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Conservation Need for a Plant Species with Extremely Small Populations Linked to Ephemeral Streams in Adverse Desert Environments

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Abstract: Many thousands of tree species are declining in the world, for which conservation actions are urgent. This dramatic situation is particularly evident for trees closely related to freshwater ecosystems, considered the environments most threatened by global change. In extremely arid environments such as deserts, where the few plant species present are able to survive by exploiting the little water available, the situation is extremely critical. A representative case is *Vachellia gerrardii* subsp. *negevensis*, a tree with a wide distribution range but locally restricted to small and isolated populations. Knowledge about this tree is incomplete in Iraq and, to fill this gap, several surveys were conducted in the Al-Najaf desert over three years (2019–2021). In each locality where this species was found, several ecological and population parameters were recorded. Our results indicate that *Vachellia gerrardii* subsp. *negevensis* was restricted to a single population, fragmented into five subpopulations confined in extremely peculiar ecological niches. Several threats related to anthropogenic activities and climate change affect the population, causing a significant reduction in the population size combined with a continuous decline in habitat quality and number of mature plants. Despite this critical situation, there are no conservation measures for this species. The establishment of a national preserve or part would be important and constitutes the fundamental prerequisite for the conservation of multiple species.

Keywords: *Acacia gerrardii* subsp. *negevensis*; Al-Najaf desert; conservation; endangered tree; freshwater plants; *Vachellia gerrardii* subsp. *negevensis*

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1. Introduction

Biodiversity is declining globally and current estimates indicate that 39% of plant species are at risk of extinction [1]. This alarming situation significantly affects a large percentage of tree species considered as flagship species such that it was estimated that 30% of tree species are threatened with extinction, and at least 142 tree species are recorded as extinct in the wild [2–4]. Accordingly, for numerous tree species that grow in various regions of the world reduced to a small relict population, or recently rediscovered e.g., [4–6], urgent conservation actions are required, considering that individual tree species often play a fundamental role in their ecosystems, such as food sources for herbivores, providing nesting habitats, shade, and filling a central role in nutrient cycling, among others.

Freshwater ecosystems, classified as temporary [7], are considered an important resource in desert environments providing vital resources for a wide range of *taxa* as well as valuable ecosystem services for local people [7]. Despite their importance, these freshwater ecosystems and their inhabitants are less well studied than those in mesic environments [7–10]. They are also among the world's most threatened ecosystems, with water extraction, habitat degradation, and flow modification directly impacting biodiversity and ecosystem functions [11–15]. In particular, in recent decades, inland waters are being subjected to abnormal levels of impacts from human activities as well as the effects of climate change [12–14,16]. These threats are intensified further by the natural isolation of freshwater habitats [17,18]. All these threats are expected to further increase the fragmentation of desert freshwaters. Persistence in fragmented desert freshwaters, which are typically spatially and temporally variable, often requires that species maintain wide geographic ranges to enable dispersal when hydrological connectivity allows (i.e., during floods); such connectivity is also spatially and temporally variable [19–21]. As a consequence, the resultant modifications of several ecological parameters caused by these threatening factors could have strong effects on the distribution of many riverine species e.g., [22,23]. Freshwater-related plants, among vascular plants, are an especially relevant and sensitive group to human impact, with a larger proportion of endangered species than the average [24]. Recently, climate change has imposed new selection pressures towards the distribution of freshwater-related plants e.g., [25–27]. This scenario is particularly exacerbated when the amount of superficial water is naturally scarce like in deserts and where the survival capacity of organisms is closely related to the ability to adequately exploit this situation of severe aridity. The effects of climate change and rising temperatures could alter this fragile equilibrium and cause a contraction of the distribution range of numerous species present in such extreme environments. In this context, it is essential to monitor and study this interesting biodiversity in order to have the basic knowledge necessary to activate, if necessary, adequate conservation actions.

Acacia sensu lato (including the genus *Vachellia* [28]) is defined as a 'keystone genus' due to the significant ecological role in the dryland ecosystems; in fact, these plants influence soil conditions and plant composition [29–32], but some species developed particular adaptations for survival in extreme arid environments. In addition, the shadow of *Acacia* trees is essential for the water and energy conservation of several animal and plant species [33–35]. *Vachellia gerrardii* subsp. *negevensis* (basionym: *Acacia gerrardii* Benth subsp. *negevensis* Zohary [28]) is a tree with irregular distribution and is found in an area ranging from the eastern Mediterranean to southwestern Asia (i.e., Israel, Palestine, Jordan, Iraq, Kuwait, and Saudi Arabia). This species tree is able to grow in environmental situations characterized by severe aridity like deserts where this plant survives owing to its ability to effectively utilize by its extensive root system the small amount of surface water transitorily available in the ephemeral streams and the ground water. Although this plant species has developed particular adaptations for survival in extreme environments, reduction in water availability can affect its demographic patterns and its mortality rates, resulting in increased mortality in relation to the reduction of water availability [36].

This species is of great importance in the regions in which it grows for various reasons: (i) it characterizes these landscapes and forms peculiar plant communities, (ii) it improves the fertility of the soil by nitrogen fixation, and (iii) is a socio-economic resource providing animal fodder and wood for the energy demands of the local population [37]. However, data on the ecology, distribution, and population size of this interesting tree are generally fragmented and unclear in countries such as Kuwait and Saudi Arabia [38]. Also in Iraq, the knowledge of this species, its current distribution, and conservation status remain contradictory. The oldest record indicated the presence of c. 30 individual trees in 1947, which was reduced to a single tree in the 1960s–1970s [39]. Afterward, Thalen [40] reported the presence of a small group of plants in a single locality in the southern desert, while more recently 758 plants have been registered [37].

Given the extirpation risks posed to this tree and the additional dispersal constraints on this species in the neighboring areas, it is critical to constantly update the knowledge on the conservation status of *Vachellia gerrardii* subsp. *negevensis* in Iraq to propose an adequate conservation strategy.

2. Materials and Methods

The genus *Acacia* Mill. (Leguminosae, *Mimosoideae*) shows a pantropical distribution and includes approximately 1500 species [41]. Recent molecular studies have shown that this genus is polyphyletic and, consequently, it has been split into at least five different genera [28]. However, one of them, *Vachellia* Wight and Arnott, still includes species with several phenotypic similarities that make their taxonomic distinction rather difficult, especially when the species distribution ranges overlap, as in Middle East and Arabian Peninsula [38]. An example of this unclear taxonomic situation is represented by the Talh tree *Acacia gerrardii* Benth. subsp. *negevensis* Zohary, now referred to as *Vachellia gerrardii* (Benth.) P.J.H. Hurter subsp. *negevensis* (Zohary) Ragup., Seigler, Ebinger, and Maslin [28].

Starting from the most updated data reported in Al-Rammahi and Mohammad [37], to have an accurate picture of the ecology, distribution, and conservation status of *Vachellia gerrardii* subsp. *negevensis* in Iraq and to be able to propose adequate conservation measures, several surveys in the Al-Najaf desert were conducted from February 2019 to March 2021. A total of 26 field trips that lasted for 47 days were conducted throughout the entire study area. In particular, a systematic and comprehensive search throughout the Al-Najaf desert was planned with particular attention to areas close to ephemeral streams and all wadis. In each locality where this species was found, the eco-geographic characteristics, position (with a GPS), number of individuals, number of mature trees producing fruits, and main threats were recorded. Each tree was identified with a unique number along with GPS coordinates. The population size was determined by a direct count of the total number of plants and the demographic trend of the population was elaborated as the ratio between the number of mature individuals present in the two consecutive surveys. Major threats to *Vachellia gerrardii* subsp. *negevensis* were identified through repeated field observations, and categorized following the IUCN Threats Classification Scheme (version 3.2; [42]).

To verify and update, if necessary, the extinction risk of *Vachellia gerrardii* subsp. *negevensis* the Red List criteria at regional levels guidelines for their application [43] were used. Specifically, considering the available data, the B, C, and D criteria have been considered. Specifically, Criterion B refers to geographic range size, and fragmentation, number of locations (*sensu* IUCN), decline or fluctuation; criterion C refers to small and declining population size and fragmentation, or few subpopulations and, finally, criterion D refers to a very small population or very restricted distribution [43]. To apply criterion B, the Extent of occurrence (EOO; the area contained within the shortest continuous imaginary boundary that could be drawn to encompass all known sites of occurrence of a *taxon*, excluding cases of vagrancy) and the Area of occupancy (AOO—the area within its 'extent of occurrence' which is occupied by a *taxon*, excluding cases of vagrancy) were calculated from the distribution records. To estimate EOO, the minimum convex polygon that included all the occurrences was drawn [43] with unsuitable areas excluded by deriving the correspondent α-hull using the Delauney triangulation [43–45] The EOO and AOO values were automatically calculated by using a dedicated software (GeoCAT–Geospatial Conservation Assessment Tool; [46]). To assess the C and D criteria, only the mature individuals (*sensu* IUCN) were considered; in addition, according to updated guidelines [43], the individual trees that flower without producing viable seeds do not qualify as mature individuals and consequently do not contribute to the estimate of population size.

3. Result

Our results confirm that, in Iraq, *Vachellia gerrardii* subsp. *negevensis* is a small tree that has a height up to a maximum of 11 m (often 4–5 m) and grows on flan ephemerally wet, desert alluvial streambed (Birkat Al-Talhat). It also grows at the muddy base of large wadis (Abu Talah and Weier streams; Figure 1). In this ecological context, this species survived owing to its ability to effectively utilize the small amount of surface water transitorily available in the ephemeral streams and the ground water. *Vachellia gerrardii* subsp. *negevensis* flowers from April to December and bears fruits from October to February, producing a large number of seeds. Ripe seeds were collected and then stored at the laboratory; however, only 10% of them were suitable for germination because over 90% was infested with bruchid insects and unable to germinate.

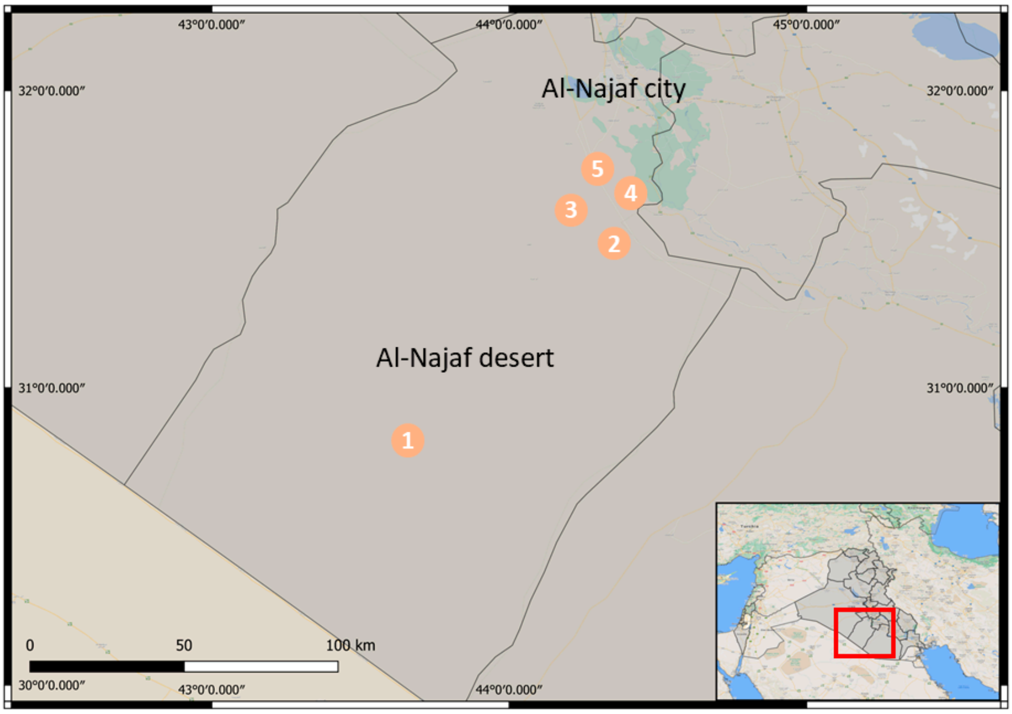

Figure 1. Locations of the five subpopulations of *Vachellia gerrardii* subsp. *negevensis* in the Al-Najaf desert (Iraq): (**1**) Birkat Al-Talhat, (**2**) Abu Talah stream (mid part), (**3**) Weier stream (initial part), (**4**) Abu Talah stream (terminal part), (**5**) Weier stream (terminal part).

Our results confirm that, in Iraq, a single population of *Vachellia gerrardii* subsp. *Negevensis* is present, fragmented into five localities (called subpopulations hereafter) of variable sizes and affected by several severe threats (Table 1; Figure 2). Four subpopulations are close to one another (2–10 km as the crow flies), while the last one (Birkat Al-Talhat; no. 1 in Figure 1), which includes the largest number of individuals, was isolated and <70 km away from the nearest subpopulation.

The Iraqi population in 2020 comprised a total of 758 individuals, 287 of which are mature plants. However, 128 mature plants, although blooming, do not produce seeds, which significantly reduces the number of reproductive individuals. Currently, the number of mature plants that effectively produce seeds considerably varies among the subpopulations, and, in two of these, they are reduced to only two individuals, which poses serious problems for their persistence in the future (Table 1).

Table 1. Characteristics of the five known subpopulations of *Vachellia gerrardii* subsp. *negevensis* in Iraq. The major threats are reported according to their importance, starting with the most impacting, and are indicated according to the following IUCN codes [42]: 2.3 = Nomadic grazing; 3.2 = Mining and quarrying activities; 5.3 = Logging and wood harvesting; 6.1 = Recreational activities; 6.2 = Military exercises; 8.1 = Invasive non-native/alien species; 8.2 = Problematic species, pests; 11 = Climate Change.

Locality	No. of Plants (2020)	No. of Mature Plants (2020)	No. of Mature Plants Producing Seeds (2020)	No. of Plants (2021)	No. of Mature Plants (2021)	No. of Mature Plants Producing Seeds (2021)	Seedling Recruitment	Main Threats	Historical Population Trend (Last 10 Years)
Birkat Al-Talhat	275	122	84	210 (−23.6%)	81	81 (−4%)	Yes	5.3; 8.2; 11; 2.3; 6.1; 6.2.	Continuous decline
Abu Talah stream (mid part)	204	75	39	204	70	39	Yes	5.3; 8.2; 11; 2.3; 6.1.	Continuous decline
Abu Talah stream (terminal part)	52	8	2	50 (−4%)	6	0 (−100%)	Yes	5.3; 8.2; 11; 2.3; 6.1; 6.2.	Decline
Weier stream (initial part)	221	80	32	221	80	32	No	5.3; 8.2; 11; 2.3; 6.1; 6.2.	Stable
Weier stream (terminal part)	6	2	2	6	0	2	No	5.3; 8.2; 11; 2.3; 6.1; 3.2; 8.1.	Continuous decline
Total	758	287	159	691 (−8.9%)	237	154 (−3.2%)			

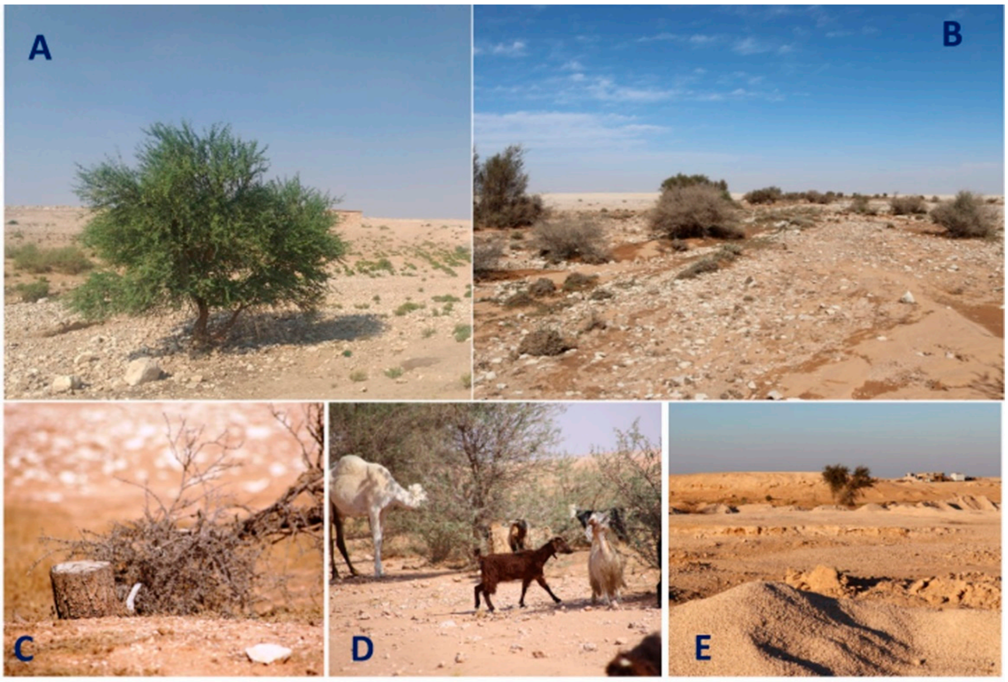

Figure 2. In the upper part an isolated tree of *Vachellia gerrardii* subsp. *negevensis* (**A**) and a representative image of the habitat where this species is found (**B**). In the lower part, the effects of the main threats on the species: cutting (**C**), unregulated grazing (**D**), and quarrying activities (**E**).

Despite these critical issues, a high number of seedlings was observed in some subpopulations, although most of these seedlings disappeared within a month mostly through grazing by goats and sheep (Table 1). More in general, it is evident that *Vachellia gerrardii* subsp. *negevensis* is affected by several threats, many of which are related to anthropogenic activities. In fact, excluding the effects of ongoing climate change related to global warming and pest infestations mentioned above, the main threats are linked to the activities of the local population (Bedouins) and tourists, which frequently use the main stem and branches for fuel (out of 287 mature trees, 124 were recently damaged) and the nomadic grazing of large herds of sheep, goats, and camels, thereby affecting the seedlings and young plants. Localized threats are represented by the introduction of invasive species such as *Vachellia farnesiana* (L.) Wight and Arn., continuous military activities, increasing use of off-road cars as well as the presence of a quarry for the extraction of sand and gravel materials (Table 1; Figure 2).

The previous knowledge of these subpopulations indicates a historical reduction of >30% in the population size occurred in the last 10 years as a consequence of the pressure exerted by several threats (Table 1). In particular, our monitoring data show a significant decline in the regional population size that took place in 2021 (8.9% compared to the consolidated population data of 2020); this decline mostly affected two subpopulations and in one of these (Birkat Al-Talhat, the most important area of *Vachellia gerrardii* subsp. *negevensis* and the only site where seedling recruitment is effective), a reduction of ≈24% of the overall plants was documented (Table 1). The decline observed in Abu Talah stream (terminal part) is also significant although more limited in number, since it led to the disappearance of all adult individuals producing seeds in this subpopulation (Table 1).

Following the Criterion B, the current EOO (Extent of Occurrence) and AOO (Area of Occupancy) are 680.73 km^2 and 72 km^2, respectively. Based on the main threat (5.3.2: Intentional use), five locations have been identified. Habitat quality and the number of mature individuals are declining in all sites, and a reduction of EOO and AOO is likely to affect the species in the near future. According to Criterion C, the population is composed of less than 2500 mature individuals, subjected to a continuous decline, and no subpopulation has more than 250 mature plants. According to Criterion D, the Iraqi population consists of

287 mature trees, 128 of which, even though they bloom, do not produce seeds. All these factors—as well as the reduced EOO, AOO, the observed continuous decline in habitat quality, and the number of mature plants—enabled confirming the assessment of *Vachellia gerrardii* subsp. *negevensis* as Endangered (EN) species at the regional level.

4. Discussion

Acacia populations are affected by climatic changes, and it was demonstrated that the reduction in water availability is related to demographic patterns and mortality rates [29]. Our results indicate that *Vachellia gerrardii* subsp. *negevensis* is experiencing this critical situation. In the Al-Najaf desert, a severe ecological context, this species survived owing to its ability to effectively utilize the small amount of surface water transitorily available in the ephemeral streams and the ground water by its extensive root system. The climate of Al-Najaf desert is characterized by extremely hot summers and cool winters, with future scenarios indicating a global increase in temperatures due to global warming; in the last several years, in fact, temperature extremes reached 50 °C in southern parts of Iraq during summer [24], with maximum peaks of 54 °C in the southern desert [47]. The annual average of minimum temperature is increasing faster than maximum temperature and the overall temperature in Iraq is found to increase much faster compared to the global average [48]. Although precipitation is generally very low, the region receives transitory violent rainstorms in winter, which result in the uprooting of some trees [37,38]. These ecological conditions to which the plant is subjected could be particularly limiting for in situ germination and seedling survival [33].

Considering the lack of information on the dispersal capacity, the assumed "monophyletic" and ancient origin of this species [49–51], which, in the past, occupied most of the Al-Najaf desert supported by the relative proximity of all localities, all localities of *Vachellia gerrardii* subsp. *negevensis* were considered in this study, as a precautionary approach, as a single population fragmented into five subpopulations. Deeper analyses are needed to clarify the relationships that exist (or not) among these subpopulations. Our results confirm a worsening situation of the conservation status of this plant in Iraq, mainly due both to the effects of climate change and anthropogenic activities. The combined effects of natural change (a long-term drought period) and anthropogenic disturbance (dam construction) strongly negatively affect plant mortality and recruitment [29].

In this study, the same populations previously reported [37,38] are confirmed albeit with a substantial reduction in the population size. The observed causes of this reduction, at least in the last few years, are mainly attributable to human-related activities, while the effects of climate change are harder to quantify in these ecological contexts. However, there is indirect evidence such as the spread of invasive species which could be favored both by climate change e.g., [27,52,53], and human pressure like the increasing abundance of *Vachellia farnesiana* (L.) Wight and Arn. in the terminal part of Weier stream.

Although our updated data confirm the previous IUCN assessment of *Vachellia gerrardii* subsp. *negevensis* [38], considering the continuous decline and the dramatic and abrupt reduction in the population size observed in the last year, in particular in the site most representative of this plant in Iraq, it is reasonable to consider a deterioration in the conservation status of the species in the near future, and this would have cascading effects on the entire food-web and cause a drastic loss of biodiversity considering the key role of this genus [32,33].

Despite the critical situation, there are no conservation measures for this species in Iraq. Based on our findings, an articulated conservation strategy is urgent and necessary to reverse the extinction trend for this tree. As a first precautionary measure, it would be useful to declare the distribution area of *Vachellia gerrardii* subsp. *negevensis* as a national nature reserve to legally protect this endangered tree. This official measure, which is fundamental for the subsequent steps of the conservation strategy, could favour ecotourism in the area, with economic benefits for the local population by motivating them to protect the natural resources of the territory. Additionally, it could support conservation actions for other threatened plants of conservation interest such as *Rhazya stricta* Decne [54]. Moreover, the suggestion of the nature reserve in the area is aimed to protect the biodiversity in its all shapes animals and plants. In fact, the study area embraces at least 12 species of conservation concern including the two mentioned plants, one vulnerable (VU) reptile *Uromastyx aegyptia* (Forskål. 1775) [55], nine birds assessed by Al-Rammahi and Mohammad [56] comprising the endangered (EN) species *Falco cherrug* (J.R. Gray. 1834), *Aquila nipalensis* (Hodgson. 1833), and *Neophron percnopterus* (Linnaeus. 1758), and the vulnerable (VU) *Aquila clanga* (Pallas. 1811), *Falco vespertinus* (Linnaeus. 1766), *Marmaronetta angustirostris* (Ménétrés. 1832), *Chlamydotis macqueeni* (Gray. 1834), *Streptopelia turtur* (Linnaeus. 1758), and *Lanius meridionalis* subsp. *aucheri* (Bonaparte. 1853). Furthermore, two mammals are also present—*Hyaena hyaena* (Linnaeus. 1758) assessed as VU [57] and *Felis margarita* (Loche. 1858), which was assessed as NT [58].

As a second step, a genetic characterization both at the population and subpopulation levels should be done. Since genetic data on threatened plant populations can facilitate the development of adequate conservation strategies, particularly for isolated species or those whose populations are reduced to a small number of individuals [59,60], in-depth genetic studies are needed as these populations have been geographically isolated from those in neighboring countries for a long time. This analysis would also make it possible to clarify the relationships between the Iraqi tree population and others of the same species not only to eliminate doubts about the existence of an endemic tree exclusive to Iraq (i.e., *V. iraqensis*) but also to define the genetic diversity of each subpopulation in order to identify potential sources for future population reinforcement.

After declaring the Al-Najaf desert as a national nature reserve, further practical conservation actions for *Vachellia gerrardii* subsp. *negevensis* could be implemented. Despite the reduced number of individuals producing seeds and the high rate of infested seeds, and although conservation in the Germplasm Bank represents precautionary (and economic) measures to preserve the population genetic variability, seed collection would be propaedeutic and crucial to activate translocation and transplantation programs to reverse the population decline, starting from ex situ multiplicated plants e.g., [61,62]. Such practices would be urgent for the two subpopulations subject to the most risk (the terminal parts of Abu Talah and Weier streams), accompanied by passive protective measures such as fences to eliminate uncontrolled grazing, as already largely experienced e.g., [38,62–64]. In any case, a specific monitoring program should be established to constantly monitor the conservation status of this threatened tree.

Finally, a sensibilization campaign aimed at raising the awareness of the local people and farmers may be a further key in ensuring the conservation of this endangered tree, since the main threats are attributable to reckless human activities. People should be informed and involved in protecting this species and its habitat because it represents a symbol for the community and its cultural identity.

This study of *Vachellia gerrardii* subsp. *negevensis* in Iraq is an example of the type of conservation approach required for several trees worldwide that are often poorly known or reduced to extremely small populations e.g., [5,6,62–64], many of which are close to extinction and for which their conservation has not received the popular and political support that it deserves.

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