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Diversity and conservation strategies of wild Orchidaceae species in the West Rif region (northern Morocco)

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Abstract

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The Rif Mountains of Morocco are rich in vascular plant species, particularly in species of the Orchidaceae family, and are considered one of the biodiversity hotspots of the Mediterranean region. To date, the diversity, distribution and threats to the Orchidaceae of the Western Rif have been little studied. The objectives of this study were to make an inventory of Orchidaceae species diversity, to assess human activities and ecological factors affecting the distribution and *in situ* conservation of Orchidaceae in the West Rif, and to prioritise conservation efforts. A total of 53 sites were surveyed during the growing and flowering seasons of Orchidaceae in the study area. During this study, 25 species and subspecies of the Orchidaceae family were recorded. The genus *Ophrys* was the most diverse of the seven Orchidaceae genera recorded during this study. However, the most abundant species was *Serapias parviflora* Parl. Four new taxa (*Ophrys phryganae* Devillers-Tersch. & Devillers, *Ophrys sicula* Tineo, *Ophrys tenthredinifera* subsp. *grandiflora* (Ten.) Kreutz and *Ophrys villosa* Desf.) were recorded for the first time in Morocco during this study. In the West Rif region, the main threats to Orchidaceae species are the cultivation of annual crops, deliberate fires, livestock grazing, harvesting of terrestrial plants, road construction, recreational activities, urban development, solid waste disposal, timber harvesting and expansion of tree plantations. The results of this study provide recommendations for the *ex situ* and *in situ* conservation of Orchidaceae species at national and regional levels.

Keywords: conservation programmes, distribution, human activities, *in situ* conservation, Moroccan orchids.

INTRODUCTION

The family Orchidaceae is one of the most species-rich and diverse families of flowering plants (Chase et al., 2015), comprising approximately 27 801 species (7.9% of angiosperms) belonging to 899 genera (Plant List, 2024). They are found in many terrestrial ecosystems and are divided into three main ecological groups: terrestrial, epiphytic and lithophytic. Species of this family are widespread and occur on most continents, even in the most extreme desert environments, with most species inhabiting tropical and subtropical regions (Dressler, 1981; Whigham & Willems, 2003; Delforge, 2006).

Wild Orchidaceae species are highly related to and dependent on other organisms such as insects, fungi and phorophytic trees for their growth, reproduction and survival, and could be indicator species for environmental and ecosystem health (Delforge, 2006; Akhalkatsi et al., 2014; Rasmussen & Rasmus-

sen, 2018; Luo et al., 2020; Xi et al., 2020). However, despite their ecological importance, geographical and taxonomic diversity, Orchidaceae are threatened by intrinsic and extrinsic factors such as habitat destruction, increasing soil salinity, recurrent fires, pests, diseases, abundance of highly specialised pollinators and the action of mycorrhizal fungi (Swarts & Dixon, 2009; Akhalkatsi et al., 2014; Rasmussen & Rasmussen, 2018). They are also threatened by legal and illegal trade for ornamental, medicinal and food purposes (Bellakhdar, 1997; Ghorbani et al., 2017; Hinsley & Roberts, 2017; Hinsley et al., 2018).

To ensure their conservation, many Orchidaceae species have been included in the Red List of the International Union for Conservation of Nature (IUCN) and in the Appendices of the CITES Convention. However, their global market is highly developed. Only 1060 taxa of the Orchidaceae family are classified as endangered or critically endangered in their native range, and six species are considered already extinct (3.8% of the family) (CITES, 2022; IUCN, 2023). Although all species of the Orchidaceae family found in Morocco are protected by Appendix II of the CITES Convention and by Law No. 29-05 of 2011 on the protection of species of wild fauna and flora and their trade (Government of Morocco, 2011), tubers of *Orchis* and *Ophrys* species are threatened by the illegal trade in their tubers (Bellakhdar, 1997).

The diversity of Orchidaceae species in the flora of Morocco is still insufficiently studied. This plant family includes about 40 taxa in the country (Fennane et al., 2014), but it is still low compared to Tunisia, where 50 taxa have been recorded (Martin et al., 2015). The main diversity of Orchidaceae species in Morocco is associated with the highly diverse landscape of the Rif Valley, with 38 taxa recorded in this region (Valdés et al., 2002). Apart from the general inventories by Valdés et al. (2002), Mateos & Valdés (2010), Chambouleyron (2012) and Vázquez et al. (2012), we did not find any specific studies on the inventory and conservation of Orchidaceae species in the Western Rif Valley area.

Research and monitoring efforts are crucial to understand, protect, and conserve the rare and endangered species populations (Taura & Gudžinskas, 2024), such as Orchidaceae species. This study aimed to reveal the diversity of the Orchidaceae family and identify the human activities and ecological factors affecting their distribution and *in situ* conservation in the West Rif area. It also aimed to prioritise conservation efforts and develop a decision-making tool for managers.

MATERIALS AND METHODS

The Western Rif is in the northeastern part of Morocco (Fig. 1). Following the floristic subdivision of Valdès et al. (2002), this area of 2152 km² extends from the Oued Laou to Jbel Moussa on the Strait of Gibraltar. This part of the Rif Valley contains numerous natural ecosystems (forest, coastal and marine ecosystems) of great bio-ecological value. Some of these ecosystems have been declared Sites of Biological and Ecological Interest, namely Jbel Moussa, the Smir Lagoon and the northern part of the Intercontinental Biosphere Reserve of the Mediterranean (ANEF, 2022).

The climate in this area is Mediterranean, sub-humid to humid. Annual precipitation ranges from 400 mm to more than 700 mm. Mean monthly temperatures vary between 6°C and 22°C, but can sometimes fall below 6°C. The number of dry months, when the recorded temperature (°C) is more than twice the precipitation (mm), ranges between three and five months in the subhumid area and never exceeds 4 months in the humid area (Mokhtari et al., 2014). The bedrock is limestone-dolomitic, overlying a Palaeozoic nappe of deformed sedimentary rocks and outcrops of crystalline nappe with metamorphic rocks in the northeastern part of the study area. The most important mountains are Jbel Moussa in the north and Jbel Kelti in the south (Michard, 1976).

Field surveys were carried out during three growing seasons, from 18 April 2021 to 3 June 2023, in natural and disturbed ecosystems in the area extending from Oued Laou to Jbel Moussa (Fig. 1). To ensure a representative geographical coverage of the study areas, different habitat types were visited, and some sites were visited several times, depending on the growth and flowering periods of the Orchidaceae species.

Before the field surveys, we analysed the methods and results of studies to determine the parameters that influence the diversity, distribution and conservation issues of Orchidaceae species (Amich et al., 2009; Vázquez et al., 2012; Djordjević et al., 2014; Aouadj et al., 2020, 2023; Babali et al., 2018; Pahl & Qumsiyeh, 2021). We selected nine parameters to assess and record during field surveys based on these

works. At each site, species diversity was assessed, and the number of Orchidaceae individuals in each species was counted. Vascular plant cover at each study site was estimated using the following scale: less than 5% (extremely sparse vegetation), 5–25% (very sparse), 25–50% (sparse), 50–75% (moderately dense) and 75–100% (very dense vegetation). We also recorded the geographical coordinates and altitude of the study site (m), exposure, slope (in %), and anthropogenic threats to the Orchidaceae species and associated plant groups. Anthropogenic threats to the studied species were identified according to the IUCN categories of human activities (IUCN, 2024).

Target species in the field were randomly searched throughout the study area. Once at least one individual of an orchid species was found, the study site and population were assessed and described using the nine established parameters. Recorded plants of the family Orchidaceae were identified according to their morphological characteristics using the available floras (Valdés et al., 2002; Fennane et al., 2014) and the specialised work of Delforge (2006). The nomenclature of the species recorded was verified and updated by consulting specialised databases (APD, 2024; Euro+Med, 2024).

RESULTS

Ecological preferences

During this study, a total of 53 sites were surveyed in 10 areas of the West Rif region (detailed characteristics of each study site are presented in Appen-

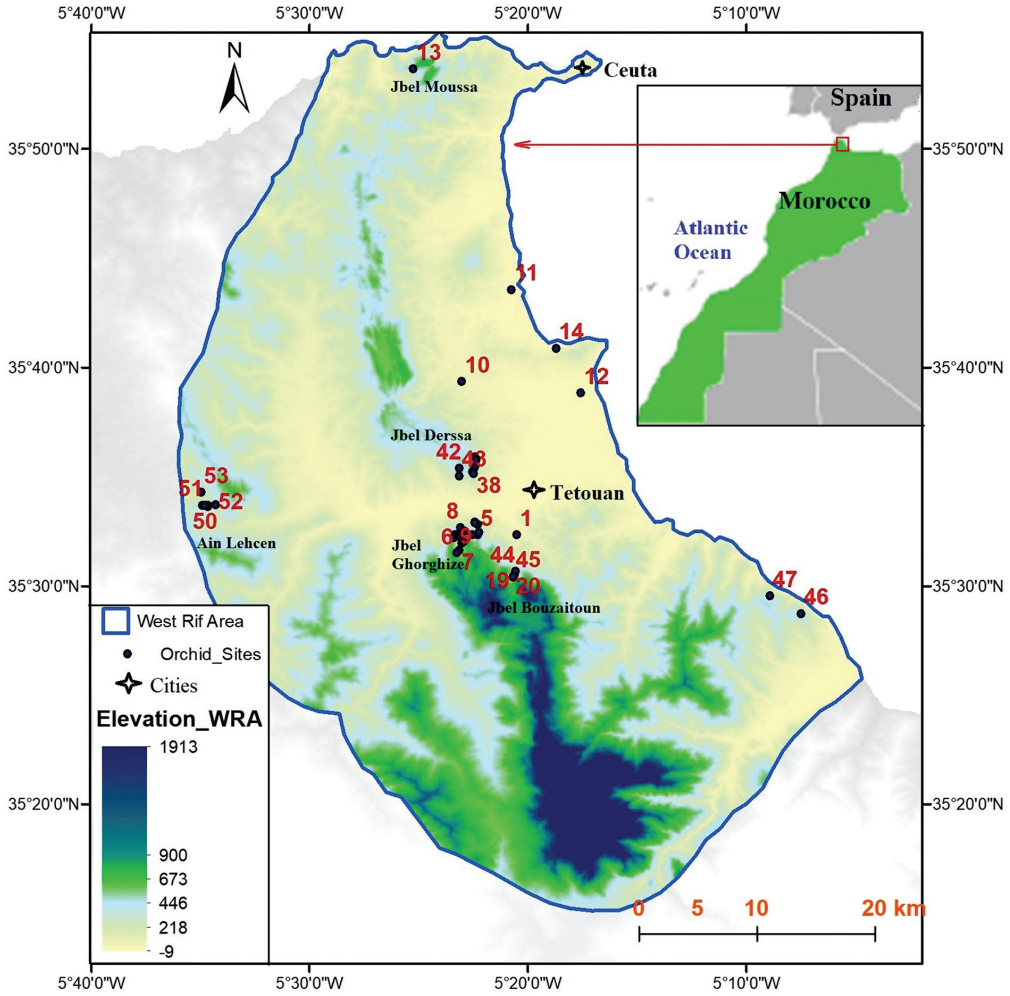

Fig. 1. Map of study sites in the West Rif region. Study sites: Ain Zarka (1), Jbel Ghorghiz (2–9, 15–17 and 21–35), Oued Ellil (10), Khandak Lkbir (11), Capo Negro (12 and 14), Jbel Moussa (13), Jbel Bozaytoun (18–20, 44 and 45), Jbel Derssa (36–43), Oued Laou (46 and 47), Ain Lahcen (48–53).

dix 1). The target species of the Orchidaceae family were observed at altitudes ranging from 71 to 696 m. Most surveyed sites were in Jbel Ghorghize and Jbel Derssa, with 26 and 8 sites, respectively. The analysis showed that most orchid species recorded preferred the northeastern and northern slopes, ranging from 5% to 75%. Most of the species analysed prefer sites with a plant cover between 50% and 100%, because denser plant cover retains soil moisture better, which is essential for most of the Orchidaceae species.

Species diversity

Twenty-five taxa of the family Orchidaceae, belonging to seven genera, were recorded at the study sites in the West Rif region (Table 1). The genus *Ophrys* was represented by the largest number of taxa, comprising 15 species and subspecies. However, the most common species in the study area was *Serapias parviflora* Parl., with 19 records. Five taxa, *Cephalanthera longifolia* (L.) Fritsch, *Ophrys battandieri* E.G. Camus, *Ophrys numida* Devillers-Tersch. & Devillers, *Ophrys sicula* Tineo and *Ophrys villosa* Desf. were found at only one site each.

In addition, we identified a total of 92 taxa of vascular plants associated with Orchidaceae in the West Rif region. These vascular plants, *Ampelodesmos mauritanicus* (Poir.) T.Durand & Schinz, *Calicotome villosa* (Poir.) Link, *Chamaerops humilis* L., *Pistacia lentiscus* L., *Quercus coccifera* L., and several species of the genera *Cistus*, *Erica* and *Lavandula*, form matorral habitats of varying density.

Two sites in the Jbel Derssa area (sites 39 and 36) have the highest number of target taxa. At these two sites, 10 and 9 taxa of the Orchidaceae family were recorded, respectively. Although only three species were recorded at the three study sites (sites 39, 51 and 47), they were the richest in number of individuals. These three sites recorded 132, 126 and 105 individuals of the target species, respectively. At the two study sites (sites 1 and 19), only single individuals of the target species (*Ophrys apifera* and *Ophrys fusca*, respectively) were recorded (Table 1, Appendix I).

A detailed analysis of the plant specimens collected during this study confirmed the occurrence of four new Orchidaceae taxa in Morocco. *Ophrys phryganae* Devillers-Tersch. & Devillers, *Ophrys sicula* Tineo, *Ophrys tenthredinifera* subsp. *grandiflora* (Ten.) Kreutz and *Ophrys villosa* Desf. were recorded for the first time in the country (Fig. 2).

Ophrys phryganae (Fig. 2) was recorded at two localities in the study area. The first locality was found near Jbel Ghorghize (site 23), where it grew on a south-westerly slope with a gradient of 70% at an altitude of 312 m. This species occurred in open garrigue habitat, with plant cover ranging from 50% to 75%. The dominant species in this habitat were *Ampelodesmos mauritanicus* and *Pistacia lentiscus*. The second site was recorded near Ain Lehcen (site 53), on a west-facing slope with a gradient of 50% at an altitude of 219 m. The individuals recorded grew in matorral habitat, with plant cover ranging from 75% to 100%. The dominant species in this habitat were *Ampelodesmos mauritanicus*, *Pistacia lentiscus* and *Tetraclinis articulata* (Vahl) Mast.

Ophrys sicula (Fig. 2) was found at one site near Jbel Ghorghize (site 34), where it grew on a north-eastern slope with a 5% gradient at an altitude of 696 m. This species occurred in a garrigue habitat, with plant cover ranging from 75% to 100%. The dominant species in this habitat were *Ajuga iva* (L.) Schreb., *Allium roseum* L., *Arisarum vulgare* O.Targ. Tozz., *Chamaerops humilis*, *Drimia maritima* (L.) Stearn, *Origanum compactum* Bentham, *Pistacia lentiscus* and *Tetraclinis articulata*.

Ophrys tenthredinifera **subsp.** ***grandiflora*** (Fig. 2) was recorded at two localities in the study area. The first locality was near Jbel Ghorghize (site 23), where it grew on a south-facing slope with a gradient of 25% at an altitude of 194 m. This subspecies occurred in a matorral habitat, with plant cover ranging from 75% to 100%. The dominant species in this habitat were *Asparagus acutifolus* L. and *Pistacia lentiscus*. The second site was recorded near Jbel Ghorghize (site 25), on a southwest-facing slope with a gradient of 50% at an altitude of 312 m. This species occurred in a garrigue habitat, with plant cover ranging from 50% to 75%. The dominant species in this habitat were *Asparagus acutifolus*, *Chamaerops humilis* and *Pistacia lentiscus*.

Ophrys villosa (Fig. 2) was found in one locality near Jbel Ghorghize (site 26). It grew on a south-western slope with a gradient of 60% at an altitude of 490 m. This species occurred in an open garrigue habitat, with a plant cover ranging from 50% to 75%. The dominant species in this habitat were *Ampelodesmos*

mauritanicus, *Calicotome villosa*, *Chamaerops humilis*, *Cistus albidus* L. and *Pistacia lentiscus*.

In addition, two species, *Ophrys battandieri* E.G. Camus and *Ophrys numida* Devillers-Tersch. & Devillers, were recorded for the second time in Morocco during this study.

Ophrys battandieri (Fig. 2) was recorded at one new locality (site 39) near Jbel Derssa. It was found on a north-facing slope with a gradient of 30% at an altitude of 281 m. This species prefers garrigue habitats, with plant cover ranging from 75% to 100%. The dominant species in the habitat were *Chamae-*

Table 1. Orchidaceae species diversity, number of individuals and threats to species in the West Rif region. Threat abbreviations: a – annual crop cultivation, f – fire, g – grazing, h – terrestrial plant harvesting, r – road construction, ra – recreational activities, u – urban expansion, w – waste disposal, wh – wood harvesting, wp – tree plantations

Species names and their synonyms	Site number (number of individuals recorded at the site)	Total number of individuals	Threats
Anacamptis pyramidalis (L.) Rich.	36(5), 37(24), 42(17), 43(20)	66	f, g, h, r, u, wp
Cephalanthera longifolia (L.) Fritsch	13(25)	25	ra, wh
Epipactis helleborine (L.) Crantz	10(8), 11(6)	14	f, r, w
Gennaria diphylla (Link) Parl.	14(12), 18(12), 20(4), 47(20)	48	g, ra, r, u
Neotinea conica (Willd.) R.M. Bateman (*Orchis conica* Willd.)	22(8), 36(2), 40(12)	22	f, h, r, u, wh, wp
Neotinea tridentata (Scop.) R.M. Bateman, Pridgeon & M.W. Chase	20(1), 17(30), 22(10), 28(11)	52	a, r
Ophrys apifera Huds.	1(1), 5(6), 31(5), 33(4), 41(10), 46(50), 47(60), 49(5), 51(70), 52(30)	241	g, r, u, w, wp
Ophrys battandieri E.G. Camus	39(14)	14	g, r, wh, wp
Ophrys bombyliflora Link	15(16), 22(14), 29(12), 32(10), 36(2), 39(2), 48(12)	68	f, g, h, r, u, w, wp
Ophrys fusca Link	19(1), 20(15)	16	a
Ophrys lutea Cav.	16(18),18(9), 31(14), 22(14), 30(5), 29(14), 28(12), 27(10), 20(10), 32(7), 33(4), 48(3), 51(6), 52(6)	132	a, g, r, u, w, wp
Ophrys numida Devillers-Tersch. & Devillers	50(7)	7	
Ophrys phryganae Devillers-Tersch. & Devillers	23(2), 53(26)	28	a, wp
Ophrys scolopax Cav.	5(6), 24(2), 31(7), 32(4), 33(15), 34(2), 36(2), 38(1), 39(16), 45(2), 48(5), 52(19), 53(50)	81	a, f, g, h, r, u, w, wh, wp
Ophrys sicula Tineo	34(2)	2	g, r
Ophrys speculum Link	4(4), 31(6), 33(1), 36(2), 48(25)	38	f, g, r, u, w, wp
Ophrys tenthredinifera subsp. *grandiflora* (Ten.) Kreutz (*Ophrys grandiflora* Ten.)	12(1), 25 (3)	4	f, r, u
Ophrys tenthredinifera Willd.	12(1), 25(3), 39(2), 46(2)	8	a, f, g, r, wh
Ophrys villosa Desf.	26(12)	12	a, r
Orchis anthropophora (L.) All.	21(11), 31(12), 32(26), 35(5), 36(10), 37(17), 38(12), 39(32)	125	a, f, g, h, r, u, wh
Orchis intacta Link (*Neotinea maculata* (Desf.) Stearn)	45(12), 46 (2)	14	a, g, r
Orchis italica Poir.	37(2), 39(3)	5	a, f, g, h, r, u, wh, wp
Serapias lingua L.	3(5), 36(17), 38(20), 39(25), 44(11), 45(12)	90	a, f, g, h, r, u, wh, wp
Serapias parviflora Parl.	2(15), 3(8), 32 (13), 33(8), 34(1), 35(3), 36(11), 38(10), 39(24), 40(8), 44(12), 45(11), 46(30), 47(25), 49(60), 50(3), 51(50), 52(20), 53(20)	332	a, f, g, h, r, u, w, wp
Serapias strictiflora Welw. ex Veiga	36(15), 38(12), 39(14), 40(6), 44(6)	53	f, g, h, r, u, wh, wp

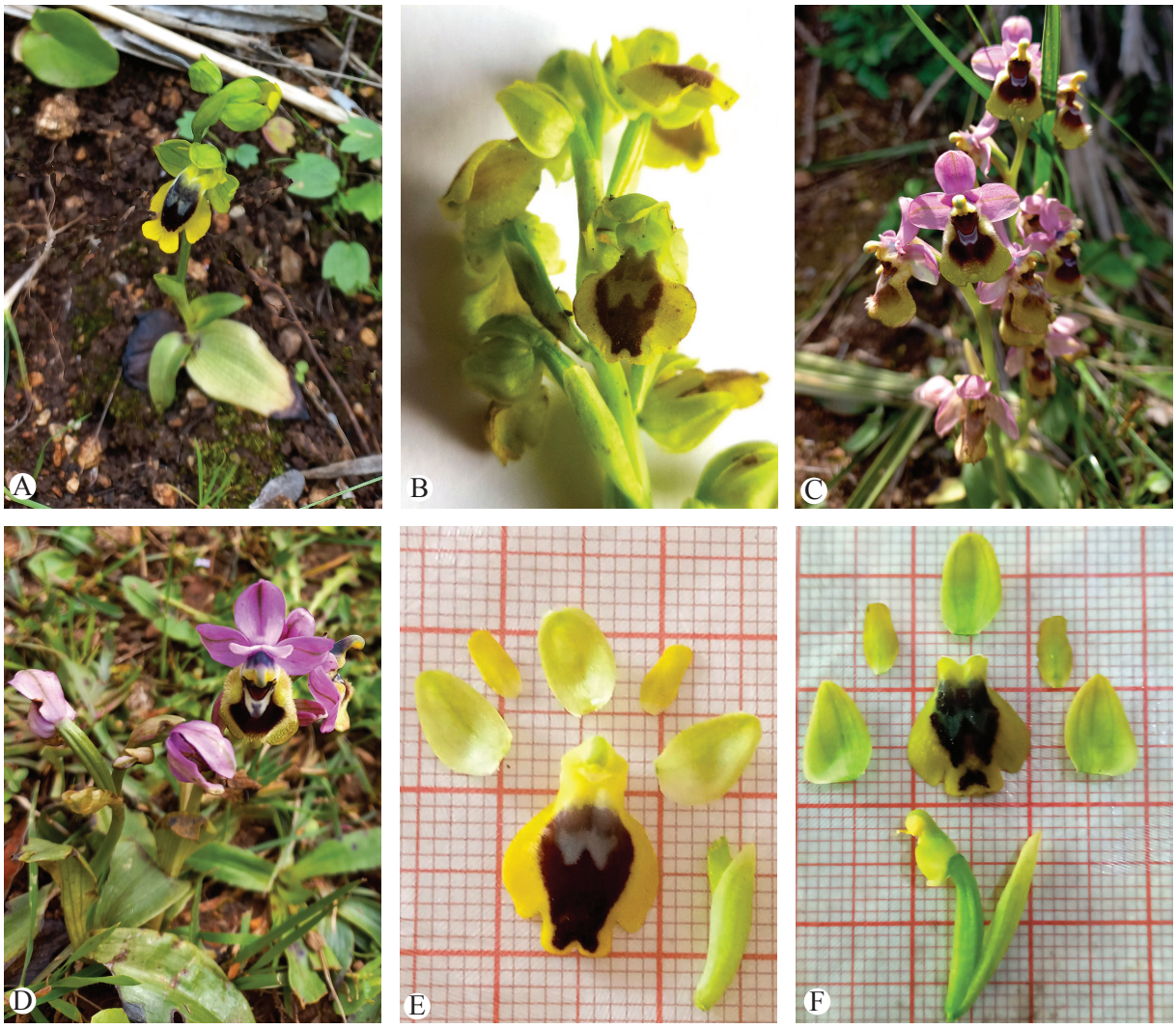

Fig. 2. New records of Orchidaceae in the West Rif area (Morocco). (A), *Ophrys phryganae* (Ain Lehcen, 9 April 2023); (B), *Ophrys sicula* (Jbel Ghorghize, 12 April 2022); (C), *Ophrys tenthredinifera* subsp. *grandiflora* (Jbel Ghorghize, 2 April 2022); (D), *Ophrys villosa* (Jbel Ghorghize, 2 April 2022); (E), *Ophrys numida* (Ain Lehcen, 9 April 2023); (F), *Ophrys battandieri* (Jbel Derssa, 19 April 2022). Photographs by Y. El Karmoudi (A, B, C and D) and M. Libiad (E and F).

rops humilis, *Moraea sisyrinchium* (L.) Ker Gawl., *Pistacia lentiscus* and *Prasium majus* L.

Ophrys numida (Fig. 2) was found at one new locality near Ain Lehcen (site 50), where it grew on a north-western slope with a gradient of 50% at an altitude of 585 m. This species occurred in a matorral habitat with plant cover ranging from 75% to 100%. The dominant species in this habitat were *Ampelodesmos mauritanicus*, *Calicotome villosa*, *Cistus monspeliensis* L., *Cistus salviifolius* L., *Crataegus monogyna* Jacq., *Erica arborea* L., *Pistacia lentiscus*, *Quercus coccifera* L. and *Quercus suber* L.

Conservation

The results of this study showed that species of the Orchidaceae family and their habitats in the West Rif region are threatened by several human activities: cultivation of annual crops, fires, intensive grazing, harvesting of terrestrial plants, road construction, recreational activities, expansion of urban areas, solid waste disposal, timber harvesting and establishment of tree plantations (Table 1). The encroachment of the urban areas around Jbel Derssa and Jbel Ghorghize, as well as the collection of ter-

restrial plants and the conversion of natural habitat into arable land (particularly at site 39), are threatening the orchids in these areas with extinction. In addition, mature plantations of *Pinus halepensis* Mill. have a negative impact on the populations of many of the species studied in the West Rif region. Thus, in the most studied areas around Jbel Ghorghize and Jbel Derssa, we found no Orchidaceae species among mature pines, except for *Ophrys apifera* Huds.

In the Jbel Ghorghize area, Orchidaceae species occupy the gaps in the stands of *Pistacia lentiscus*, *Ampelodesmos mauritanicus* and *Chamaerops humilis*. In addition, these species could provide reliable mechanical protection against animal grazing. We found some surviving individuals of the target species in the clumps of *Ampelodesmos mauritanicus* and *Chamaerops humilis*. At several sites, we found several viable populations of the study species between *Ampelodesmos mauritanicus* and *Chamaerops humilis*, which probably protect the soil from erosion and create favourable conditions for the existence of orchids. Unfortunately, these two species are highly flammable and often increase the risk of fire, which can damage orchid populations. The intense spread of *Dittrichia viscosa* (L.) Greuter (at 14 sites of the study area) indicates a significant disturbance of the habitats and an existing threat to the species of the Orchidaceae family.

DISCUSSION

The West Rif region, where 25 species and subspecies of the family Orchidaceae have been recorded, is an essential hotspot of their diversity in Morocco. The orchid diversity of this region is greater than that of Bouhachem Natural Park (Morocco), where 22 species have been recorded (Chambouleyron, 2012), the West Bank (Palestine), where 23 species have been recorded (Pahl & Qumsiyeh, 2021), and the Tell region (western Algeria), where only 11 species have been recorded (Aouadj et al., 2023). In the West Bank (Palestine), where 23 species of the family Orchidaceae have been recorded, only nine are found in fewer than 20 localities (Pahl & Qumsiyeh, 2021). In contrast, in the West Rif region, all species of this family were recorded in fewer than 20 localities, and five taxa were found in one locality each. These differences in species frequency could be explained by a gradual decline of orchid populations in the West Rif region.

This study revealed the presence of two species belonging to the *Ophrys subfusca* group in the West Rif region, *Ophrys battandieri* and *Ophrys numida*. This group is characterised by a lateral lobe of the labellum that forms an angle of approximately 45° with the longitudinal axis of the labellum (Delforge, 2006). *Ophrys battandieri* has been first recorded in Morocco by Chambouleyron (2012). This species is characterised by an inflorescence with 8–10 flowers, a small labellum with a glabrous margin, rounded and downward curved lateral lobes of the labellum, and a reduced median lobe. The main patch of dark labellum hairs is separated from that at the apex of the middle lobe by a yellow stripe at the sinuses (Amich et al., 2009; Delforge, 2006). *Ophrys numida* has been first reported from Morocco by Vázquez et al. (2012). The inflorescence of *Ophrys numida* usually has eight flowers; the labellum is almost flat, only slightly transversely convex. A dark patch of labellum hairs nearly separates the lateral lobes at the sinuses (Amich et al., 2009; Delforge, 2006).

The *Ophrys lutea* group is characterised by an outer edge of the lateral lobe of the labellum forming an angle of approximately 65° with the longitudinal axis of the labellum (Delforge, 2006). In the study area, this group is represented by three species. *Ophrys lutea* is characterised by a labellum more than 14 mm long. *Ophrys phryganae* is like *Ophrys lutea*, but has small flowers (the labellum less than 12 mm long) and a labellum bent at the base. *Ophrys sicula* has exceedingly small flowers, and the labellum is about 9 mm long, almost flat at the base, and horizontal or slightly inclined upwards (Delforge, 2006).

In the study area, the *Ophrys tenthredinifera* group is represented by three taxa. *Ophrys tenthredinifera* and *Ophrys villosa* are characterised by the hairs above the middle lobe of the labellum, which are the same as the hairs on the rest of the labellum margin. *Ophrys tenthredinifera* is characterised by a large trapezoidal labellum and a bract longer than the ovary. *Ophrys villosa* is characterised by a small labellum, more brightly coloured sepals and petals, and dark hairs in the centre of the labellum, surrounded by a well-defined band of long and fine submarginal hairs. The third taxon in this group is *Ophrys tenthredinifera* subsp. *grandiflora*. Its bracts are the same colour as the sepals; the flowers are larger, and the labellum is 13–20 mm long, trapezoidal, with a

distinct tuft of hairs above the middle lobe. Its stigmatic cavity is brownish to olive green, with rounded pseudo-eyes at the edge (Delforge, 2006).

Despite protected areas in the West Rif region, activities that threaten orchid habitats continue, demonstrating the lack of adequate protection. During this study, we identified several human activities that pose a real threat to the survival and reproduction of rare species. Five of these factors have been identified in other studies (Hansen et al., 2001; Delforge, 2006; Swarts & Dixon, 2009; Akhalkatsi et al., 2014; Pahl & Qumsiyeh, 2021). The most serious threats to orchid populations are expansion of annual crop fields, timber harvesting, alien tree plantations, intensive grazing and urban development. These activities can significantly reduce orchid populations and diversity by destroying or fragmenting their habitats.

Some plant species are coping with the effects of climate change by expanding their natural range northwards (Hansen et al., 2001; Keel et al., 2011). However, the northward expansion of some orchid species is limited by their strong reproductive dependence on pollinating insects (Hansen et al., 2001; Swarts & Dixon, 2009). In addition, other factors have a strong limiting effect on expanding the natural range of species in the Orchidaceae family. For example, the northward spread of *Ophrys sicula* is limited by large urban areas around Jbel Ghorghize, and large areas of unsuitable habitat (extensive pine forests) prevent its spread to higher mountain elevations.

The reproduction and survival of many orchid species depend on pollinators and stable environmental conditions (Delforge, 2006; Luo et al., 2020; Pahl & Qumsiyeh, 2021). Plant-insect interactions are a challenge for their conservation. Although *Gennaria diphylla* (Link) Parl. has adopted a successful reproductive strategy of early flowering to take advantage of reduced competition for pollinators, pollination success is complemented by autogamy (Claessens et al., 2022). In Europe, this species is endangered (IUCN, 2023), while in Morocco, it is considered vulnerable (Fennane, 2018).

The policy of creating natural reserves could increase the chances of *in situ* conservation of endangered orchid species. In Morocco, more than 154 biological and ecological interest sites were identified in 1996 (CEIBM, 2023). These nationally protected areas are important habitats for several species of the Orchidaceae family, such as Bouhachem Natural Park (Chambouleyron, 2012). The conservation of orchids in Morocco requires a multifaceted approach that includes *ex situ* conservation and translocation to suitable habitats (Swarts & Dixon, 2009; Libiad et al., 2020). Necessary conservation measures include habitat protection through the establishment of new protected areas and the expansion of existing ones, sustainable harvesting of wild populations, scientific research and monitoring of population status and trends, public education, and strict enforcement of existing laws (such as Law No. 29-05 of 2011). Collaboration between managers and scientists is also essential to ensure the long-term survival of these emblematic plants. In addition, national biodiversity conservation policies should pay more attention to the *in situ* conservation of orchid species through promulgating legislation aimed at supporting scientific research, particularly in ecology, genetics and conservation measures.

During this study, we identified 25 species and subspecies belonging to seven genera of the Orchidaceae family. Understanding the relationships between human impact, climate change, and biodiversity conservation can solve many environmental problems. The situation of orchids in the West Rif region of Morocco is a miniature reflection of the global biodiversity conservation crisis. Habitat conservation and restoration programmes must be developed and implemented to mitigate the effects of climate change and human activities on orchid populations. Investing additional resources and extending the systematic analysis of rare and endangered species to other areas of the Rif region of Morocco could reveal new natural values and identify priorities for biodiversity conservation.

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Appendix I

Geographical characteristics of the study sites in the West Rif region. Abbreviations: NO – number of Orchidaceae individuals at a site, SR – number of species recorded at the site.

Area	Site	Latitude (°N)	Longitude (°W)	Date	Altitude (m)	Exposure	SR	NO
Ain Zarka	1	35.5150	-5.3423	18 April 2021	271	NE	1	1
Jbel Ghorghize	2	35.5396	-5.3874	2 May 2021	321	N	1	15
	3	35.5392	-5.3887		445	NW	2	13
	4	35.5369	-5.3901		582	NW	1	4
	5	35.5390	-5.3725		388	NW	2	12
	6	35.5381	-5.3871	9 May 2021	388	NE	1	11
	7	35.5273	-5.3858		490	NE	1	8
	8	35.5445	-5.3846		195	E	1	10
	9	35.5252	-5.3885		632	E	1	6
	15	35.5392	-5.3763	18 March 2022	491	NE	1	16
	16	35.5392	-5.3763		491	NE	1	18
	17	35.5392	-5.3763		491	NE	1	30
	21	35.5328	-5.3841	2 April 2022	490	SW	1	11
	22	35.5395	-5.3860		282	SW	4	46
	23	35.5383	-5.3861		312	SW	1	2
	24	35.5395	-5.3860		282	SW	1	2
	25	35.5383	-5.3861		312	SW	2	3
	26	35.5328	-5.3841		490	SW	1	12
	27	35.5382	-5.3864		312	SW	1	10
	28	35.5372	-5.3847		355	SW	2	23
	29	35.5337	-5.3831		500	SW	2	26
	30	35.5319	-5.3824		556	SW	1	5
	31	35.5370	-5.3721	12 April 2022	461	NE	5	44
	32	35.5302	-5.3738		564	NE	5	60
	33	35.5258	-5.3742		655	NE	5	32
	34	35.5249	-5.3744		696	NE	3	5
	35	35.5408	-5.3707		436	NE	2	8
Oued Ellil	10	35.6559	-5.3838	14 June 2021	71	SW	1	8
Khandak Lkbir	11	35.7262	-5.3765	17 June 2021	143	W	1	6
Capo Negro	12	35.6473	-5.2927	4 March 2022	194	S	1	2
	14	35.6813	-5.3123	12 March 2022	215	N	1	12
Jbel Moussa	13	35.8945	-5.4206	6 March 2022	556	S	1	25
Jbel Bozaytoun	18	35.508	-5.3443	18 April 2021	301	N	2	21
	19	35.5083	-5.3437	22 March 2022	274	N	1	1
	20	35.5064	-5.3451		359	N	4	30
	44	35.5110	-5.3426	13 May 2022	257	E	3	29
	45	35.5071	-5.3447		344	N	4	37
Jbel Derssa	36	35.5907	-5.3740	14 April 2022	331	NE	9	66
	37	35.5871	-5.3756	14 April 2022	379	NE	3	43
	38	35.5858	-5.3749	19 April 2022	357	NE	5	45
	39	35.5969	-5.3733		281	N	10	132
	40	35.5984	-5.374	11 May 2022	281	NE	3	26
	41	35.5956	-5.3733		313	N	1	10
	42	35.5896	-5.3861		403	S	1	17
	43	35.5899	-5.3861		405	S	1	20

Area	Site	Latitude (°N)	Longitude (°W)	Date	Altitude (m)	Exposure	SR	NO
Oued Laou	46	35.4789	-5.1254	10 March 2023	229	N	4	84
	47	35.4924	-5.1487	31 May 2023 3 June 2023	217	N	3	105
Ain Lahcen	48	35.5613	-5.5782		317	N	4	45
	49	35.5605	-5.5782		339	N	2	65
	50	35.5613	-5.5822	9 March 2023	285	NW	2	10
	51	35.5614	-5.5796	9 April 2023	335	N	3	126
	52	35.5618	-5.5722		385	N	4	75
	53	35.5713	-5.5833		219	W	3	96