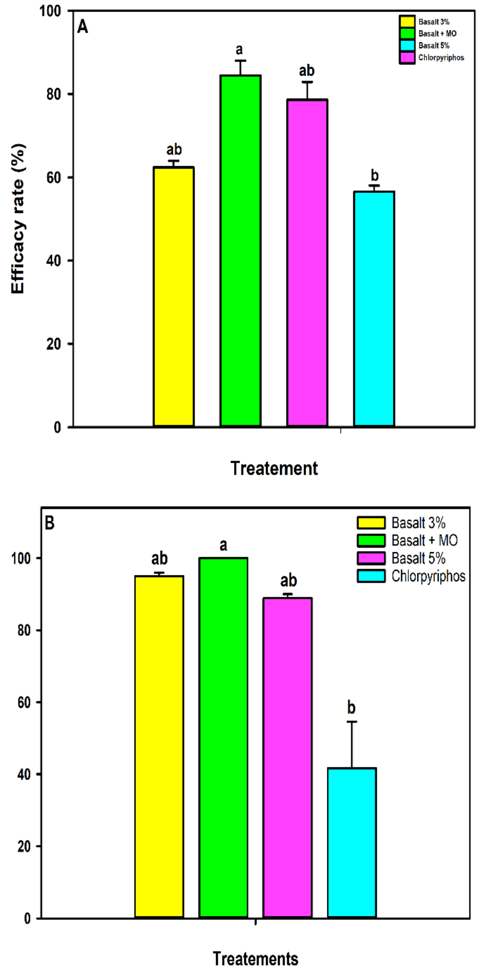

Figure 3. Efficacy rates of different treatments applied in the control of *D. opuntiae* at El Kalâa Soghra (A) and Ennadhour (B). Values are means ± standard error (n = 3). Different letters indicate significant differences between treatments (Mann-Whitney U test, $P < 0.05$).

4 DISCUSSION

The first application of Farina di Basalto (FdB) Type XF at 3% combined with horticultural mineral oil (MO) at 1% resulted in adult female mortality rates of 44.11% and 77.78% at the El Kalâa Soghra and Ennadhour sites, respectively. This initial treatment was associated with visible degradation of the cuticular wax layer,

a key protective barrier in scale insects. The second application markedly increased the mortality, reaching 89.29% and 93.70% at El Kalâa Soghra and Ennadhour, respectively. Notably, a third application at Ennadhour site achieved complete mortality (100%) of adult females.
While the exact way the FdB-HM combination works is not fully understood yet, its effectiveness is likely due to several overlapping, non-specific effects working together. These may include spiracular blockage leading to asphyxiation, disruption of the cuticle resulting in desiccation, and increased susceptibility to ultraviolet (UV) radiation due to the removal of protective wax and lipid layers (Ramdani et al., 2020). The removal of these hydrophobic surface compounds exposes the insect's body to environmental stressors, accelerating dehydration and mortality. The lethal effects of soaps and detergents on arthropods have been attributed to multiple mechanisms, including the removal of protective wax layers, disruption of cell membranes, repellency, dislodgement from plant surfaces, and drowning (Curkovic, 2016).
Previous studies have documented the broad-spectrum insecticidal properties of basalt flour against various economically important pests, including stored-product insects, aphids, thrips, leaf beetles, fruit flies, date moths, citrus leaf miners, and citrus mealybugs (Elimem et al., 2020, 2021, 2022, 2023; Lahfef et al., 2023). The insecticidal activity of basalt-based products has been partly attributed to their high silicon content, which is absorbed by plants primarily as monosilicic acid (H_4SiO_4) (Rodrigues et al., 2011). Silicon accumulation in plant tissues contributes to bolster crop resilience against pathogens and pests by forming a mechanical barrier that impedes feeding. Additionally, silicon may induce biochemical responses, such as the enhanced synthesis of defensive secondary metabolites including tannins and phenolic compounds, which act as feeding deterrents or toxic agents (Ahire et al., 2021; Rinder and Hagke, 2021; Lahfef et al., 2023). Thus, this rock dust can effectively suppress insect populations and mitigate crop damage without causing their complete eradication, thereby preserving ecological balance and minimizing the risk of resistance development. Its moderate yet sustained action supports the establishment of a resilient agroecosystem, progressively reducing the dependence on intensive pest control interventions.
Otherwise, Basalt, applied as a powder, acts against pests by altering the pH of aerial plant surfaces from mildly acidic, preferred by most pests, to slightly alkaline, and through mechanical effects that disrupt the insect’s body, including their eyes and tracheae (Stoleru and Sellitto, 2016).
Importantly, the use of basalt-based treatments aligns well with principles of ecological safety and sustainable agriculture. Unlike synthetic chemical insecticides, which often present risks of environmental contamination, non-target effects, and resistance development, FdB and MO are derived from naturally occurring substances with minimal ecotoxicological footprint. Their multi-target, mechanical modes of action reduce the likelihood of resistance development and support their compatibility within integrated pest management (IPM) frameworks. Furthermore, the absence of harmful residues and the preservation of beneficial arthropod populations reinforce the ecological sustainability of these treatments,

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offering a viable and environmentally responsible alternative for managing *D. opuntiae* infestations in cactus agroecosystems.

5 CONCLUSION

This study highlights the potential of basalt flour, especially when combined with mineral oil, as a natural and sustainable solution for managing *D. opuntiae* infestations in cactus crops. The treatment with 3% Farina di Basalto® type XF and 1% mineral oil consistently performed well, significantly reducing pest numbers and preventing the appearance of new individuals. These results suggest that basalt-based treatments can play a valuable role in sustainable agriculture, offering a safer and more environmentally responsible alternative for pest control.

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Conflict of Interest
The authors declare no conflict of interest.

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