



Nectar feeding by the Arabian sunbird (*Cinnyris hellmayri*) and its potential role in the pollination of *Aloe dhufarensis* in Oman

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ABSTRACT

Pollination interactions remain poorly documented in Oman, particularly for endemic and threatened plant species, representing a major geographic gap in pollination ecology. We report field observations of floral visitation, pollen movement, and putative pollination in *Aloe dhufarensis*, a species restricted to the monsoon-influenced mountains of southern Oman and southeastern Yemen. Observations were conducted over approximately 150 min by four independent observers and encompassed several hundred open flowers. Visitation was overwhelmingly dominated by the Arabian sunbird *Cinnyris hellmayri*, with more than 200 visits recorded and consistent contact with floral reproductive structures. Occasional visits by a nemestrinid fly (*Nemestrinus* sp.) and the honeybee *Apis florea* were also documented. Sunbirds consistently accessed nectar while perched and inserted their bills deeply into the floral tube, frequently aligning the bill coaxially with the corolla through active cervical torsion, and contacting reproductive structures. Position-dependent floral orientation and flexible pedicels facilitated this interaction by allowing near-coaxial alignment between the bill and floral tube, potentially promoting efficient nectar access and opportunities to pollen transfer. In addition, fruit set was relatively high in the study population, with around 64% (± 24 SD) of the flowers setting fruits. These observations provide baseline evidence of avian pollination in *A. dhufarensis* and highlight the need for further studies of plant-pollinator interactions in southern Arabian Peninsula.

Pollination interactions involving endemic and threatened plant species remain poorly documented in large parts of the Arabian Peninsula, despite their potential relevance for conservation and management. This lack of information is particularly evident in Oman, where empirical data on plant-pollinator interactions remain scarce and are largely restricted to a limited number of focal studies (Monks, 2021). Here, we report field observations of floral visitation, pollen transport, and putative pollination of *Aloe dhufarensis* Lavranos (Asphodelaceae), a narrow-range species restricted to the Dhofar Mountains of southern Oman and adjacent southeastern Yemen (Al-Khulaidi, 2021), by the Arabian sunbird *Cinnyris hellmayri*. This aloe species is considered threatened due to its narrow distribution, habitat degradation and increasing anthropogenic pressures (Al-Khulaidi, 2021). It occurs on open montane slopes characterised by exposed rocky terrain, sparse shrub cover and limited soil development, where individuals grow

directly on shallow, well-drained rocky substrates, often rooted in crevices or pockets of coarse mineral material between exposed stones. Plants typically occur as isolated individuals or small clusters and are visually conspicuous against the surrounding low and stunted vegetation (Fig. 1). Flowering individuals produce erect, branched inflorescences bearing numerous tubular, reddish to salmon-coloured flowers. Flowers open sequentially along the inflorescence, with flowers opening acropetally and showing position-dependent orientation along the raceme. Breeding-system data are currently unavailable for *A. dhufarensis*. However, studies in other *Aloe* species frequently report very low reproductive success after self-pollination, often consistent with late-acting self-incompatibility (Hargreaves et al., 2012), indicating strong dependence on effective animal-mediated pollen transfer. Nevertheless, self-compatible exceptions have been documented in some species (Patrick et al., 2018). Consequently, reproductive output in

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Fig. 1. Habit and flowering individual of *Aloe dhufarensis* Lavranos growing on exposed rocky substrate in the Jabal Samhan massif (Dhofar Mountains, southern Oman). The species occurs on shallow, well-drained rocky slopes and produces erect, branched inflorescences bearing numerous tubular, pinkish flowers, predominantly oriented horizontally to slightly pendulous.

this species may depend strongly on effective animal-mediated pollen transfer, as reported for several other *Aloe* species (e.g. Botes et al., 2009; Diller et al., 2022).

Field observations were conducted in the Jabal Samhan massif (Dhofar Mountains, southern Oman; 17°07'24.2"N 54°44'19.5"E) on 25 January 2026 between 11:30 and 14:00 h. The study area encompassed

approximately 5000 m² of open montane habitat characterized by exposed rocky terrain, sparse shrub cover and limited soil development. The landscape is dominated by fractured bedrock and coarse rocky substrates, with vegetation occurring in discontinuous patches, typical of monsoon-influenced mountain environments in southern Dhofar (Fig. 1). Four independent observers simultaneously monitored different groups of flowering plants to avoid overlap in observations. Each observer conducted approximately 150 min of observations, yielding a cumulative effort of approximately 600 observer-minutes across several flowering individuals and several hundred open flowers. Observations were restricted to a single day and a limited temporal window. Consequently, although several hundred open flowers were monitored, additional floral visitors occurring at other times of the day or during different periods of the flowering season cannot be excluded. During the observation period, we recorded more than 200 feeding visits by male and female individuals of *Cinnyris hellmayri*, which overwhelmingly dominated the visitation spectrum. A visit was defined as a discrete foraging event in which an individual approached and fed on one or more flowers before departing from the focal plant. In contrast, only 18 visits by a large nemestrinid fly (*Nemestrinus* sp.) and three visits by *Apis florea* were observed. Although the exact number of sunbird visits was not formally quantified in the field, they accounted for the overwhelming majority (>95%) of recorded floral interactions.

The floral architecture of this aloe species allows visiting birds to access nectar by perching directly on the inflorescence branches and erect plant leaves rather than hovering. Observed individuals of *Cinnyris hellmayri* consistently foraged while perched, inserting the bill into the floral tube and contacting the anthers and stigma with the bill and facial region (Fig. 2). Video recordings documenting these interactions were obtained using a Canon Legria HF G30 video camera. In several instances, pollen grains were visibly adhering to the feathers surrounding the bill (rictal and supraloral feathers), providing direct evidence of pollen transportation. During nectar feeding, these facial regions repeatedly entered deeply into the floral tube and frequently contacted reproductive structures, suggesting opportunities for pollen transfer. Video recordings of both male and female individuals revealed a consistent pattern of nectar access tightly linked to floral orientation and position along the inflorescence. Flowers opened acropetally, and their orientation varied with position: basal flowers were typically strongly declinate to pendulous, whereas medial and distal flowers were oriented more horizontally. Sunbirds accessed nectar exclusively while perched, either directly on the inflorescence axis or on the basal rosette leaves. Recent studies indicate that perch availability can strongly influence feeding position and flower-probing behaviour in sunbirds, introducing substantial behavioural flexibility beyond expectations based solely on floral morphology (Johnson et al., 2020; van der Niet, 2024). Basal flowers, oriented downward, were accessed from lower perches, whereas medial and distal flowers were mainly approached laterally while perched on the inflorescence axis. During nectar feeding, the bill was inserted deeply into the floral tube, typically aligned nearly coaxially with the longitudinal axis of the corolla. In addition to floral orientation facilitating coaxial access, sunbirds exhibited pronounced cervical mobility, actively torsioning the neck to align the bill with the longitudinal axis of the corolla, even when the body axis remained oblique relative to the flower (Fig. 2G and H). This behavior, observed in both males and females, enables precise coaxial insertion of the bill and facilitates repeatable positioning of the head within the floral tube during nectar extraction, a configuration consistent with effective contact with reproductive structures. In many instances, the flexible pedicel allowed passive reorientation of the flower during probing, further facilitating alignment between the floral tube and the bill. Together with active cervical torsion and the availability of alternative perching positions, these observations suggest a degree of behavioural flexibility that may facilitate effective nectar extraction despite variation in floral orientation. This pattern was observed consistently across multiple individuals and in both sexes (Fig. 2).

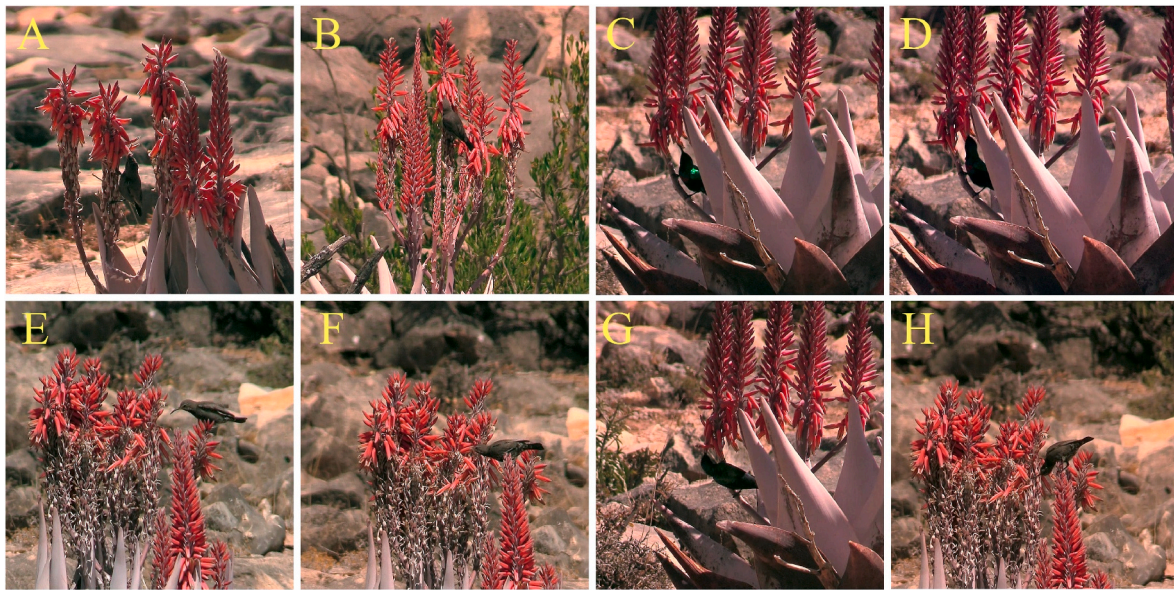


Fig. 2. Perch-mediated nectar feeding by *Cinnyris hellmayri* on *Aloe dhufarensis*. (A–D) Access to basal flowers from lower perches on leaves or inflorescence branches. (E–H) Access to medial and distal flowers while perched on the inflorescence axis or adjacent branches. Birds inserted their bills deeply into flowers while contacting reproductive structures. Images also illustrate variation in flower orientation and body positioning during nectar feeding.

In addition to sunbirds, *Nemestrinus* sp. visited 18 times during the observation period. Individuals accessed nectar using their elongated proboscides and frequently inserted their mouthparts deeply into the floral tube during visits, potentially allowing contact with reproductive structures. Although visitation frequency was considerably lower than that of sunbirds, these observations suggest a possible contribution to pollen transfer. However, given the observational nature of this study, their effectiveness as pollinators remains unknown. Although Nemestrinidae are documented in neighbouring countries such as Saudi Arabia and Egypt (El-Hawagry et al., 2022), as far as we know, there are no published records of this family from Oman, underscoring broader gap in ecological knowledge of flower-visiting flies in southern Arabia. Only three visits by *Apis florea* were recorded during the entire observation period, suggesting a marginal role for this species as a floral visitor at this site and period of the year. This pattern of visitation is consistent with previous studies on tubular-flowered *Aloe* species, where bees have been shown to be relatively inefficient pollinators compared to birds (Botes et al., 2009; Diller et al., 2022).

Fruit set was quantified on two floral scapes per individual in 12 plants (24 scapes in total), once flowering had finished. Because flower positions and persistent pedicels remained clearly visible on the scapes after anthesis, we recorded the total number of flower positions and the number of developed fruits on each scape, and calculated fruit set as the percentage of flowers producing fruits. Mean fruit set was $64 \pm 24\%$ (SD), indicating that a substantial proportion of flowers developed into fruits under natural pollination conditions. Together, these observations support the hypothesis that the documented visitors, particularly *C. hellmayri*, contribute meaningfully to reproductive success in *A. dhufarensis*.

Notably, only four species of sunbirds occur in Oman (Avibase, 2026). Although other sunbird species are listed for Oman, only *C. hellmayri* was observed visiting *A. dhufarensis* during our survey. This may reflect local differences in distribution, habitat use, relative abundance or floral preferences among sunbird species, but our limited temporal sampling does not allow us to exclude occasional visits by other species. Despite the presence of nectarivorous sunbirds in Oman, quantitative field evidence documenting bird-mediated pollination in native plant species remains scarce or absent. To evaluate whether bird-mediated pollination had previously been documented in native plant species from Oman and southern Arabia, we conducted a targeted

search of the peer-reviewed literature using indexed scientific databases and complementary reference screening. Despite this effort, we were unable to locate field studies providing quantitative evidence of bird-mediated pollination in native Omani plant species. To the best of our knowledge, the interaction documented here therefore represents one of the first reported cases in the region. In neighbouring parts of southeastern Arabia, bird pollination is also considered poorly represented in the literature, with only limited and often tentative mentions, such as reports of *Cinnyris asiaticus* visiting *Aloe* species in the United Arab Emirates (Brown and Feulner, 2024).

To our knowledge, this is one of the very few documented cases of pollination interactions involving endemic plants in Oman, and the first for *A. dhufarensis*. Beyond isolated studies on a small number of woody taxa, such as investigations on floral traits and pollinator attraction in *Boswellia sacra*, empirical information on pollinator assemblages in the region remains extremely limited (Mariotti Lippi et al., 2011). This lack of data represents a significant gap, particularly in the monsoon-influenced mountains of southern Arabia, where many plant species have narrow distributions and are exposed to increasing environmental pressures.

By documenting these interactions, we aim to highlight the importance of incorporating pollination ecology into conservation assessments of threatened endemic plants in southern Arabia. Improved knowledge of plant-pollinator interactions is essential to understand the vulnerability and resilience of these systems and to design effective conservation strategies. Given the narrow distribution of *Aloe dhufarensis* in monsoon-influenced montane habitats and the ongoing habitat degradation and increasing anthropogenic pressures reported for this species (Al-Khulaidi, 2021), documenting its pollination interactions is essential to support effective conservation planning in the Dhofar Mountains. We hope that this note will encourage further field-based studies on pollination ecology in Oman and contribute to a broader recognition of the region as a priority area for the study of biotic interactions.

On the other hand, the consistent association between floral orientation and perch position observed in *Aloe dhufarensis* provides functional support for biomechanical models predicting that nectar-feeding efficiency in sunbirds depends on spatial alignment between flowers and perching substrates (Johnson et al., 2020). The combination of position-dependent floral orientation, flexible pedicels, and active

cervical adjustment facilitates near-coaxial alignment between the bill and the corolla, promoting consistent contact with reproductive structures. Similar functional relationships between floral morphology and pollen transfer efficiency have been documented in other *Aloe* species (Hargreaves et al., 2019; Diller et al., 2019). Together, these observations provide behavioural and functional evidence supporting the role of *Cinnyris hellmayri* as a legitimate pollinator of *A. dhufarensis*. Fruit production under natural conditions was relatively high and, together with observed visitation patterns, is consistent with a potential contribution of floral visitors to reproductive success. However, exclusion experiments and controlled pollination studies would be required to determine the relative contribution of birds and other floral visitors.

CRedit authorship contribution statement

Luis Navarro: Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Garbiñe Ayensa:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing. **Adela González-Megías:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing. **José María Gómez:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Luis Navarro reports article publishing charges was provided by Conference of Rectors of the Spanish Universities. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jaridenv.2026.105663>.

Data availability

Data will be made available on request.

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