TAXONOMIC AND CONSERVATION STUDIES OF THE ARABIAN PENINSULA *VERBASCUM* SPECIES

by

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A thesis submitted to the University of Birmingham for the Degree of

DOCTOR OF PHILOSOPHY

School of Biosciences

College of Life and Environmental Sciences

University of Birmingham

November 2023

ABSTRACT

Verbascum L. (Scrophularieae, Scrophulariaceae) is a genus of approximately 360 species, which are classified into two recognised sections based on seed morphology, namely Bothrospermae and Aulacospermae. The greatest diversity of *Verbascum* species is found in Western Asia in the Bothrospermae section. In contrast, species belonging to the Aulacospermae section are found mainly in tropical Africa and the Arabian Peninsula. *Verbascum* species are widely recognised for their socioeconomic value as ornamentals and traditional medicines. This genus, which includes species from the Arabian Peninsula, has a long and complicated taxonomic history due to the extreme similarity and hybridization among its species, which led to several incorrect identifications. Thus, this thesis aims to systematically review the *Verbascum* genus in the Arabian Peninsula and evaluate the conservation status of its species through taxonomic revision with morphological examinations, phylogenetic analysis, Red List assessment for each taxon, and *in situ* and *ex situ* gap analysis and conservation planning. The taxonomic revision recognises 16 *Verbascum* species in the Arabian Peninsula, including newly described and recorded species. It also provides valuable details for identifying and delimiting these species, a species identification key, typified names, new synonyms and combinations, comprehensive descriptions of each species, and ecological and geographical distribution details. The results of the phylogenetic analysis confirmed the monophyly of the genus *Verbascum* and revealed the phylogenetic relationship and species delimitation within the genus in the study area. In addition, 236 novel DNA sequences representing 16 species with four varieties

of this genus were provided to the GenBank database. The phylogenetic analysis also strongly supports the reinstatement of the genus *Rhabdotosperma* into *Verbascum*. The Red List assessment results indicated that most of the Arabian *Verbascum* taxa are threatened with extinction; four taxa are critically endangered and four are endangered. In addition, five taxa are assessed as near threatened, and five are assessed as of least concern. The Red List assessment results identified that the main threats to these taxa are habitat disturbance and loss resulting from overgrazing, suburban and agricultural expansion, climatic changes, invasive species, recreational activities and tourism, and war and civil unrest caused by human intrusions and disturbances. The gap analysis results identified the *in situ* and *ex situ* conservation for 18 taxa of Arabian *Verbascum*, revealing that 70% of its populations occur outside protected areas (PAs) and 30% occur within PAs. In addition, the *in situ* gap analysis identified six complementary PAs and eight complementary sites within PAs for more active *in situ* conservation, four of which were located outside of PAs where Other Effective Conservation Measures (OECMs) could be implemented. The *ex situ* gap analysis revealed that not enough Arabian *Verbascum* taxa are conserved in international or national gene banks; thus, there is an urgent need for *ex situ* collection for all *Verbascum* taxa, focusing on hotspot areas outside PAs. Overall, the outcomes of this thesis have provided systematic knowledge and insight into the genus *Verbascum,* as well as recommendations that can aid wildlife conservation authorities on the Arabian Peninsula to meet their targets for conserving *Verbascum* diversity.

DECLARATION

The work presented in Chapters 2, 3, 4, and 5 has been prepared for publication in journals, and the text of each chapter is mostly identical to submitted or prepared manuscripts for publication:

- **Chapter 2:** Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (2022) *Rhabdotosperma saudiarabicum* (Scrophulariaceae), a new species from Saudi Arabia. *Kew Bull*. 77: 987–992. https://doi.org/10.1007/s12225-022-10063-y
- **Chapter 3:** Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (submitted) DNA Barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula. *TAXON*.
- **Chapter 4:** Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (in preparation for submission) Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- **Chapter 5:** Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (in preparation for submission) Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- **Chapter 6:** Alzahrani, A.M., Magos Brehm, J., and Maxted, N. (in preparation for submission) Gap analysis and conservation planning of *Verbascum* taxa in the Arabian Peninsula.

Ali Mohammed Alzahrani Date: 30/11/2023

Professor Nigel Maxted Date:

ACKNOWLEDGMENTS

This PhD would not have been possible without the generous support from many people, for whom I am grateful and appreciative.

I would like to express sincere thanks to my lead PhD supervisor, Professor Nigel Maxted, for his support, extremely valuable guidance, advice, encouragement, and patience throughout my doctorate research. I would also like to extend my gratitude to Dr Joana Magos Brehm, my PhD co-supervisor, for her support, guidance, patience and regular feedback. In addition, I wish to thank Dr Shahina Ghazanfar as my PhD co-supervisor for advising and reviewing my work. I would also like to thank Dr Lesley Batty, my internal assessor, for her helpful feedback during our meetings.

I would like to acknowledge Al-Baha University in Saudi Arabia, which provided financial support for this work, as well as the tremendous effort, assistance and support from those working at the Saudi Arabian Cultural Bureau in London.

I am eternally thankful to the curators and staff members of herbaria at National History Museum, London (BM), the Royal Botanical Garden Edinburgh (E), Royal Botanical Gardens, Kew (K), King Saudi University, Riyadh (KSU), King Abdulaziz City for Science and Technology (MUZ), the Oman Botanic Garden, Muscat (OBG), the Natural History Museum, Muscat (ON), National Agriculture and Water Research Center, Riyadh (RIY) and the Sharjah Seed Bank and Herbarium, Sharjah (SSBH) for providing facilities and access to their herbarium collections while conducting my study.

Thanks are also extended to Tony Miller, Dr Sophie Neale, Dr Annette Patzelt, Dr Abdul Wali Al-Khulaidi, Dr Nageeb Al-Sagheer, Saif Al Hatmi, Khadija Al Maawali, and Salim Al Rahbi for providing me with data throughout the course of my study. I am also extremely grateful to Dr Mauricio Parra-Quijano for his help and time. Many thanks go to my colleagues, Jade Phillips, Wiguna Rahman, Ria Cahyaningsih, Ahmed Aldow and Ibrahim Alzahrani for their support and help along this journey.

I am thankful to my best friends Ateah Alfakih and Nafee Alothyqi for their support, advice and suggestions. A special thanks also to Jamaan Algamdi, Mohammed Aljohani, and Abdulssalam Khafsha for their assistance and friendship during the fieldwork. I would also like to thank Suhair Almalki for the botanical illustrations.

I extend my sincerest appreciation and gratitude to my father, mother, brothers, sisters and relatives back home in Saudi Arabia for their support, encouragement and advice. I am also grateful to my wonderful wife, Atheer, for her support, encouragement and understanding while I was busy during my studies.

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LIST OF ABBREVIATION

AOO	Area Of Occupancy
BI	Bayesian Inference
BM	Natural History Museum (London, UK)
comb. nov.	a new combination
CR	Critically Endangered
DD	Data Deficient
DNA	Deoxyribonucleic Acid
E	Royal Botanic Gardens, Edinburgh (UK)
EN	Endangered
EOO	Extent Of Occurrence
GBIF	Global Biodiversity Information Facility
GeoCAT	Geospatial Conservation Assessment Tool
ITS	Internal Transcribed Spacer
IUCN	International Union for Conservation of Nature
K	Royal Botanic Gardens, Kew (UK)
KSU	King Saudi University (Riyadh, Saudi Arabia)
LC	Least Concern
MP	Maximum Parsimony
MUZ	King Abdulaziz City for Science and Technology (Riyadh, Saudi Arabia)
NT	Near Threatened
OBG	Oman Botanic Garden (Muscat, Oman)
OECMs	Other Effective Conservation Measures
ON	Natural History Museum (Muscat, Oman)
PAs	Protected Areas
PCR	Polymerase Chain Reaction
RIY	National Agriculture and Water Research Center (Riyadh, Saudi Arabia)
sp. nov.	a new species
SSBH	Sharjah Seed Bank and Herbarium (Sharjah, UAE)
stat. nov.	a new rank
synon. nov.	a new synonym
UNEP-WCMC	United Nation Environment Programme World Conservation Monitoring Centre

CHAPTER 1. INTRODUCTION

1.1 Introduction

1.1.1 Scrophulariaceae

Verbascum L. is a genus of the figwort or foxglove family, Scrophulariaceae, which comprises 306 genera and about 5850 species (Fischer, 2004; Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017). Scrophulariaceae is grouped into three subfamilies: Pseudosolaneae, Antirrhinoideae and Rhinanthoideae, and eight tribes: Scrophularieae Dumort. (1827), Limoselleae Dumort. (1827) Hemimerideae Benth. (1835), Teedieae Benth. (1835), Buddlejeae Bartl. (1830), Leucophylleae Miers (1850), Aptosimeae (Benth.) Benth. (1876), and Myoporeae Rchb. (1837) (Stevens, 2001; Oxelman *et al*., 2005). Scrophulariaceae is globally distributed and grows in a range of habitats, especially open grassy areas and in disturbed places, such as around farms, sides of roads and paths. It is rarely found in tropical rainforests. *Verbascum* species are annual, biennial or perennial; take the form of herbs, shrubs or, rarely, climbers or trees; have erect or prostrate stems; have opposite, alternate or whorled leaves; have bisexual flowers with five sepals free or five petals (two upper-lipped and three lower-lipped); have four or five stamens; and have two carpels (Stevens, 2001; Fischer, 2004; Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017).

1.1.2 The genus *Verbascum* L.

Verbascum (Mullein) is derived from the Latin word *barbascum*, which means ‘bearded stamen’ (Stearn, 1998; Gledhill, 2008). *Verbascum* is a complex and challenging genus taxonomically due to the extreme similarity and hybridisation among its species (Huber-Morath, 1978). As mentioned above, it belongs to the family Scrophulariaceae in the tribe Scrophularieae (Oxelman *et al*., 2005), which

contains about 360 species from around the world (Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017). *Verbascum* species are classified as monoecious, and they may be annual, biennial or perennial herbs or, rarely, small shrubs. They are distinguished by the seed morphology (longitudinally furrowed or transversally elongated seeds), the number of stamens, the colour and hairs of stamens, the shape of anthers, the hair type of the indumentum, the number of flowers per bract, the presence or absence of pedicels, the presence or absence of bracteoles, and the shape and size of capsules (Figure 1.1; Murbeck, 1925; 1933; Ferguson, 1971; Huber-Morath, 1978; Grabias, Swiatek and Swietoslawski, 1991; Juan, Fernandez and Pastor ,1997; Fischer, 2004; Karavelioğulları and Aytaç, 2008; Remal, 2014; Sotoodeh, 2015). Species are found in Asia, Africa and Europe but are most common in Western Asia, especially Turkey (243 species) and Iran (44 species; Murbeck, 1933, 1939; Huber-Morath, 1978; Sharifnia, 2007; Yılmaz and Dane, 2012; Ranjbar and Nouri, 2015; Sotoodeh, 2015).

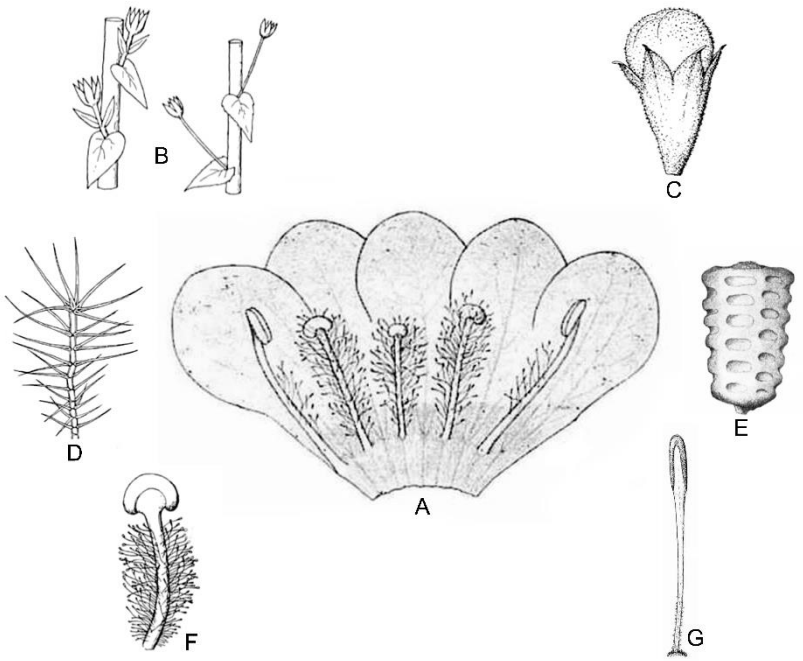

Figure 1.1. Some characteristics of the *Verbascum* genus: A. position of stamens; B. number of flowers per bract; C. calyx shape; D. indumentum type; E. seed surface; F. stamen colour and hairs and G. stigma type (Murbeck, 1933).

1.1.3 Economic botany of the *Verbascum* L. genus

In *De Materia Medica* (40-90 CE), the Greek author Dioscorides wrote about traditional uses of *Verbascum* by Muslim botanists, such as for treating diarrhoea, muscle bruising, chronic coughing and toothache (Figure 1.2; Harvardartmuseums, 2019). For example, *V. sinuatum* is still used to treat psoriasis (Amenta *et al*., 2000); *V. thapsus* is used for asthma and coughing (Lust and Tierra, 2010); and *V. phlomoides* is useful for treating diarrhoea, coughing, spasms, toothache, pain and inflammation (Spiridon, Bodirlau and Teaca, 2011; Segneanu *et al*., 2019). In addition, studies demonstrated that some *Verbascum* species can serve as antibiotic against bacteria, fungi, viruses and insects during *in-vitro* and *in-vivo* tests (Dülger *et al*., 2002; Akdemir, Tatlı and Khan, 2003;

Şengül *et al*., 2005; Khoshnoud *et al*., 2008; Sener and Dülger, 2009). In addition, several species have socio-economic importance as ornamentals and in traditional medicinal uses (Heywood *et al*., 2007; Kell *et al*., 2007; Simpson, 2010).

Figure 1.2. Illustrated folio from a manuscript of Dioscorides' De Materia Medica, which describes traditional uses of *Verbascum* in Arabic (Harvard art museums, 2019).

1.1.4 Historical classification of the *Verbascum* L. genus

Verbascum L. has a long and complicated taxonomic history and advances in morphological and phylogenetic approaches have revealed more *Verbascum* taxa. This study aims to highlight important studies that have driven changes in how this genus and its species are classified.

Belli, under the name Arcturus, was the first to describe the *Verbascum* L. genus in a letter to botanist Carolus Clusius, who later added the description to his book *Rariorum Plantarum Historia* (1601). The genus was *Blattaria* by Morison in 1715. Subsequently, Linnaeus (1753) split the genus into *Celsia* L. and *Verbascum* L. according to the number of stamens (the former has four, and the latter has five).

Schrader (1813) wrote the first generic monograph of *Verbascum* L., including sixty species distinguished by the decurrence of leaves and the number of flowers in the axil of each bract. In 1840, Berchtold and Pfund published another monograph on *Verbascum* L., dividing species based on whether the flowers were grouped or separated in the axil of each bract. The first section contained two groups: species with and without decurrent leaves, and the second section contained two groups with varying stamen numbers and types.

Grisebach (1844) described and divided the *Verbascum* L. genus into six sections in *Spicilegium Florae Rumelicae Et Bithynicae*, but his work was not accepted by other researchers. In the same year, in his book *Diagnoses plantarum Orientalium novarum*, Boissier (1844) described new species within this genus he found during his travels with other botanists around the Mediterranean and Asia.

Bentham (1846) reviewed the genera *Celsia* and *Verbascum* as part of his work on Scrophulariaceae in *De Candolle*, *Prodromus Systematis Naturalis Regni Vegetabilis*. Moreover, he combined 116 species of *Verbascum* and *Celsia*, arranging the genera into two sections based on stamen type: sect. *Thapsus* (lower, decurrent and longer anthers) and sect. *Lychnitis* (reniform

anthers). He applied the same classification to these genera, although *Celsia* had four stamens, while *Verbascum* had five and each section was divided into groups. In 1875, Franchet studied *Verbascum* L. in France and Central Europe and classified it into two sections, which were the same as those defined by Bentham but called sect. *Heterandra* (formerly sect. *Thapsus*) and sect. *Isoandra* (formerly sect. *Lychnitis*). In *Flora Orientalis*, Boissier (1879) also followed Bentham's classification and classified *Verbascum* species into two sections. A few years later, in *Revisio generum Plantarum*, Kuntze (1891) pointed out that some species of *Celsia* L. have four stamens plus one staminode, which led him to suggest that *Celsia* L. be included in *Verbascum* L.

In his first monograph on the genus *Celsia* L., Murbeck (1925) divided it into sect. *Bothrospermae* and sect. *Aulacospermae* according to the morphological appearance of seeds. Based on the type of anther, the former was separated into subsect. *Nefflea* (all anthers reniform) and subsect. *Arcturus* (two anterior decurrent anthers; Figure 1.3). In his second monograph, Murbeck (1933) divided the genus *Verbascum* L. into two sections: sect. *Bothrospermae* and sect. *Aulacospermae*, according to the morphological appearance of seeds. Based on the number of flowers in the axil of the bracts, the former was further split into subsect. *Fasciculata* (flowers grouped into clusters) and subsect. *Singuliflora* (solitary flowers; Figure 1.4).

Hartl (1977) separated the genus *Rhabdotosperma* as a new distinct genus from *Verbascum* on an argument of seed morphology (previously considered as *Celsia* L. and *Verbascum* L. sect. *Aulacospermae* by Murbeck 1925, 1933). The majority of *Verbascum* taxa were included in the section

Bothrospermae, and sect. *Aulacospermae* contained only six tropical species (Murbeck, 1925, 1933; Hartl, 1977; Huber-Morath, 1978). Additionally, Huber-Morath (1973, 1978) included the genera *Celsia* L. and *Staurophragma* Fisch. and Mey. to *Verbascum* while revising its species as part of a project to document the flora of Turkey. He grouped species of the *Bothrospermae* Murb. section into 13 artificial groups based on the number of stamens, the hair type of the indumentum and the number of flowers per bract (Table 1.1).

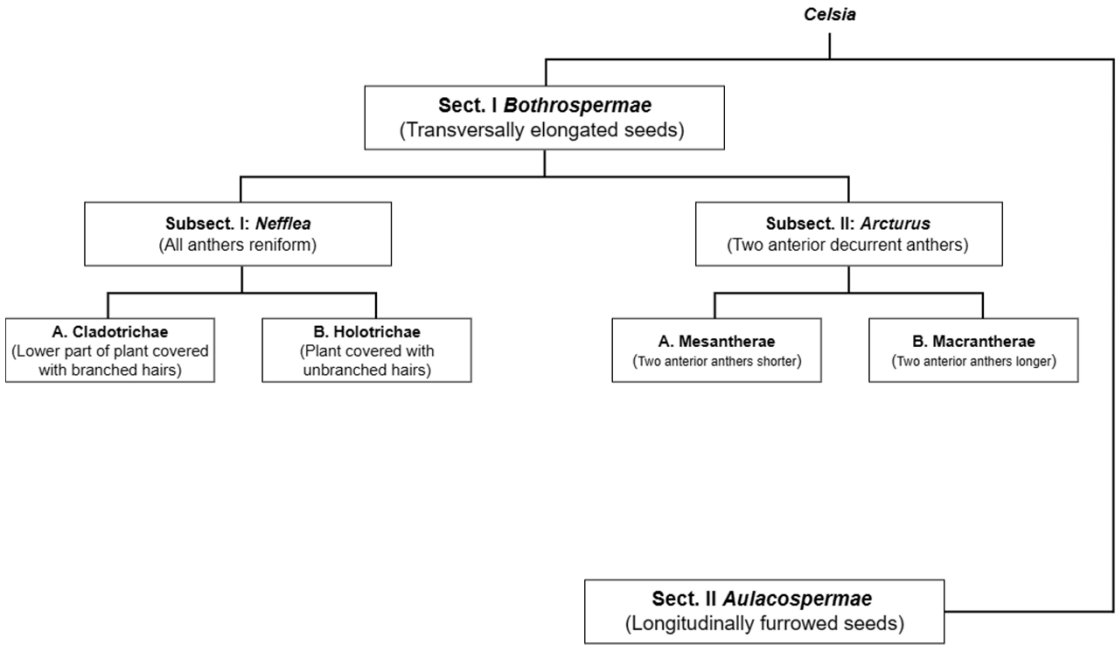

Figure 1.3. Classification of the genus *Celsia* (Murbeck, 1925).

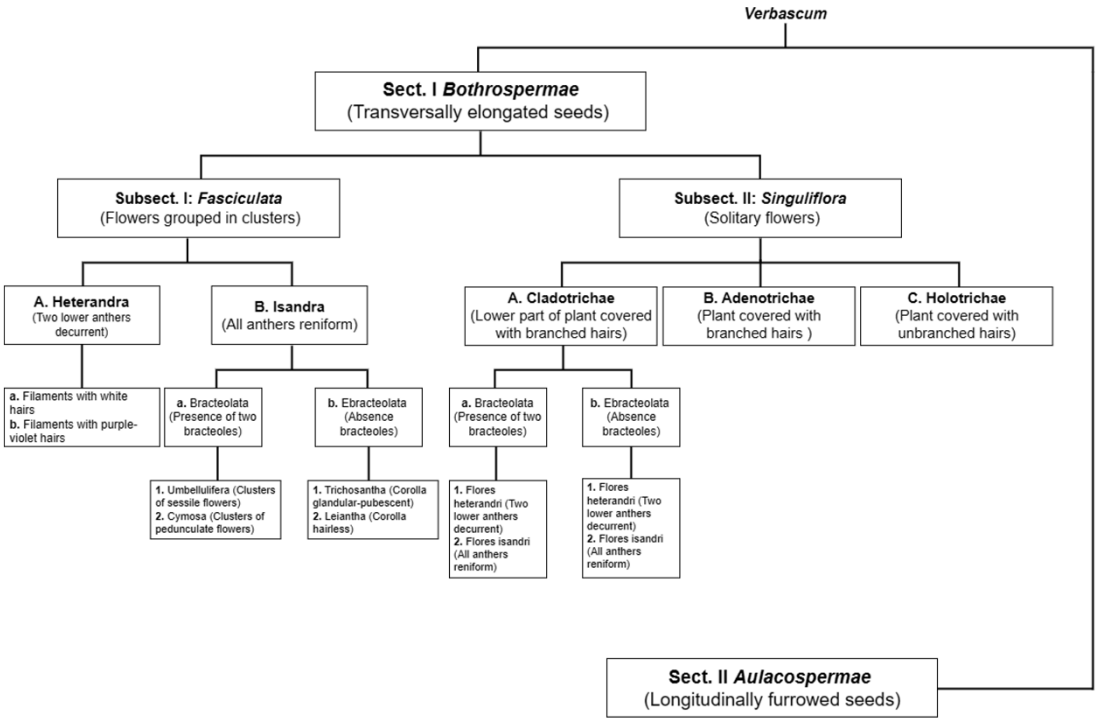

Figure 1.4. Classification of the genus *Verbascum* (Murbeck, 1933).

Table 1.1. Summary of the classifications of *Verbascum* L. with key distinguishing characteristics.

Reference	Classification
Linnaeus (1753)	Number of stamens: *Celsia*: Four stamens *Verbascum*: Five stamens
Schrader (1813)	Two groups: Group I: Decurrent leaves Group II: Number of flowers inserted in the axil of each bract
Berchtold & Pfund (1840)	Sect. I: Grouped flowers Group I: Decurrent leaves Group II: Without decurrent leaves Sect. II: Solitary flowers and longitudinal grooved seeds Group I: One type of stamen Group II: Several types of stamen
Grisebach (1844)	Six sections
Bentham (1846)	Sect. I: Thapsus (two decurrent lower anthers) Sect. II: Lychnitis (all reniform anthers)

Franchet (1875)	Sect. I: Heterandra (two decurrent lower anthers) Sect. II: Isoandra (all reniform anthers)
Boissier (1879)	Sect. I: Thapsus (two decurrent lower anthers) Sect. II: Lychnitis (all reniform anthers)
Murbeck (1925)	Sect. I: Bothrospermae (honeycombed sculpted seeds) Subsect. I: Nefflea (all reniform anthers) Subsect. II: Arcturus (two decurrent anterior anthers) Sect. II: Aulacospermae (longitudinal grooved seeds)
Murbeck (1933)	Sect. I: Bothrospermae (transversally elongated seeds) Subsect. I: Fasciculata (flowers grouped in clusters) Subsect. II: Singuliflora (solitary flowers) Sect. II: Aulacospermae (longitudinally furrowed seeds)
Huber-Morath (1973)	Included *Celsia* L. and *Staurophragma* Fisch. and Mey. to the genus *Verbascum*
Hartl (1977)	Considered sect. Aulacospermae of *Celsia* and *Verbascum* a new genus *Rhabdotosperma*
Huber-Morath (1978)	Thirteen artificial groups: I. Number of stamens II. Type of hairs III. Number of flowers per bract

Many approaches have been adopted to find a suitable classification system for *Verbascum*. Yet, none of these methods was generally agreed to have establishing the delimitations and relationships between and within species (Attar *et al*., 2007). Until now, botanists have mainly relied upon Murbeck's (1933) classification, but a number of new species have been identified, particularly from the Middle East (Al-Hemaid, 2001; Karavelioğulları, Duran and Hamzaoğlu, 2004; Sutory, 2004; Karavelioğulları, Vural and Polat, 2006; Parolly and Tan, 2007; Sharifnia and Assadi, 2007; Karavelioğulları, Uzunhisarcikli and Celik, 2008; Parolly and Eren, 2008; Yilmaz and Dane, 2008, 2012; Dane and Yılmaz, 2009; Karavelioğulları *et al*., 2009; Bani *et al*., 2010; Karavelioğulları, Yüce and Başer, 2014; Sotoodeh *et al*., 2014; Fırat, 2015; Karavelioğulları, 2015; Karavelioğulları

et al., 2015; Ranjbar and Nouri, 2015; Sotoodeh *et al*., 2015, 2016; Negaresh and Khoshroo, 2017; Çingay, Demir and Cabi, 2018).

1.1.5 Morphological studies

Taxonomists have extensively studied the morphological characteristics of *Verbascum* taxa in order to understand and identify its species. Some of these characteristics are discussed below, especially those mentioned in major floras, monographs, revisions and studies (Table 1.2; Murbeck, 1925, 1933; Post, 1933; Zohary and Feinbrun-Dothan, 1966; Ferguson, 1971; Huber-Morath, 1971, 1978, 1984; Wood, 1997; Chaudhary, 2001; Sharifnia, 2007; Al-Hadeethi *et al*., 2014; Remal, 2014; Ghazanfar, 2015; Sotoodeh, 2015).

Table 1.2. Key morphological characteristics of the *Verbascum* genus based on some major floras, monographs, revisions and studies.

Morphological characteristics	
Habit	annual, biennial or perennial herbs or small shrubs
Stems	erect
Leaf shapes	lanceolate, ovate, oblong, elliptical or orbicular
Leaf arrangements	rosette, alternate or rarely opposite
Leaf margins	entire, crenate, serrate, sinuate or lobed
Petiole	present or absent
Length of petiole	centimetres or millimetres
Type of hairs	glandular hairs, simple hairs or different types of branched hairs
Pedicels	present or absent
Length of pedicels	centimetres or millimetres
Bracts and bracteoles	present or absent
Shape of bracts and bracteoles	triangular, lanceolate, linear or ovate
Inflorescences	raceme, lax, spikes or panicles
Type of flowers	single flower in the axil of the bract with absent bracteoles, single flower in the axil of the bract with two present bracteoles, group of flowers in the axil of the bract with absent bracteoles, clusters of pedunculate flowers with two

	present bracteoles or clusters of sessile flowers with two present bracteoles
Calyx lobes	triangular, lanceolate, linear, spatulate, oblong or ovate
Corolla	yellow or rarely different colours
Number of stamens	four or five (four fertile and one staminode)
Length of stamens	equal to subequal or two longer anterior stamens
Type of anthers	all anthers reniform (medifixed), obliquely inserted or longitudinally inserted with or without decurrence (basifixed)
Type of filaments	hair up to anthers, glabrous near the apex, hair in the middle or glabrous
Length of filaments	millimetres
Colour of filaments	yellow, orange or red
Colour of filament hairs	white, yellow, red or purple to violet
Stigma types	spatula, straight, hemispherical, rhombic, ring-like or disc-shaped
Ovary	two carpels
Capsule shapes	glabrous, subglabrous, ovoid, ovoid-elliptic, elliptic or elliptic-oblong
Seeds surface	*Bothrospermae* (transversally elongated) or *Aulacospermae* (longitudinally furrowed)

The surface of seeds is the most important characteristic distinguishing sect. *Bothrospermae* and sect. *Aulacospermae* (Murbeck, 1925, 1933; Karavelioğulları, 2015). In both sections, seeds are numerous, but they vary in size, may be brown or black and may be oblong, trigonous or prismatic in shape (Juan, Fernandez and Pastor ,1997; Attar *et al*., 2007; Remal, 2014; Sotoodeh, 2015) (Figure 1.5).

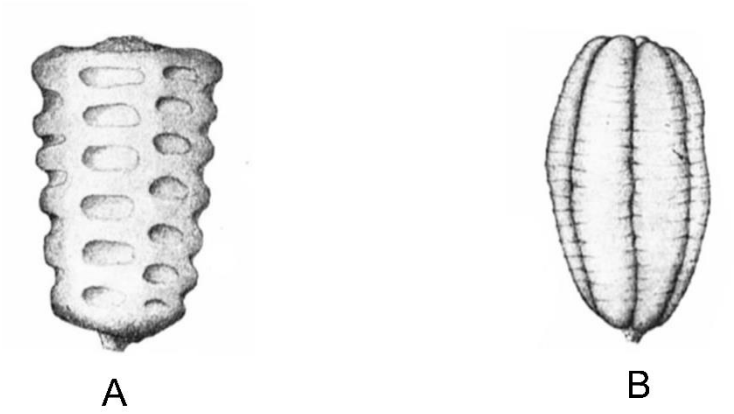

Figure 1.5. The morphological appearance of seeds in the genus *Verbascum*: A. *Bothrospermae* (transversally elongated) and B. *Aulacospermae* (longitudinally furrowed) (Murbeck, 1933).

The two sections are also distinguished by the number of flowers in the axil of the bract. *Bothrospermae* was split into the subsections *Fasciculata* (flowers grouped in clusters) and *Singuliflora* (solitary flowers). Murbeck (1933) described five types of flowers: a single flower in the axil of the bract with absent bracteoles, a single flower in the axil of the bract with two present bracteoles, a group of flowers in the axil of the bract with absent bracteoles, clusters of pedunculate flowers with two present bracteoles and clusters of sessile flowers with two present bracteoles (Figure 1.6). In addition, flowers may be characterised by different types of inflorescences, such as terminal racemes, spikes or panicles.

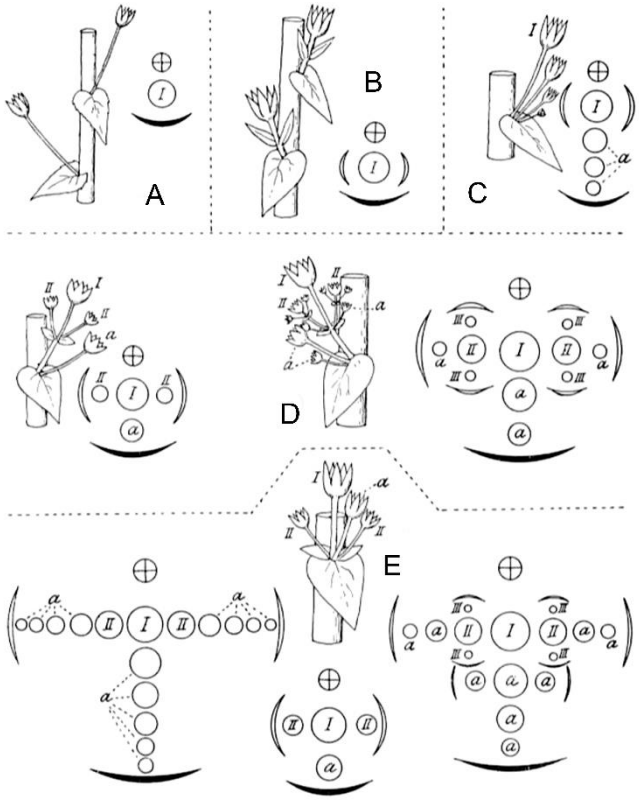

Figure 1.6. Five types of flowers with present or absent bracts and bracteoles in the *Verbascum* genus: A. single flower in the axil of the bract with absent bracteoles; B. single flower in the axil of the bract with two present bracteoles; C. a group of flowers in the axil of the bract with absent bracteoles; D. clusters of pedunculate flowers with two present bracteoles and E. clusters of sessile flowers with two present bracteoles (Murbeck, 1933).

The number of stamens is the third characteristic distinguishing *Bothrospermae* from *Aulacospermae*. This feature was the main argument for inclusion of the genus *Celsia* in *Verbascum* due to confusion regarding the presence of fertiles and staminodes. In 2008, Karavelioğulları and Aytaç revised group A of this genus in Turkey, which was created by Huber-Morath (1978) while writing the *Flora of Turkey*. They found that some species have four stamens, and others have five (sometimes four fertiles and one staminode). In addition, three types of anthers with attached filaments (all reniform, obliquely inserted and

longitudinally inserted with or without decurrence) and two lengths of stamens (equal to subequal or two longer anterior stamens) were described. Moreover, the hairs on the filament (hair up to the anthers, hair in the middle, glabrous near the apex and glabrous) were used to distinguish species (Figure 1.7; Murbeck, 1933; Huber-Morath, 1978).

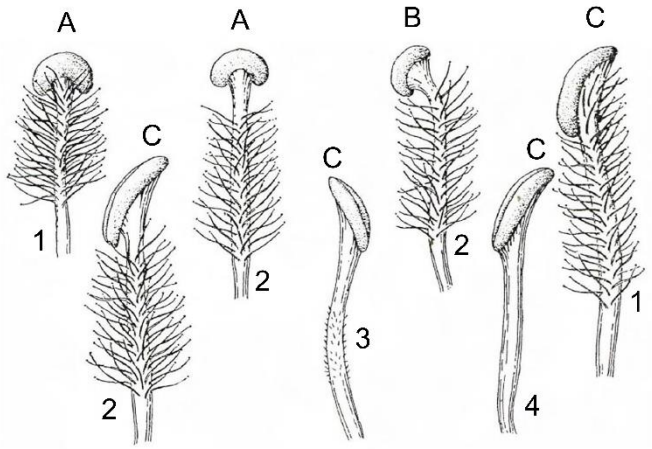

Figure 1.7. Types of anthers in *Verbascum* taxa: A. reniform (medifixed); B. obliquely inserted, and C. longitudinally inserted, with or without decurrence (basifixed). Types of filaments: 1. hair up to anthers; 2. glabrous near the apex; 3. hair in the middle and 4. glabrous (Huber-Morath, 1978).

The form of sepals is the fourth characteristic used to distinguish species. Six shapes have been identified: triangular, lanceolate, linear, spatulate, oblong and ovate (Figure 1.8; Murbeck, 1933; Remal, 2014). In addition, Murbeck (1933) described six types of stigmata: spatula, straight, hemispherical, small rhombic

or heart-shaped, very small ring-like and large, circular or disc-shaped (Figure 1.9). Further, several capsule shapes have been recorded: glabrous, subglabrous, ovoid, ovoid-elliptic, elliptic, elliptic-oblong, pyramidal and cylindrical (Juan, Fernandez and Pastor, 1997; Attar *et al*., 2007; Sotoodeh, 2015). Juan, Fernandez and Pastor (1997) identified two forms of capsules, subequal locules and septicidal dehiscence, and further divided each form into two types depending on whether branched hairs were present or absent.

Hair characteristics play a significant role in classification of the *Verbascum* genus. Murbeck (1933) divided hairs into three main types: glandular hairs, simple hairs and different types of branched hairs (Figure 1.10). Later, Grabias, Swiatek and Swietoslawski (1991) studied the morphology of hairs in some *Verbascum* species, dividing the species into two groups based on whether they featured headless hairs or headed hairs.

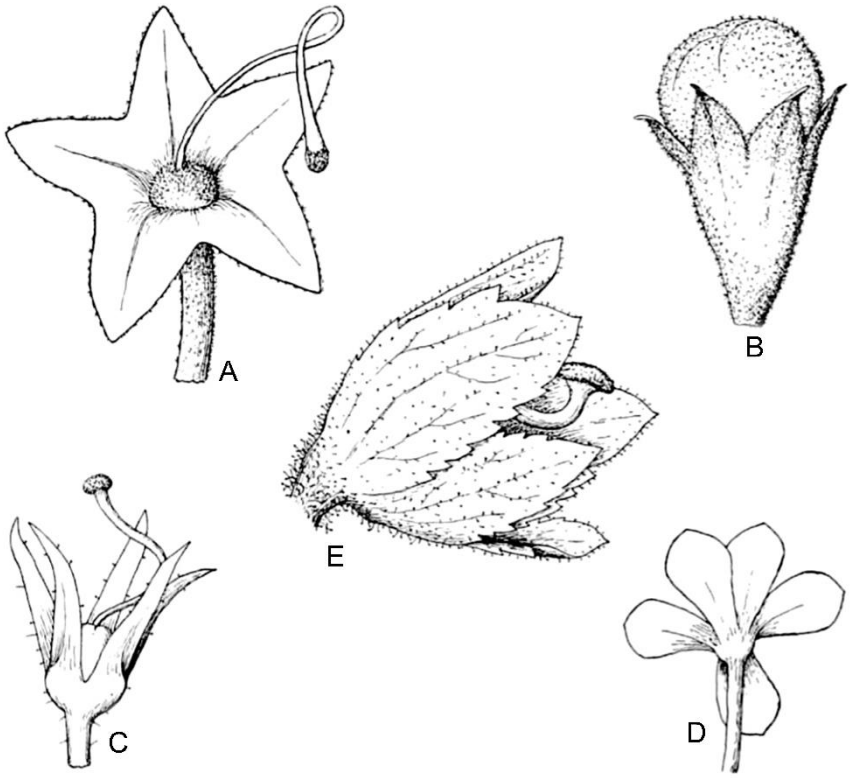

Figure 1.8. Sepal forms in *Verbascum* species: A. triangular; B. lanceolate; C. linear; D. spatulate and E. oblong (Murbeck, 1933).

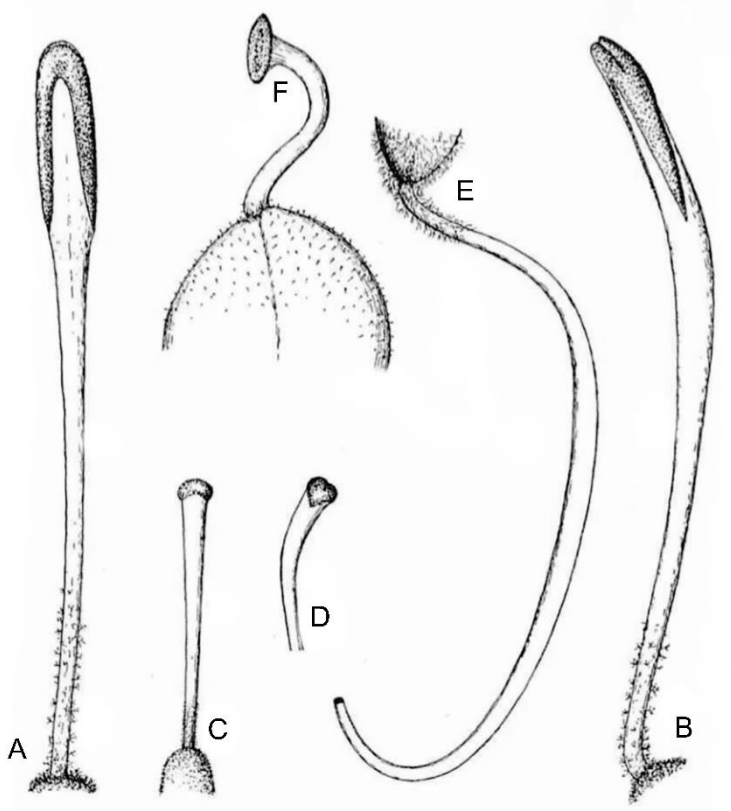

Figure 1.9. Stigma types in *Verbascum* species: A. spatula; B. straight; C. hemispherical; D. rhombic; E. ring-like and F. disc-shaped (Murbeck, 1933).

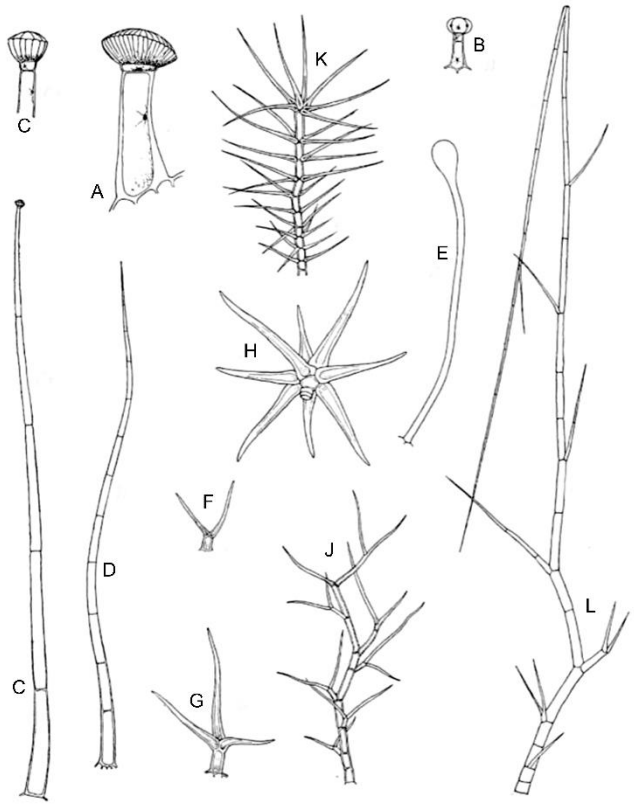

Figure 1.10. Three types of hairs in *Verbascum* species: A–C. glandular hairs; D and E. simple hairs and F–L. different types of branched hairs (Murbeck, 1933).

1.1.6 Palynological studies

Botanists have attempted to use pollen morphology to improve the identification and classification of the *Verbascum* genus. Kheiri *et al*. (2006) examined seven *Verbascum* taxa from Urmia via light and scanning electron microscopy (SEM), which allowed them to describe several shapes of pollen grains. Al-Hadeethy *et al*. (2014) studied the pollen morphology of 20 *Verbascum* species in Iraq and divided them into four groups according to the shape of their pollen grains: subprolate, prolate sheroidal, prolate and oblate spheroidal. Öztürk *et al*. (2018) investigated the pollen grains of six species from five different groups of the

genus (Huber-Morath, 1978) found in Turkey. They identified four shapes of pollen: prolate, subprolate, prolate-spheroidal and oblate-spheroidal (Öztürk *et al*., 2018).

1.1.7 Genomic studies

Phylogenetic systematics is one of the most important techniques for classifying and understanding the pattern of evolutionary history between and within species (Simpson, 2010). However, *Verbascum* has not widely benefited from the application of these. Remal (2014) investigated the phylogenetic relationships among *Verbascum* species from cpDNA and nrDNA in the Mediterranean. His results strongly support previous works that include taxa with four stamens (*Celsia* L.) within the genus *Verbascum* L. Nevertheless, he stated that most of the morphological characteristics fit poorly on the phylogenetic tree, which cannot be used to establish natural infrageneric groups. Later, Sotoodeh (2015) studied the molecular phylogeny of 37 species of *Verbascum* in Iran based on the nuclear (ITS) and four chloroplastic (*trn*L-F, *trn*S-G, *trn*H-*psb*A and *mat*K) regions. However, he claimed that more molecular studies are needed as his phylogenetic findings did not support the current infrageneric classification.

In the same year, Ghahremaninejad *et al*. (2015) studied 25 *Verbascum* taxa from Turkey and Iran and used DNA sequence data from the nrDNA ITS and the plastid sequences *trn*Y/T, *trn*S/G and *psb*A–*trn*H. They found that the current subgeneric classification of *Verbascum* (Murbeck, 1933) did not properly reflect its phylogeny and proved that morphological characteristics are useful for identifying species but limited for determining infrageneric relationships.

1.1.8 Area of study (the Arabian Peninsula)

1.1.8.1 Geographical position

The Arabian Peninsula (Arabia, or Jazirat Al-Arab) is an enormous region covering about 2,590,000 km^2. It is bordered by the Red Sea to the west, the Indian Ocean to the southeast and the Arabian Gulf and Gulf of Oman to the northeast. It is located between Africa and Asia and includes seven countries and their islands: Saudi Arabia, Yemen, Oman, the United Arab Emirates (UAE), Kuwait, Qatar and Bahrain (Figure 1.11).

Figure 1.11. A map of the Arabian Peninsula and its countries was generated by QGIS 3.22 (2022).

1.1.8.2 Plant conservation in the Arabian Peninsula

The Arabian Peninsula contains about 3,418 plant species belonging to 144 families, of which over 600 are endemic to Yemen, Oman and Saudi Arabia (Al

Farhan *et al*., 2008). However, this richness and diversity of plant species faces physical and biological threats, such as desertification, habitat loss as a result of long-term climatic changes, urban and agricultural expansion and uncontrolled grazing, leading to further decline or loss of populations and plant species diversity (Miller and Cope, 1996; Collenette, 1998; Ghazanfar and Fisher, 1998; Brown and Mies, 2012).

As part of the Arabian Peninsula's plant conservation activities, strategies such as the IUCN Important Plant Area Programme (https://www.iucn.org/), which aims to identify plant diversity hotspots and designate the most significant as important plant areas and so areas to focus conservation implementation (Al-Abbasi *et al*., 2010; Hall and Miller, 2011), were developed to preserve this diversity. This programme led to the designation of four important plant areas: Jabal Qaraqir (Llewellyn *et al*., 2010), the Farasan Archipelago (Hall *et al*., 2010), 'Uruq Bani Ma'arid (Hall *et al*., 2011), and Jabal Aja' (Llewellyn *et al*., 2011) (Figure 1.12). The Arabian Peninsula has 228 protected areas, which comprise 18.07% of Saudi Arabia, 1.24 % of Yemen, 4.29 % of Oman, 30.83% of the United Arab Emirates, 18.07% of Qatar, 18.46% of Kuwait, and 34.09% of Bahrain (UNEP-WCMC and IUCN 2023) (Figure 1.13).

Figure 1.12. A map of four important plant areas in the Arabian Peninsula: Jabal Qaraqir, the Farasan Archipelago, 'Uruq Bani Ma'arid and Jabal Aja' was obtained from UNEP-WCMC and IUCN (2023) and generated by QGIS 3.22 (2022).

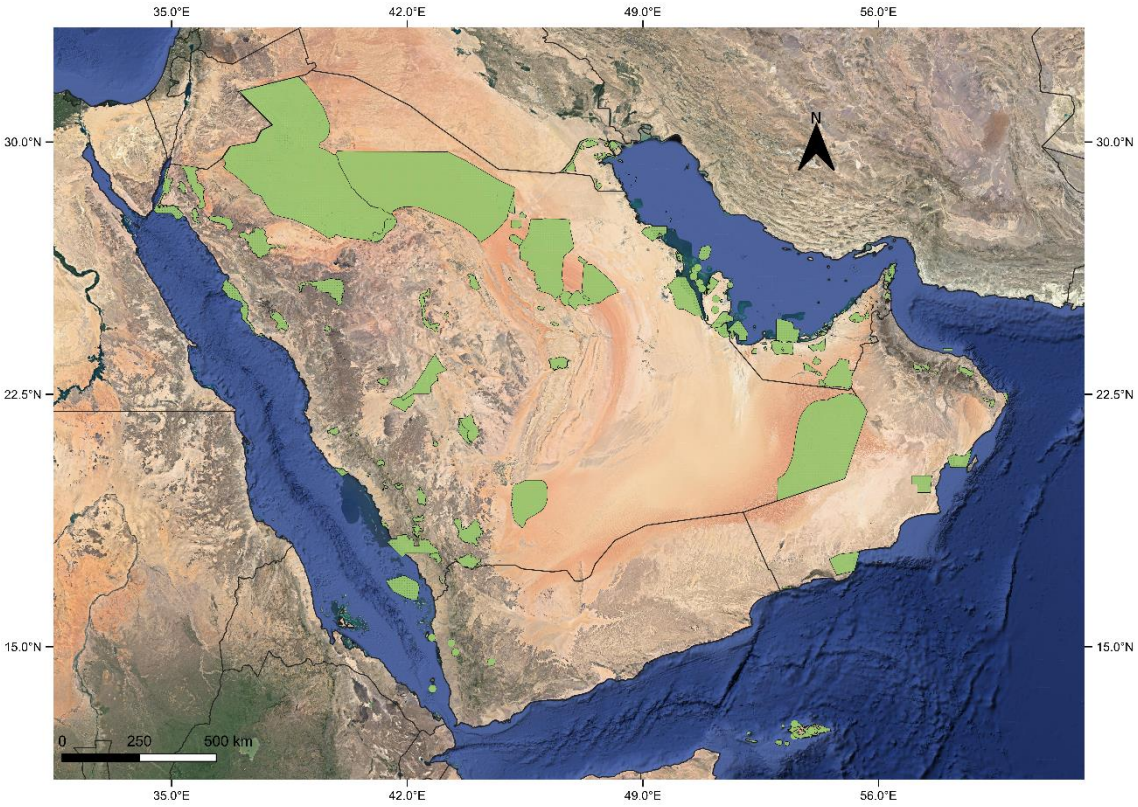

Figure 1.13. A map of 228 protected areas on the Arabian Peninsula was obtained from UNEP-WCMC and IUCN (2023) and generated by QGIS 3.22 (2022).

Since the complete Red List for the Arabian Peninsula has not yet been compiled, inventories for individual countries such as Oman (Patzelt, 2015a) and Yemen (Miller and Al-Khulaidi [unpublished]) have been produced (Hall and Miller, 2011). In the *Checklist of Botanical Species in Saudi Arabia* (1998), Collenette compiled the first inventory of threatened species in Saudi Arabia, and the majority of species are classified as endangered. Although, Collenette did not use the IUCN Red List Categories and Criteria for assessing the species; rather, she relied primarily on her subjective but extensive field observations over her experience of more than two decades in this region.

1.1.8.3 Historical review of *Verbascum* species in the Arabian Peninsula

The Arabian Peninsula and its plant species are of interest to botanists and naturalists from all over the world due to its geographical position between Africa and Asia (Ghazanfar and Fisher, 1998). Therefore, many specimens have been collected from this area. One of the most extensive collection efforts was conducted by the naturalist Pehr Forsskal from 1732–1736. During that period, Forsskal collected *C. ramosa* from Yemen, which was later listed in *Plants of Pehr Forsskal's Flora Aegyptiaco-Arabica* (Hepper and Friis, 1994). Deflers (1889) described two new species in his book *Voyage au Yemen*, *C. bottae* and *V. yemense* and later described *V. longibracteatum* as a new species from Yemen (Deflers, 1896). Baker (1894) described *V. luntii* from Alrail in Hadhramaut, Yemen. In addition, in one volume of *Flora Arabica*, Blatter (1921) recorded six species from Saudi Arabia and Yemen: *C. bottae*, *V. longibracteatum*, *V. schimperianum*, *V. yemense*, *V. luntii* and *V. sinaiticum*. In his monograph of the genus *Celsia*, Murbeck (1925) described three new species: *C. deserticola*, *C. akdarensis* and *C. melhanensis*, and two known species, which are *C. bottae* and *C. parviflora* from the Arabian Peninsula. Later, he wrote another monograph regarding the *Verbascum* genus in which he described three species from Arabia, *V. schimperianum*, *V. yemense* and *V. longibracteatum* (Murbeck, 1933). Half a century later, Huber-Morath (1793, 1978) included the genera *Celsia* L. and *Staurophragma* Fisch. and Mey. in the genus *Verbascum* L. while revising species for Flora of Turkey and described a new species from Oman, *V. omanense* (Huber-Morath, 1984).

1.1.8.3.1 Saudi Arabia

In *Flora of Saudi Arabia*, Migahid (1974) recorded three species with different morphological characteristics: *C. scrophulariifolia*, *V. schimperianum* and *V. nubicum*. In *Illustrated Guide to the Flowers of Saudi Arabia*, Collenette (1985) listed *Verbascum* as having ten species with different morphological characteristics, altitudinal variations and distributions. Later, in her *Checklist of Botanical Species in Saudi Arabia* (Collenette, 1998) and *Wildflowers of Saudi Arabia* (Collenette, 1999), she listed 18 species (Table 1.3). Similarly, in *Flora of the Kingdom of Saudi Arabia*, Chaudhary (2001) described eighteen species (Table 1.4). Based on Collenette's collections at the Royal Botanic Gardens, Kew (K) and Edinburgh (E) herbaria, Al-Hemaid (2001) described eight new species (Table 1.3).

Table 1.3. List of eight new species of *Verbascum* from Saudi Arabia and their corresponding number in the Kew (K) and Edinburgh (E) herbaria collections.

No.	Collenette's collections	Herbarium	Al-Hemaid (2001)
1	*V*. sp. nov. 3757	E	*V. abyadicum*
2	*V*. sp. nov. 2091	K	*V. asiricum*
3	*V*. sp. 5321	E	*V. chaudharyanum*
4	*V*. sp. 6977	E	*V. hema-figranum*
5	*V*. sp. 7116	K	*V. medinecum*
6	*V*. sp. nov. 9072	K	*V. sheilae*
7	*V*. sp. 5277	E	*V. shiqricum*
8	*V*. sp. 9115	K	*V. tabukum*

In her thesis (unpublished, in Arabic), Bokhari (2002) reviewed the genus *Verbascum* using several taxonomical methods, including morphology, anatomy, chemistry and palynology. She described twelve species, including the new record species *V. fruticulosum*, and divided *V. sinaiticum* into two new

subspecies, *V. sinaiticum* subsp. *sinaiticum* and *V. sinaiticum* subsp. *najaticum* (Table 1.4), but her thesis was not adequately documented. Importantly, she confirmed and accepted one species, *V. shiqricum*, from Al-Hemaid's (2001) study and rejected the others.

Bokhari and Alfarhan (2006) studied the morphology of pollen grains and their surfaces in twelve species of *Verbascum* in Saudi Arabia: *V. bottae*, *V. decaisneanum*, *V. longibracteatum*, *V. nubicum*, *V. melhanense*, *V. schimperianum*, *V. yemense*, *V. transjordanicum*, *V. deserticola*, *V. sinaiticum*, *V. fruticulosum* and *V. shiqricum*.

Table 1.4. List of *Verbascum* species in principal floras and revision works concerning Saudi Arabia.

Migahid (1974)	Collenette (1985)	Collenette (1998, 1999)	Chaudhary (2001)	Bokhari (2002)
C. scrophulariifolia	*V. bottae*	*V. bottae*	*V. bottae*	*V. bottae*
V. schimperianum	*V. decaisneanum*	*V. decaisneanum*	*V. decaisneanum*	*V. decaisneanum*
V. nubicum	*V. longibracteatum*	*V. longibracteatum*	*V. longibracteatum*	*V. longibracteatum*
	V. nubicum	*V. nubicum*	*V. nubicum*	*V. nubicum*
	V. melhanense	*V. melhanense*	*V. melhanense*	*V. melhanense*
	V. schimperianum	*V. schimperianum*	*V. schimperianum*	*V. schimperianum*
	V. yemense	*V. yemense*	*V. yemense*	*V. yemense*
	V. sinaiticum	*V. transjordanicum*	*V. transjordanicum*	*V. transjordanicum*
	V. sp. nov.	*V.* sp. aff. *deserticola*	*V. deserticola*	*V. deserticola*
	V. sp.	*V. sinaiticum*	*V. sinaiticum*	*V. fruticulosum*
		V. sp. nov. 2091	*V. shiqricum*	*V. sinaiticum* subsp. *sinaiticum*
		V. sp. nov. 3757	*V. chaudharyanum*	*V. sinaiticum* subsp. *najaticum*
		V. sp. nov. 9072	*V. asiricum*	*V. shiqricum*
		V. sp. 5277	*V. sheilae*	
		V. sp. 6977	*V. hema-figranum*	
		V. sp. 7170	*V. tabukum*	
		V. sp. 9015	*V. abyadicum*	
		V. sp. 9115	*V. medinecum*	

1.1.8.3.2 Yemen

In the *Handbook of the Yemen Flora*, Wood (1997) listed *Verbascum* as having four species with different morphological characteristics: *V. bottae*, *V. melhanense*, *V. yemense* and *V. sinaiticum*. Recently, Al-Khulaidi (2013) listed six species in this genus: *V. bottae*, *V. melhanense*, *V. yemense*, *V. sinaiticum*, *V. longibracteatum* and *V. luntii*.

1.1.8.3.3 Oman

In *Wild Flowers of Northern Oman*, Mandaville and Bovey (1978) listed one species, V*. cedreti*. Ghazanfar (1992) listed three species in *An Annotated Catalogue of the Vascular Plants of Oman and Their Vernacular Names*: *V. cedreti*, *V. akdarense* and *V. omanense*. More recently, she described three species, *V. akdarense*, *V. omanense* and *V. sinaiticum* in *Flora of the Sultanate of Oman* (Ghazanfar, 2015). In the *Photographic Field Guide to the Plants of the Western Hajar Mountains, Sultanate of Oman*, Patzelt (2015b) recorded one species, *V. akdarense*.

1.1.8.3.4 United Arab Emirates

In *Flora of the United Arab Emirates*, Western (1989) reported just one species, *V. omanense*. Later, Jongbloed *et al*. (2003) changed *V. omanense* to *V. cedreti* in the book *Comprehensive Guide to the Wild Flowers of the United Arab Emirates*.

1.1.8.3.5 The rest of the Arabian Peninsula (Kuwait, Bahrain, and Qatar)

In the other countries of the Arabian Peninsula, Kuwait, Bahrain and Qatar, no species of *Verbascum* have been recorded (Daoud and Al-Rawi, 1985; M.D and C.D Cornes, 1989; Norton *et al*., 2009).

1.1.8.4 Problematic taxonomy of *Verbascum* species in the area of study

Currently, *Verbascum* is represented by about 24 species in the Arabian Peninsula, but this number is still changing (Table 1.5). In particular, new taxa have been discovered in Saudi Arabia (Al-Hemaid, 2001). Due to the extreme similarity and hybridisation among *Verbascum* species, there may be several misclassifications or misidentifications. Additionally, many undiscovered species may have been ignored in herbaria due to their complexity, old treatments and the high number of specimens (Huber-Morath, 1978; Sotoodeh *et al*., 2014). Even though some studies have investigated genus in the Arabian Peninsula, they mostly examined species' morphological characteristics. There remains no complete taxonomic revision or phylogeny study of this genus in the Arabian Peninsula.

Table 1.5. List of accepted species of *Verbascum* in the Arabian Peninsula and references.

Species	Distribution	References
V. abyadicum Hemaid	Saudi Arabia	Migahid (1974)
V. asiricum Hemaid		Collenette (1999)
V. bottae (Defl.) Hub.-Mor.		Al-Hemaid (2001)
V. chaudharyanum Hemaid		Chaudhary (2001)
V. decaisneanum O. Kuntze		Bokhari (2002)
V. deserticola (Murb.) Hub.-Mor.		Bokhari and Alfarhan (2006)
V. fruticulosum Post.		
V. hema-figranum Hemaid		
V. longibracteatum Defl.		
V. medinecum Hemaid		

V. melhanense (Murb.) Hub.-Mor. *V. nubicum* Murb. *V. schimperianum* Boiss. *V. scrophulariifolium* (Hochst.) Hub.-Mor. *V. sheilae* Hemaid *V. shiqricum* Hemaid *V. sinaiticum* Benth. *V. tabukum* Hemaid *V. transjordanicum* Murb. *V. yemense* Defl.		
V. akdarense (Murb.) Hub.-Mor. *V. cedreti* Boiss. *V. omanense* Hub.-Mor. *V. sinaiticum* Benth.	Oman	Ghazanfar (1992, 2015)
V. cedreti Boiss. *V. omanense* Hub.-Mor.	UAE	Western (1989) Jongbloed *et al*. (2003)
V. bottae (Defl.) Hub.-Mor. *V. longibracteatum* Defl. *V. luntii* Baker *V. melhanense* (Murb.) Hub.-Mor. *V. sinaiticum* Benth. *V. yemense* Defl.	Yemen	Wood (1997) Al-Khulaidi (2013)

1.2 Aims and Objectives

The thesis aims to systematically review the *Verbascum* genus in the Arabian Peninsula and evaluate the conservation status of its species. The primary goal is achieved through the following objectives:

1. A morphological account and taxonomic revision of Arabian *Verbascum* taxa. This involves (a) undertaking a field survey to collect new specimens and compare them with old collections from global and local herbaria, (b) examining all morphological characteristics and using those mentioned by other authors, (c) establishing the delimitations and relationships between and within the species to be accepted, and (d) developing and improving

the classification of *Verbascum* by incorporating descriptions, distributions, ecologies, illustrations, combinations, synonyms, typification and Key identifications.

2. A genomic investigation of *Verbascum* and *Rhabdotosperma* species in the Arabian Peninsula to have a better understanding of the delimitations and relationships between the accepted taxa.
3. A red list assessment of Arabian *Verbascum* taxa according to the International Union for the Conservation of Nature (IUCN) criteria and categories with supporting documentation and justification as well as a distribution map for each species. This will consist of (a) estimating the number of population, their size and their distributional range of each taxa, (b) assessing the conservation status, (c) identifying threats and (d) proposing conservation actions if needed.
4. A gap analysis and *in situ* and *ex situ* conservation plan for the genus *Verbascum* on the Arabian Peninsula.

1.3 Thesis Outline

This thesis is divided into seven chapters:

- **Chapter 1.** presents a general introduction and taxonomic overview of the genus *Verbascum* in the Arabian Peninsula.
- **Chapter 2.** describes a new species of the genus *Rhabdotosperma* in the Arabian Peninsula.
- **Chapter 3.** reveals the phylogenetic relationships of the genus *Verbascum* in the Arabian Peninsula.

- **Chapter 4.** gives a detailed morphological account and taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- **Chapter 5.** Provides an evaluation for the Red List of *Verbascum* taxa in the Arabian Peninsula.
- **Chapter 6.** presents gap analysis and conservation planning of *Verbascum* taxa in the Arabian Peninsula.
- **Chapter 7.** presents a general discussion and conclusion of the thesis chapters.

CHAPTER 2. *RHABDOTOSPERMA SAUDIARABICUM* (SCROPHULARIACEAE), A NEW SPECIES FROM SAUDI ARABIA

The work presented in this chapter has been published in Kew Bulletin.

Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (2022) *Rhabdotosperma saudiarabicum* (Scrophulariaceae), a new species from Saudi Arabia. *Kew Bull*. 77: 987–992. https://doi.org/10.1007/s12225-022-10063-y

Author contribution:

Conceived and designed the study: A.M.A.

Data collation and preparation: A.M.A.

Performed analysis: A.M.A.

Interpreted results: A.M.A., J.M.B., S.A.G., N.M.

Wrote the paper: A.M.A.

Critically reviewed the paper: A.M.A., J.M.B., S.A.G., N.M.

2.1 Abstract

A new species of *Rhabdotosperma* (Scrophulariaceae) is described from southwestern Saudi Arabia. For 75 years, the species was confused with *R. bottae* and *Verbascum melhanense*. The new species is illustrated with information on identification, distribution, specimens examined, habitat, conservation status, phenology, etymology, and taxonomic notes.

Keywords: Al-Soudah, Arabian Peninsula, Asir, critically endangered, endemic, *Verbascum*.

2.2 Introduction

The genus *Rhabdotosperma* Hartl belongs to the family Scrophulariaceae in the tribe Scrophularieae (Oxelman *et al*., 2005). It was separated as a new genus from *Verbascum* by Hartl (1977), (formerly recognised as *Celsia* L. and *Verbascum* L. sect. *Aulacospermae* by Murbeck, 1925, 1933) on account of seed morphology, a distinction followed by Lobin and Porembski (1994) and Fischer (2004). *Rhabdotosperma* species are distinguished from their closely related *Verbascum* sister species by having longitudinally furrowed seeds (aulacospermous), a dilated to disciform stigma, and the absence of accessory flowers (Hartl, 1959, 1977; Fischer, 2004). The genus comprises seven species (Hartl, 1977; Lobin and Porembski, 1994; Fischer, 2004; Christenhusz, Fay and Chase, 2017).

In tropical Africa, six species of *Rhabdotosperma* were listed by Hartl (1977), namely, *R. densifolium* (Hook.f.) Hartl, *R. brevipedicellatum* (Engl.) Hartl, *R. ledermannii* (Schltr. ex Murb.) Hartl, *R. scrophulariifolium* (Hochst. ex A.Rich.) Hartl, *R. keniense* (Murb.) Hartl, and *R. schimperi* (Skan) Hartl. In the *Flora of*

Tropical East Africa, Ghazanfar, Hepper and Philcox (2008) treated the last two species as synonyms of *R. brevipedicellatum* and *R. scrophulariifolium*, respectively. Fischer (2006), however, treated *R. keniense* and *R. schimperi* as distinct taxa. *Rhabdotosperma bottae* (Deflers) Hartl is the only species reported from Yemen (Hartl, 1977; Huber-Morath, 1984; Wood, 1997) and Saudi Arabia (Collenette 1985, 1998, 1999; Chaudhary, 2001) in the Arabian Peninsula.

As part of an ongoing taxonomic revision of *Verbascum* and *Rhabdotosperma* in the Arabian Peninsula, some interesting specimens of *Rhabdotosperma* were examined that did not match any known species in the area or the surrounding regions. A comprehensive investigation was carried out to ascertain whether these specimens warranted taxonomic distinction.

2.3 Materials and Methods

Morphological and ecological data were gathered from relevant literature, herbarium specimens, and the first author's own observations during fieldwork in Saudi Arabia. Herbarium specimens were examined from BM, E, K, KSU, RIY, and the JSTOR Global Plants platform (https://plants.jstor.org/). The new species was assessed following the IUCN Red List Categories and Criteria (IUCN, 2012), and the Geospatial Conservation Assessment Tool (GeoCAT) was used to analyse and estimate the extent of occurrence (EOO) and area of occupancy (AOO) with a grid size of 2 km^2 (Bachman *et al*., 2011). The distribution map was made with QGIS software version 3.22 (2022).

2.4 Results and Discussion

2.4.1 Taxonomic Treatment

Rhabdotosperma saudiarabicum *A.Alzahrani*, sp. nov. Type: Saudi Arabia, Abha, Jabal Al-Soudah, Al-Soudah, 25 km NW of Abha, 2800 m, 22 Feb. 1982, *I. S. Collenette* 3316 (holotype K!).

http://www.ipni.org/urn:lsid:ipni.org:names:77306699-1

Biennial herb, dark green, simple or rarely branched, woody at the base, up to 40 cm tall. *Indumentum* dense glandular hairs. *Stems* erect, terete to angular. *Basal leaves* alternate, oblong-ovate, 8 – 10 × 3 – 4 cm, apex obtuse, base cordate, margins crenate, lamina dark green with sparse simple hairs on the veins below; petiole 4.5 – 6.5 cm, winged with 1 – 2 small lateral lobes. *Cauline leaves* oblong to oblong-ovate, 3.5 – 6.7 × 1.5 – 2.6 cm, apex obtuse, base cordate or semi-amplexicaul; sessile or petiole 0.8 – 2 cm. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* lanceolate-triangular, 4 – 5 mm, acute. *Lower bracts* cordate-triangular, 10 – 40 mm, acute. *Pedicel* covered with dense glandular hairs up to 6 mm long. *Calyx* 4 – 5 mm, lobes oblong, acute or mucronate, dense glandular hairs. *Corolla* 15 – 20 mm across, yellow with red streaks on the upper side and around the throat, without pellucid glands, tubeless, glabrous inside, sparse glandular hairs outside. *Stamens* 4, 3 – 5 mm long. *Filaments* red with yellowish-red hairs, two anterior glabrous near the apex, two posteriors with hairs up to the anthers. *Anthers* two anterior inserted obliquely on filaments, two posteriors with reniform anthers. *Ovary* pyriform-ovoid, sparse glandular hairs. *Style* up to 4 mm long, filiform, green or red. *Stigma* disciform. *Capsule* 6 – 8 × 4 – 5 mm, pyriform-ovoid, sparse glandular hairy.

Seeds 0.6 – 0.7 × 0.4 – 0.5 mm, brownish, oblong-cylindrical, aulacospermous (Figure 2.1, 2.2, 2.3).

Figure 2.1. *Rhabdotosperma saudiarabicum*. A, B habit, from Al-Soudah, Asir mountains, Abha, Saudi Arabia. PHOTOS: S. COLLENETTE.

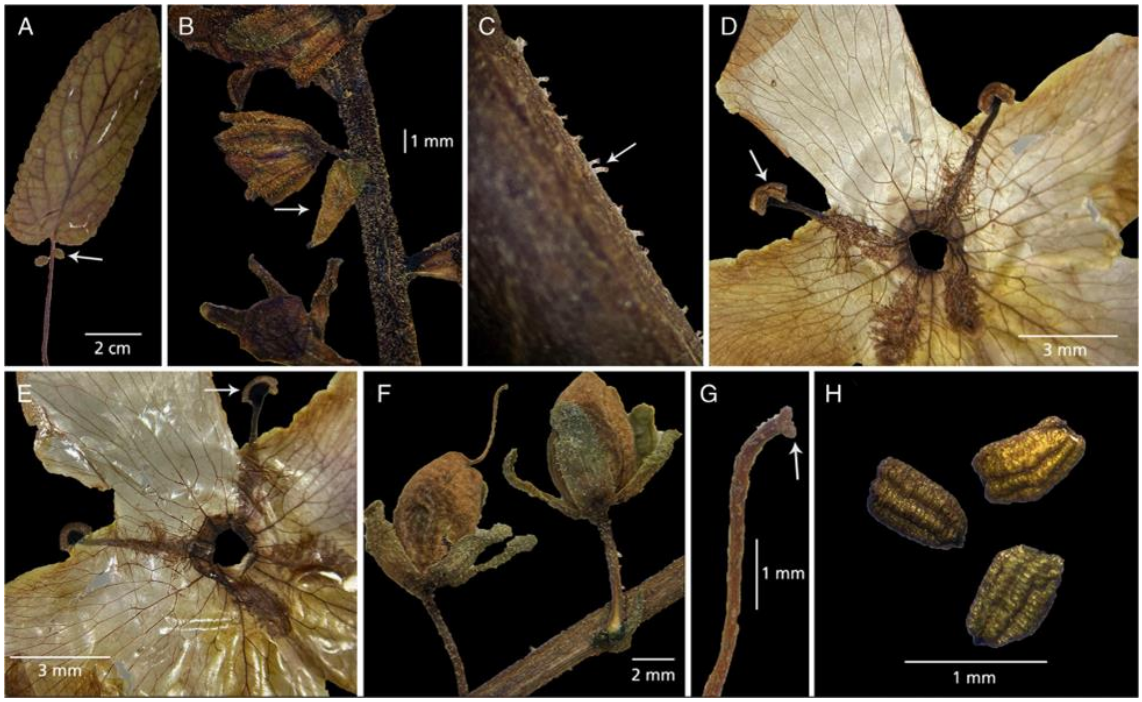

Figure 2.2. *Rhabdotosperma saudiarabicum*. A leaf and petiole with two small lateral lobes (white arrow); B calyx and upper bracts (white arrow); C stems with glandular hairs (white arrow); D, E filaments with two anterior anthers inserted obliquely (white arrows); F capsules; G stigma disciform (white arrow); H seeds aulacospermous. A – E from *I. S. Collenette* 3316; F – H from *L. Boulos* and *A. S. Ads* 14165. PHOTOS: A. ALZAHRANI.

Recognition. Rhabdotosperma saudiarabicum is morphologically similar to *R. bottae* and *R. scrophulariifolium*, sharing with these two species similarly winged petioles, oblong calyx lobes, racemose inflorescences, four stamens, two anterior filaments that are glabrous near the top, pyriform-ovoid capsules, and oblong-cylindrical seeds. However, the new species can be distinguished from *R. bottae* by its alternate leaves (vs rosette), oblong-ovate leaves (vs oblong to oblong-lanceolate), crenate margins (vs crenate-denticulate), it has sparse, simple hairs on leaf veins below (vs dense, simple hairs), 5 – 6 mm long pedicels (vs 10 – 20 mm), two anterior filaments 3 – 5 mm long (vs 7 – 8 mm), two anterior anthers inserted obliquely on filaments (vs inserted decurrent longitudinally), style length

of 3 – 4 mm (vs 8 – 15 mm), and capsules covered with sparse glandular hairs (vs glabrous). Furthermore, *R. saudiarabicum* differs from *R. scrophulariifolium* in having dense glandular indumentum (vs glandular with sparse, simple and forked hairs), oblong-ovate leaves (vs oblong), crenate margins (vs toothed-crenate), sparse, simple hairs on leaf veins below (vs dense, simple hairs on the veins on both sides), 5 – 6 mm long pedicels (vs 6 – 30 mm), calyx 4 – 5 mm long (vs 6 – 9 mm), and capsules covered with sparse glandular hairs (vs glabrous). Morphological comparison of these three species is given in Table 2.1.

Distribution. Al-Soudah, Asir Mountains, Abha, southwestern Saudi Arabia (Figure 2.4).

Specimens examined. SAUDI ARABIA. Abha: Jabal Al-Soudah, Al-Soudah, 25 km NW of Abha, 2800 m, 22 Feb. 1982, *I. S. Collenette* 3316 (K!, holotype); Al-Soudah, 3048 m, 1 July 1946, *D. Vesey-FitzGerald* 16082/4 (BM!); Al Mahmoud, 35 km N of Abha, 10 km below Jabal Al-Soudah, 21 May 1980, *L. Boulos* and *A. S. Ads* 14165 (K!); Waterfall beauty spot 10 km NW of Abha, Jabal Al-Soudah Road, 2530 m, 8 May 1985, *I. S. Collenette* 5368 (E!); Al-Soudah, 11 Aug. 1952, *J. D. Tothill* 116 (BM!).

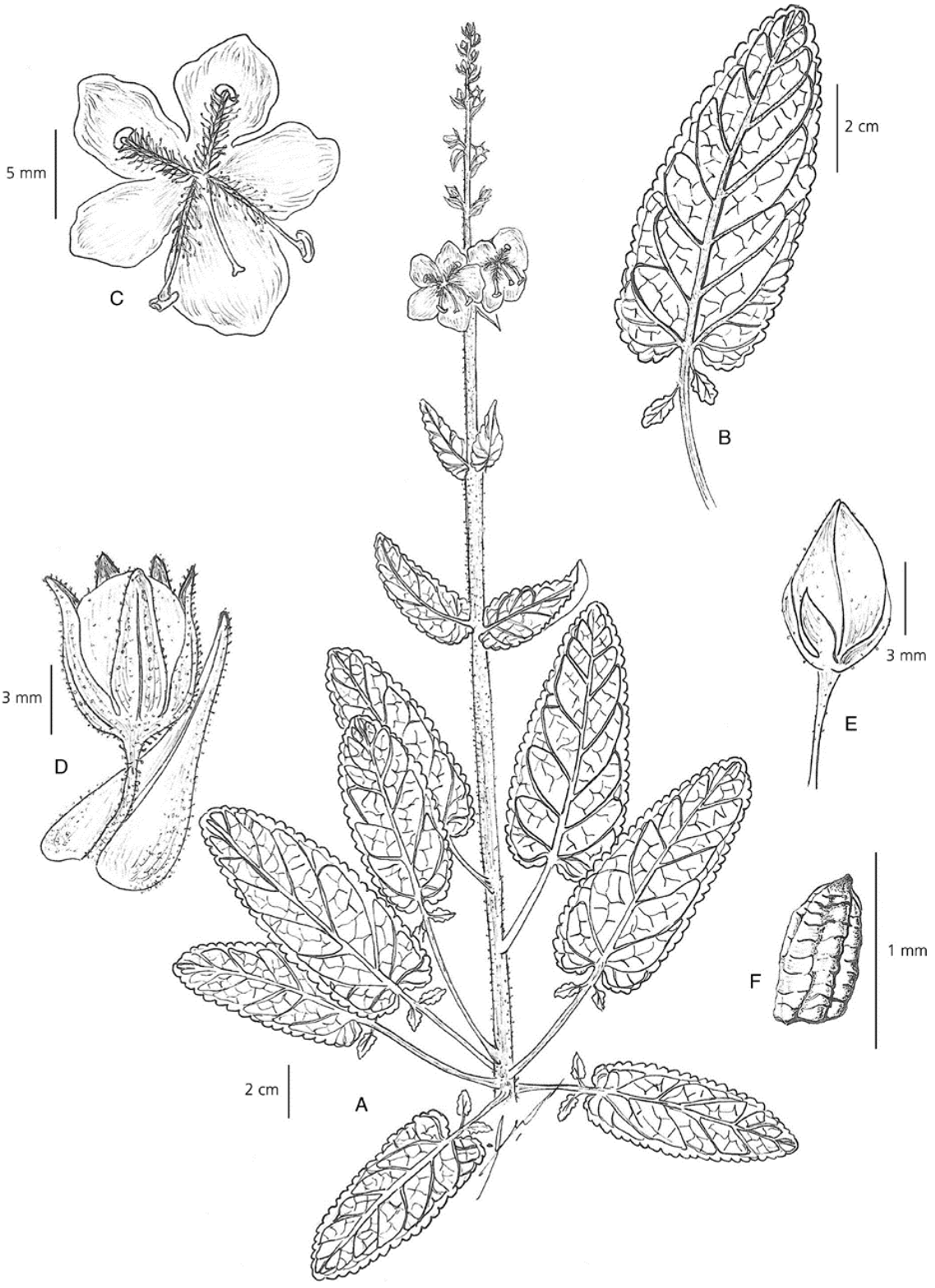

Figure 2.3. *Rhabdotosperma saudiarabicum*. A habit; B leaf and petiole with two small lateral lobes; C flower (showing two anterior anthers inserted obliquely); D calyx and upper bract (densely covered in glandular hairs); E capsule; F seed. A

– D from *I. S. Collenette* 3316; E – F from *L. Boulos* and *A. S. Ads* 14165. DRAWN BY SUHAIR ALMALKI.

Habitat. The species is known from evergreen woodlands in the Asir mountains from Saudi Arabia at altitudes ranging from 2500 – 3000 m, where it grows in granite crevices and near streams. Associated plants observed within the locality include *Juniperus procera* Hochst. ex Endl., *Vachellia origena* (Hunde) Kyal. & Boatwr., *Hypericum revolutum* Vahl, *Dodonaea viscosa* subsp. *angustifolia* (L.f.) J.G.West, *Erica arborea* L., *Rosa abyssinica* R.Br. ex Lindl., *Clutia lanceolata* Forssk., *Euryops arabicus* Steud. ex Jaub. & Spach, *Nepeta deflersiana* Schweinf. ex Hedge, *Lavandula dentata* L., *Mentha longifolia* var. *schimperi* (Briq.) Briq., *Plantago lanceolata* L., and *Veronica anagallis-aquatica* L.

Conservation Status. Rhabdotosperma saudiarabicum is endemic to Al-Soudah in the Asir Mountains of Saudi Arabia; three localities of five specimens are known from this area. The species was last recorded in 1985 by Collenette. However, during fieldwork in Al-Soudah in 2019, 2020, and 2021, the first author failed to find it, indicating that it might be either very rare or extinct from the type locality. The locality is under threat from suburban and agricultural expansion, colonisation by invasive species such as *Opuntia ficus-indica* (L.) Mill., *Nicotiana glauca* Graham, *Tagetes minuta* L., *Argemone ochroleuca* Sweet, and *Verbesina encelioides* (Cav.) Benth. & Hook.f. ex A.Gray, and recently, as a tourism destination and recreation area. Due to the close proximity of the localities where specimens of *R. saudiarabicum* were recorded (Figure 2.4), and to the fact that they face the same threats, we treated them as a single location based on the IUCN's definition of "location". Additionally, we estimated that the number of

mature individuals may be less than 50, its extent of occurrence is 11.566 km2, and the area of occupancy is 12 km^2. Therefore, we assessed the species as Critically Endangered (CR), meeting B1ab (iii)+D.

Table 2.1. Morphological comparison of *Rhabdotosperma saudiarabicum* and similar species.

Characters	***R. saudiarabicum***	***R. bottae***	***R. scrophulariifolium*** (Murbeck 1925)
Plant height (cm)	up to 40	up to 85	up to 120
Indumentum	densely covered with glandular hairs	densely covered with glandular hairs	densely covered with glandular hairs and sparse simple and forked hairs
Basal leaf dimensions (cm)	8 – 10 × 3 – 4	4 – 15 × 1 – 5	4 – 12 × 1.5 – 4
Petiole length (cm)	4.5 – 6.5	2 – 6.5	4 – 12
Pedicel (mm)	5 – 6	10 – 20	6 – 30
Calyx lobe length (mm)	4 – 5	4 – 5.5	6 – 9
Corolla indumentum	sparse glandular hairs outside	dense glandular hairs outside	sparse glandular hairs outside
Filaments (mm)	two anterior 3 – 5 with anthers inserted obliquely	two anterior 7 – 8 with anthers inserted decurrent longitudinally	two anterior 3 – 4 with anthers inserted obliquely
Style length (mm)	3 – 4	8 – 15	5 – 7.5
Capsule size (mm)	6 – 8 × 4 – 5	6 – 8 × 4 – 6	7 – 10.5 × 5 – 6.5
Capsule indumentum	sparse glandular hairs	glabrous	glabrous
Seed size (mm)	0.6 – 0.7 × 0.4 – 0.5	0.8 – 0.9 × 0.4 – 0.5	0.8 – 0.9 × 0.4 – 0.5

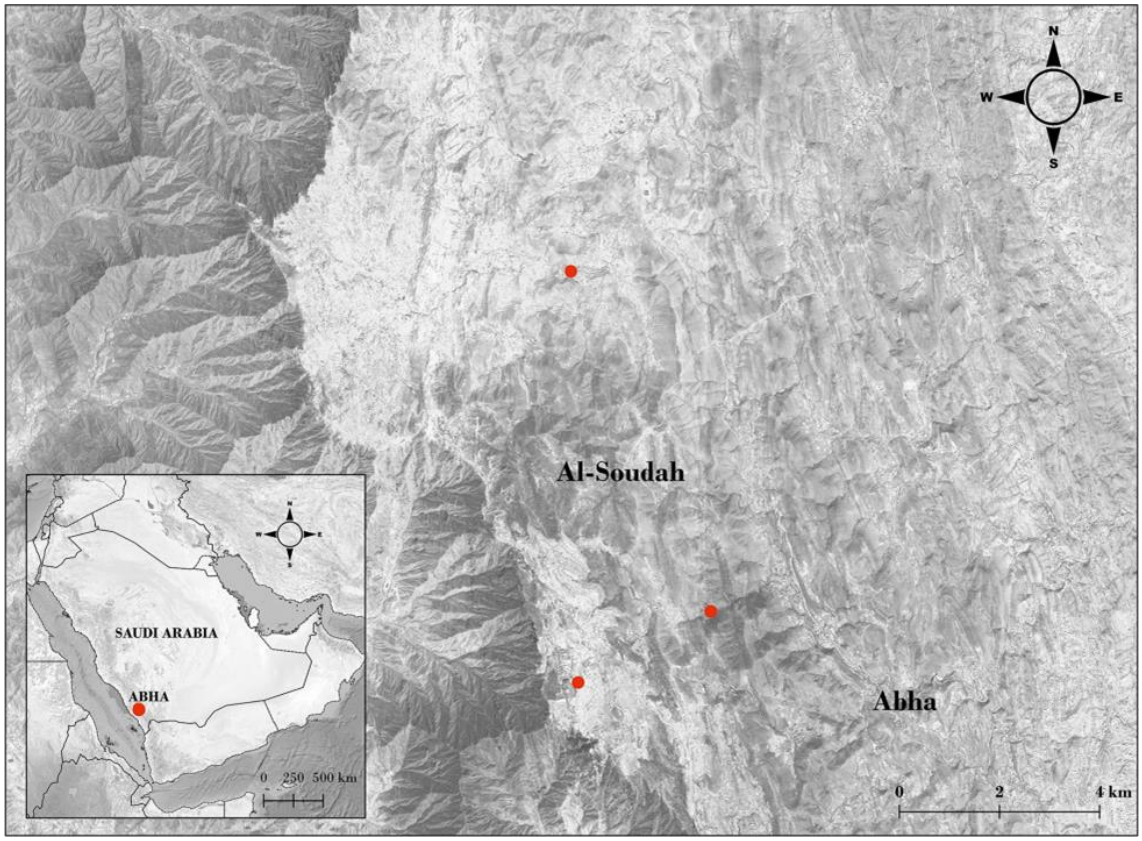

Figure 2.4. Distribution map of *Rhabdotosperma saudiarabicum* in Saudi Arabia.

Phenology. Rhabdotosperma saudiarabicum was collected with flowers from February to August and in fruit from May to July.

Etymology. The specific epithet is derived from Saudi Arabia, where this species is endemic.

Notes. Specimens of this newly described species were included in *Verbascum melhanense* (Murb.) Hub.-Mor. or *R. bottae* in all published floras of Saudi Arabia (Collenette, 1985, 1998, 1999; Chaudhary, 2001), leading to its misidentification over the last 75 years. Seed morphology is the most distinctive and stable character separating *Verbascum* and *Rhabdotosperma* (Murbeck, 1925, 1933; Hartl, 1977; Huber-Morath, 1978). Hence, *V. melhanense* is not included in this morphological comparison of similar species presented in Table 2.1 because of

the transversally elongated seeds (bothrospermous, Hartl, 1959) that characterise *Verbascum*.

CHAPTER 3. DNA BARCODING OF THE GENUS *VERBASCUM* (SCROPHULARIACEAE) IN THE ARABIAN PENINSULA

The work presented in this chapter has been submitted in TAXON.

Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (submitted) DNA Barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula. *TAXON*.

Author contribution:

Conceived and designed the study: A.M.A., J.M.B., N.M.

Data collation and preparation: A.M.A.

Performed analysis: A.M.A.

Interpreted results: A.M.A., J.M.B., S.A.G., N.M.

Wrote the paper: A.M.A.

Critically reviewed the paper: A.M.A., J.M.B., S.A.G., N.M.

3.1 Abstract

Verbascum L. and *Rhabdotosperma* Hartl are members of the family Scrophulariaceae. The first genus comprises approximately 360 species from almost all part of the world, while the second contains a total of 8 species from tropical Africa and the Arabian Peninsula. Since 1977, the relationships between *Verbascum* L. and *Rhabdotosperma* continue to be contested. The present study aims to present the phylogenetic relationships and species delimitation among *Verbascum* species in the Arabian Peninsula. For phylogenetic analyses, Maximum parsimony and Bayesian inference were performed. The phylogenetic analysis of nuclear (ITS) and three chloroplastic (*rbcL*, *matK*, and *trnL*) sequences confirmed the monophyly of the genus *Verbascum* including the genus *Rhabdotosperma*. In addition to presenting novel phylogenetic relationships among the different species of *Verbascum* on the Arabian Peninsula, this study also provides 236 DNA sequences representing 16 taxa with 4 varieties of this genus. Moreover, the phylogenetic analysis strongly supports the reinstatement of the genus *Rhabdotosperma* into *Verbascum* based on the Bayesian and Maximum parsimony analyses.

Keywords: *Verbascum*, *Rhabdotosperma*, phylogeny, species delimitation, Arabian Peninsula.

3.2 Introduction

Verbascum L. and *Rhabdotosperma* Hartl belong to the family Scrophulariaceae in the tribe Scrophularieae (Oxelman *et al*., 2005). The latter genus was separated from the former genus based on Hartl's (1977) analysis of seed morphology; Lobin and Porembski (1994) and Fischer (2004) followed this

classification, which its species can be distinguished from their sister species in *Verbascum* by longitudinally furrowed seeds, the lack of accessory flowers and a stigma that is dilated to disciform in shape (Fischer, 2004; Hartl, 1977). The genus *Verbascum* comprises approximately 360 species worldwide (Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017), whereas *Rhabdotosperma* consists of 6 species from tropical Africa and 2 species from the Arabian Peninsula (Hartl, 1977; Lobin and Porembski, 1994; Fischer, 2004; Christenhusz, Fay and Chase, 2017; Alzahrani *et al*., 2022).

Most studies on the systematics of both genera have focused on morphological characteristics (Murbeck, 1925, 1933; Grabias, Swiatek and Swietoslawski, 1991; Hartl, 1977; Juan, Fernandez and Pastor, 1997; Huber-Morath, 1978). In contrast, a few studies have used molecular phylogenetics to understand the evolution of the morphology and the phylogenetic relationships between *Verbascum* and related genera or within the genus (Remal, 2014; Ghahremaninejad *et al*., 2015; Sotoodeh, 2015; Riahi and Ghahremaninejad, 2019). Until recently, the phylogeny of the genus *Rhabdotosperma* was unknown; however, as shown in the phylogenetic studies by Dong *et al*. (2022), the separation of this genus is not supported, and it forms a sister clade of other *Verbascum* species.

The genus *Verbascum* is taxonomically challenging and complex (Huber-Morath, 1978). *Verbascum* is represented by about 22 species on the Arabian Peninsula, including 2 *Rhabdotosperma* species (Huber-Morath, 1984; Western, 1989; Wood, 1997; Collenette, 1985, 1998, 1999; Chaudhary, 2001; Jongbloed *et al*., 2003; Ghazanfar, 1992, 2015; Alzahrani *et al*., 2022). The populations of

this genus exhibit variations in habitats and morphological characteristics, particularly in terms of the number of stamens, leaf shape and type of indumentum. Nevertheless, neither a complete taxonomic revision nor a phylogenetic analysis of *Verbascum* has been attempted.

Therefore, this study aims to (a) provide the first DNA barcodes for Arabian *Verbascum* species, based on nuclear (ITS) and three chloroplastic (*rbcL*, *matK*, and *trnL*) regions; (b) review the intraspecific separation between *Verbascum* and *Rhabdotosperma* species; (c) understand the relationships among Arabian *Verbascum* species and gain more insights into their evolutionary history; and (d) evaluate Arabian *Verbascum* species, particularly those described by Al-Hemaid (2001), resulting in additional morphological delimitation issues among *Verbascum* species in Saudi Arabia.

3.3 Materials and Methods

3.3.1 Taxon Sampling

In this study, 69 samples representing 20 *Verbascum* and 2 *Rhabdotosperma* species were collected from a variety of geographical locations and subpopulations on the Arabian Peninsula. Whenever possible, 2 to 4 specimens of each species were collected; thus, 32 leaf samples were collected in the field between 2020 and 2021, and 37 were herbarium specimens. All field samples and herbarium specimens are listed in Appendix 3.1. Each sample was inserted in a teabag with a label in a container containing silica gel (Kress and Erickson, 2012; Wilkie *et al*., 2013). Outgroup taxa were selected from *Scrophularia* Tourn. ex L. and *Teedia* Rudolphi, which are sister genera of *Verbascum* and *Rhabdotosperma*.

3.3.2 Molecular Methods

The molecular analysis was conducted in a laboratory of the University of Guelph, Canada. Genomic DNA was extracted from plant materials using the Maxwell® RSC PureFood GMO and Authentication Kit and the Maxwell® RSC system (Promega). The primers used for each region are listed in Table 3.1.

Table 3.1. PCR Primers used for amplification in DNA regions.

Region	Primer	Sequence (5'-3')	References
rbcL	*rbcL*a-F	ATGTCACCACAAACAGAGACTAAAGC	Levin *et al*. (2003)
	*rbcL*a-R	GTAAAATCAAGTCCACCRCG	
matK	*matK*472F	CCCRTYCATCTGGAAATCTTGGTTC	Yu, Xue and Zhowu
	*matK*1248R	GCTRTRATAATGAGAAAGATTTCTGC	(2011)
trnL	*trnL*-f	ATTTGAACTGGTGACACGAG	Taberlet *et al*. (1991)
	trnL-c	CGAAATCGGTAGACGCTACG	
ITS	ITS2F	ATGCGATACTTGGTGTGAAT	Chen *et al*. (2010)
	ITS3R	GACGCTTCTCCAGACTACAAT	

The PCRs were carried out in 25-µL reactions containing 1x HotStarTaq master mix (Qiagen), 400 µM of each primer, 0.15 µg of BSA and 2 µl of the DNA template. The GeneAmp™ PCR System 9700 (Applied Biosystems) was used to conduct the PCRs. The PCR cycling programmes were 95 °C for 10 min of denaturation, 42 cycles of 95 °C for 15 s of annealing, 52 °C or 55 °C for 1 min and 72 °C for 2 min of extension, followed by 7 min of final extension at 72 °C.

PCR products were visualised on 2% agarose gels, and then the NucleoFast® 96 PCR clean-up kit (Macherey-Nagel) was used to purify the successful products. The purified PCR fragments were sequenced bidirectionally using an ABI 3730xl Genetic Analyzer (Applied Biosystems) and the same primers as those used for the PCRs. The ABI Prism™ DNA Sequencing Analysis

Software (Applied Biosystems) assembled the sequences into a consensus sequence. The Molecular Evolutionary Genetics Analysis (MEGA11) was used to align and then combine the sequences (Tamura, Stecher and Kumar, 2021).

3.3.3 Phylogenetic Analyses

The nuclear and chloroplast data matrices were separately and jointly analysed using both Maximum Parsimony (MP) and Bayesian Inference (BI).

The jModelTest v.2.1.2 (Darriba *et al*., 2012) was used to determine the best nucleotide substitution model for each dataset. In the Akaike information criterion (AIC), the GTR+G model was selected for the chloroplast and nuclear regions in separate analyses regions, while the GTR+I+G model was selected for the combined regions.

The MP analysis was performed with PAUP* v.4.0a169 (Swofford, 2002), a heuristic search was used with 1000 random addition sequence replicates, Tree-bisection reconnection (TBR) branch swapping, the steepest descent turned on and MulTrees enabled with a maximum of 10000 shortest trees. In addition to a bootstrap analysis was conducted with 1000 replicates, TBR branch swapping with 5 replications and the steepest descent option enabled, with a maximum of 10 trees saved per replicate.

Bayesian analyses were performed in MrBayes v.3.1.2 (Ronquist and Huelsenbeck, 2003), with 1 million Markov Chain Monte Carlo (MCMC) generations, with 2 independent runs consisting of 3 heated chains and 1 cold chain. The tree sampling frequencies were set to the value 1000, which resulted in 1000 trees, then 25% Burn-in was applied to the 1000 trees, which discarded the first 250 sampled trees.

3.4 Results

Only 236 of 276 sequences of all 4 regions (ITS, *matK*, *rbcL*, and *trnL*) were successful completed in the DNA barcoding of *Verbascum* species on the Arabian Peninsula (Appendix 3.1). The combined nuclear (ITS) and chloroplastic (*rbcL*, *matK*, and *trnL*) matrices consisted of 2564 characters, of which 375 (14.6%) were variable, and 342 (13.3%) were informative. All 3 chloroplastic (matK, rbcL and trnL) matrices contained 2115 characters, 39 (1.8%) of which were variable, and 99 (4.6%) were informative. The ITS matrix contained 449 characters, of which 239 (53.2%) were variable, and 50 (11.1%) were informative (Table 3.2).

There was discordance among BI and MP trees of each individual marker (Appendices 3.2–3.9), which had less resolution and lower support values than those of the combined markers (Figure 3.1). The parsimony analysis of the combined data resulted in a strict consensus on the 10,000 most equally parsimonious trees, with a 939-tree length, a consistency index (CI) of 0.8807 and a retention index (RI) of 0.8724 (Table 3.2). In a few cases, the bootstrap values obtained from the MP analyses were either unresolved or less resolved than the posterior probability obtained from the Bayesian analyses; however, both the Bayesian and the MP analyses of the combined chloroplast and ITS genes are only provided in this paper. The phylogenetic trees from separate analyses are available in Appendices (3.2–3.9).

Table 3.2. A comparison of the individual and combined datasets from parsimony analysis.

DNA regions	**ITS**	***matK***	***rbcL***	***trnL***	**combined chloroplastic**	**combined chloroplastic and ITS**
No. of sequences	62	62	62	62	62	62
Alignment length (bp)	449	735	561	819	2115	2564
No. of variable characters (%)	239 (53.2)	16 (2.1)	7 (1.2)	16 (2.3)	39 (1.8)	375 (14.6)
No. of informative characters (%)	50 (11.1)	54 (7.3)	10 (1.7)	35 (4.2)	99 (4.6)	342 (13.3)
No. of most equally parsimonious trees	10000	7	6	1455	390	10000
Tree length	380	73	20	58	156	939
Consistency index (CI)	0.8763	0.9726	1.0000	0.9310	0.9295	0.8807
Retention index (RI)	0.8309	0.9835	1.0000	0.9728	0.9618	0.8724
Rescaled consistency (RC)	0.7282	0.9565	1.0000	0.9057	0.8940	0.7684

The Bayesian and the MP analyses of the concatenated chloroplast and ITS genes resulted in the same topologies for the phylogenetic relationships among *Verbascum* species, and strongly supported the genus *Verbascum* as monophyletic (Bayesian posterior probability (PP) = 1 / maximum parsimony bootstrap (PB) = 100; Figure 3.1). Additionally, the phylogenetic tree was divided into 2 major branches and 11 clades, including the genus *Rhabdotosperma* (indicated by nodes 1–2 and A–K, respectively).

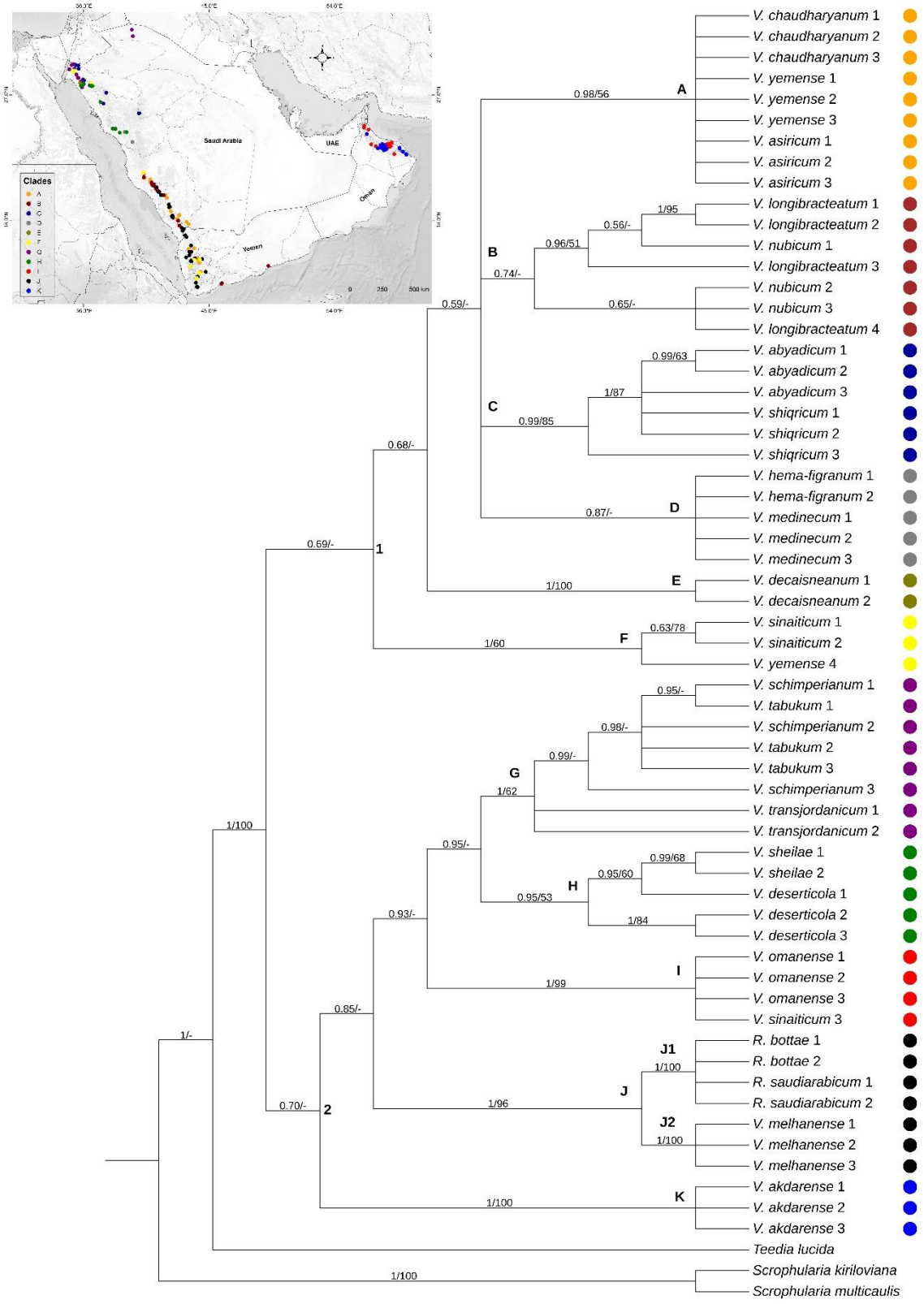

Figure 3.1. Bayesian majority-rule (50%) consensus tree of the combined chloroplast and ITS sequence data matrix. Support values on branches are Bayesian posterior probability/maximum parsimony bootstrap. Clades and

species (including study samples) are coloured, and their geographic distribution is indicated on the map.

In the first branch, clades A to D are formed in a polytomy with endemic species that share certain characteristics, including clustered flowers and stellate hairs. They are found from northwest Saudi Arabia to southern Yemen. Clade A (PP = 0.98 / PB = 56) comprises taxa found in the southwest region of the Arabian Peninsula. Clade B was supported by the Bayesian analysis (PP = 0.74) but unresolved by the MP analysis; this clade consists of a complex species with a high variation, found in the Asir mountains of southwest Saudi Arabia and the southern region of Yemen. Clade C (PP = 0.99 / PB = 85) consists of taxa found in variable habitats and species, with a wide distribution from western to northwest Saudi Arabia. Clade D was well supported by the Bayesian analysis (PP = 0.87) but not by the MP analysis; its species are endemic to the Hijaz mountains.

Clade E was strongly supported by the Bayesian and MP analysis (PP = 1 / PB = 100). It includes species that has four stamens, solitary flowers and forked hairs (rarely stellate hairs) and is found from northwest Saudi Arabia to the eastern Mediterranean. Clade F (PP = 1 / PB = 60) consists of species with set-apart distributions in the north, west and south regions of the Arabian Peninsula; this clade is a sister of the *Verbascum* taxa on the first main branch.

The Bayesian analysis strongly supported Clade G (PP = 1), whereas the MP analysis weakly supported it (PB = 62). This clade's species can be recognised by 5 stamens, often solitary or rarely dichasium inflorescence, and glandular or stellate hairs, and their habitats range from northwest Saudi Arabia to the eastern Mediterranean. Clade H (PP = 0.95 / PB = 53) is a sister of the

previous clade; however, its taxa have four stamens, solitary flowers, dense glandular hairs above and stellate hairs below, and its species are endemic from west to northwest Saudi Arabia. Clade I (PP = 1 / PB = 99) consists of species endemic to the foothills of the Hajar mountains in Oman and the UAE, with five stamens, flower clusters, bracteoles and glandular-stellate hairs.

Clade J can be divided into two strongly supported subclades (J1 and J2); both *Verbascum* and *Rhabdotosperma* species within this clade have four stamens, solitary flowers and glandular hairs; however, their seeds have distinct appearances. Subclade J1 (PP = 1 / PB = 100) consists of *Rhabdotosperma* species with longitudinally furrowed seeds, whereas Subclade J2 (PP = 1 / PB = 100) comprises *Verbascum* species with transversally elongated seeds; both subclades are endemic to the southwestern Arabian Peninsula.

Clade K's (PP = 1 / PB = 100) species can be recognised by four stamens, solitary flowers and glandular-pubescent hairs; they are found in the foothills and mountains northeast of Oman's Hajar region. This clade is a sister of the *Verbascum* and the *Rhabdotosperma* taxa on the second main branch.

3.5 Discussion

The present phylogenetic study shows that the genus *Verbascum* is monophyletic, which is consistent with the findings of previous studies (Ghahremaninejad *et al.,* 2015; Sotoodeh, 2015; Riahi and Ghahremaninejad, 2019). In addition to revealing a novel phylogenetic relationship among the various species of *Verbascum* on the Arabian Peninsula, this study also provides 59 DNA sequences from each region, representing 16 taxa and 4 varieties of this genus. The status of the *Verbascum* species from the Arabian Peninsula,

particularly Saudi Arabia, for which the morphological analysis reveals difficulties in taxon delimitation, is discussed in the following sections.

Verbascum abyadicum Hemaid and ***V. shiqricum*** Hemaid. Al-Hemaid (2001) described *V. abyadicum* and *V. shiqricum* from Saudi Arabia based on a single collection for each species. The former has 4 stamens and is found in Harrat Khaybar in western regions, whereas the latter has 5 stamens and is found near Shigry in northwest regions. However, Alzahrani *et al*. (see Chapter 4) treated *V. abyadicum* as synonyms of *V. shiqricum* since they share similar morphological characteristics and geographic distributions. *V. shiqricum* is a highly variable species that can be found in a wide range of habitats and is located in west and northwest Saudi Arabia. The combined analysis, *V. shiqricum* (1, 2 and 3) and *V. abyadicum* (1, 2 and 3) formed a monophyletic clade with strong support (PP = 0.99 / PB = 0.85; Figure 3.1 clade C).

Verbascum akdarense (Murb.) Hub.-Mor. A distinct species, *Verbascum akdarense* has solitary flowers and glandular-pubescent hairs and is endemic to the foothills and mountains of Hajar to the northeast of Oman. The phylogenetic analysis showed that *V. akdarense* (1, 2 and 3) formed a monophyletic clade with strong support (PP = 1 / PB = 100; Figure 3.1 clade K).

Verbascum asiricum Hemaid, ***V. chaudharyanum*** Hemaid and ***V. yemense*** Defl. Deflers (1889) described *V. yemense* as a species endemic to Yemen; much later, Collenette (1985) documented it in Saudi Arabia. Al-Hemaid (2001) recognised it as a distinct species from the newly described *V. asiricum* and *V. chaudharyanum* from Saudi Arabia. Due to their similarities in morphology and geographic distribution, Alzahrani *et al.* (see Chapter 4) determined *V.*

chaudharyanum to be a synonym of *V. yemense* and *V. asiricum* to be conspecific of *V. yemense*. The phylogenetic tree of *V. yemense* (1, 2 and 3), *V. chaudharyanum* (1, 2 and 3) and *V. asiricum* (1, 2 and 3) is consistent with this interpretation (PP = 0.98/ PB = 56; Figure 3.1 clade A).

Verbascum decaisneanum Kuntze. *Verbascum decaisneanum* can be recognised by its four filaments, solitary flowers and forked (occasionally stellate) hairs, and it is found in northwest Saudi Arabia, Jordan, Egypt (Sinai), Palestine, Lebanon and Syria. The combined analysis of *V. decaisneanum* (1 and 2) formed a strongly supported monophyletic clade (PP = 1/PB = 100; Figure 3.1 clade E).

Verbascum deserticola (Vatke ex Murb.) Hub.-Mor. and ***V. sheilae*** Hemaid. Murbeck (1925) treated *V. deserticola* as a distinct species and described it from Saudi Arabia. This species is found in the western and northwestern regions of Saudi Arabia. Due to its extreme variability, it has been considered either a synonym of *V. schimperianum* Boiss. or an unaccepted species. In 2001, Al-Hemaid described *V. sheilae* and *V. deserticola* and differentiated them from each other; however, Alzahrani *et al.* (see Chapter 4) considered the two taxa to be conspecific due to their similarities in morphology and geographic distribution. Moreover, the chloroplast and ITS analyses revealed that *V. sheilae* (1 and 2) and *V. deserticola* (1, 2 and 3) formed a strongly supported monophyletic clade (PP = 0.95 / PB = 53; Figure 3.1 clade H).

Verbascum hema-figranum Hemaid and ***V. medinecum*** Hemaid. Al-Hemaid (2001) described *V. hema-figranum* and *V. medinecum*, both of which are endemic to Jabal Al-Figrah in the Medina province of western Saudi Arabia. However, morphological investigations conducted by Alzahrani *et al.* (see

Chapter 4) determined that both species shared the same morphological characteristics and geographic distributions. The combination of *V. hema-figranum* (1, 2 and 3) and *V. medinecum* (1 and 2) was supported by the Bayesian analysis (PP = 0.87; Figure 3.1 clade D) but not by MP.

Verbascum longibracteatum Defl., ***V. luntii*** Baker and ***V. nubicum*** Murb. *V. luntii* and *V. longibracteatum* were described from Yemen; they share similar morphological characteristics and have habitats that are found in close proximity to each other. Baker (1894) described *V. luntii* from Alrail in Hadhramaut, Yemen; subsequently, Deflers (1896) described *V. longibracteatum* from Jabal Areys in Abyan, Yemen. Due to their similarity, Murbeck (1933) suggested that *V. luntii* should be considered a synonym of *V. longibracteatum*, which is consistent with the conclusion reached by Alzahrani *et al.* (see Chapter 4). Additionally, Collenette (1985) documented *V. longibracteatum* in southwestern Saudi Arabia, along with the related species *V. nubicum*, which was earlier described by Murbeck (1933) in Nubia, Sudan. Some authors considered *V. nubicum* a synonym of *V. sinaiticum* Benth. or an unaccepted species due to its poor collections for morphological comparison. Nevertheless, Alzahrani *et al.* (see Chapter 4) regarded *V. nubicum* from Saudi Arabia as the early growth form of *V. longibracteatum* and treated it as a synonym of the latter due to their similar morphological characteristics and geographical distributions. *V. longibracteatum* is a complex and highly variable species found in the southwestern region of Saudi Arabia and the southern region of Yemen. The combined analysis included only *V. longibracteatum* (1, 2, 3 and 4) and *V. nubicum* (1, 2 and 3), yielding limited support that can be interpreted as a failure to differentiate between the

species (PP = 074; Figure 3.1 clade B). No samples of *V. luntii* are included in this analysis.

Verbascum melhanense (Murb.) Hub.-Mor. *Verbascum melhanense* is endemic to the southwestern Arabian Peninsula. It is easy to confuse this species with *R. bottae* (Deflers) Hartl due to their similar morphological characteristics and habitats. However, it can be distinguished by its two anterior glabrous filaments and transversally elongated seeds, whereas *R. bottae* has two anterior glabrous near the apex and longitudinally furrowed seeds (see Chapter 4). The combined analysis placed *V. melhanense* (1, 2 and 3) in a strongly supported monophyletic clade (PP = 1 / PB = 100; Figure 3.1 subclade J2).

Verbascum omanense Hub.-Mor. and ***V. sinaiticum***. *V. omanense* is a species endemic to the foothills of the Hajar mountains in Oman and the UAE, and it is a highly variable species, frequently misidentified as *V. sinaiticum* or *V. cedreti* Boiss. (Mandaville and Bovey, 1978; Jongbloed *et al*., 2003; Ghazanfar, 1992, 2015). The combined analyses revealed that samples of *V. omanense* (*V. omanense* 1, 2 and 3; *V. sinaiticum* 3) from Oman and the UAE formed a strongly supported monophyletic clade (PP = 1 / PB = 99; Figure 3.1 clade I), which is consistent with the findings reported by Alzahrani *et al.* (see Chapter 4). Therefore, *V. sinaiticum* is only known from Saudi Arabia and Yemen on the Arabian Peninsula. This species can be distinguished by its dense tomentose indumentum with stellate hairs and panicle inflorescence with clustered flowers. The phylogenetic tree also showed that samples of *V. sinaiticum* (1 and 2) from Saudi Arabia and Yemen belonged to a distinct clade (PP = 1 / PB = 60; Figure 3.1 clade F). This clade includes an additional species, referred to as *V. yemense*

4, which Alzahrani *et al.* (see Chapter 4) recognise as a new species distinct from *V. sinaiticum* and *V. yemense* and which is intended to be published as "*V. sarawaticum*" as it is found in the Sarawat mountains in southeast Saudi Arabia.

Verbascum tabukum Hemaid and ***V. schimperianum***. *Verbascum tabukum* was treated as a distinct species and described by Al-Hemaid (2001), based on a single specimen, without comparing it with species from neighbouring countries. However, morphological studies (see Chapter 4) considered this species to be a synonym of *V. eremobium* Murb. due to their similar morphological characteristics and geographical distributions. The combined chloroplast and ITS analysis included *V. eremobium* (which is referred to as *V. tabukum* 1, 2 and 3; *V. schimperianum* 1 and 2) and placed them in a monophyletic clade that was strongly supported by the Bayesian analysis (PP = 0.98; Figure 3.1 clade G) but weakly supported by MP. Additionally, *V. schimperianum* could be confounded with *V. eremobium* due to their comparable geographical distributions and share morphological characteristics. The phylogenetic tree showed *V. schimperianum* (*V. schimperianum* 3) as a sister of a clade that contained *V. eremobium* (PP = 0.99; Figure 3.1 clade G), although the MP analysis provided weaker support.

Verbascum transjordanicum Murb. *Verbascum transjordanicum* is a species endemic to Jordan and northern Saudi Arabia. This is distinguishable from other Arabian *Verbascum* species by its solitary flower with five stamens, dense glandular hairs with sparse simple and forked hairs above, and dense tomentose with stellate hairs below. The phylogenetic tree revealed *V.*

transjordanicum (1 and 2) as a sister of the clades that contained *V. schimperianum* and *V. eremobium* (PP = 1 / PB = 62; Figure 3.1 clade G).

***Rhabdotosperma* group (= *Verbascum*).** Hartl (1977) separated the genus *Rhabdotosperma* from *Verbascum* on account of its seed morphology. In comparison to tropical Africa, the Arabian Peninsula is home to only two species of Rhabdotosperma namely; *R. bottae* and *R. saudiarabicum* A.Alzahrani (Hartl, 1977; Huber-Morath, 1984; Wood, 1997; Alzahrani *et al.*, 2022). However, the combined analysis of *V. bottae* (*R. bottae* 1 and 2) and *V. saudiarabicum* (*R. saudiarabicum* 1 and 2) placed them in a strongly supported monophyletic clade, nested within *Verbascum* (PP = 1 / PB = 100; Figure 3.1 subclade J1). Therefore, the phylogenetic analysis did not support this separation, and it must be reinstated into *Verbascum*, which is consistent with the recommendation of Dong *et al*. (2022); thus, Alzahrani *et al.* (see Chapter 4) regarded these *Rhabdotosperma* species as *Verbascum* species on the Arabian Peninsula.

CHAPTER 4. TAXONOMIC REVISION OF *VERBASCUM* SPECIES IN THE ARABIAN PENINSULA

The work presented in this chapter is in preparation for submission.

Alzahrani, A.M., Magos Brehm, J., Ghazanfar, S.A., and Maxted, N. (in prep) Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Author contribution:

Conceived and designed the study: A.M.A., J.M.B., N.M.

Data collation and preparation: A.M.A.

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4.1 Abstract

The species of the genus *Verbascum* L. (Scrophulariaceae) in the Arabian Peninsula are revised. Seventeen species are recognized, a key to the species is provided, all names are typified, and each species is thoroughly described. For every species, conservation assessments are provided. *Verbascum sarawaticum* A.Alzahrani and *Verbascum eremobium* Murb. are newly described and recorded species, respectively. New synonyms are made. *Rhabdotosperma* Hartl is reclassified as a synonym, and a new combination is made.

Keywords: *Verbascum*, *Rhabdotosperma*, new species, new record, new combination, Arabian Peninsula.

4.2 Introduction

Verbascum L. is the largest genus in the Figwort family (Scrophulariaceae), with a long and complex taxonomic history due to the extreme similarity and hybridization between its taxa (Huber-Morath, 1978). Linnaeus in the *Species Plantarum* (1753) divided the genus into *Celsia* L. and *Verbascum* L. based on the number of stamens (the former has four and the latter has five). Schrader (1813) wrote the first monograph on the genus *Verbascum*, which included sixty species recognised by the decurrence of leaves and the number of flowers in the axil of each bract. Later, Berchtold and Pfund (1840) wrote a second monograph on *Verbascum*, separating species based on whether the flowers were grouped (which consists of two separate groups of species with or without decurrent leaves) or solitary (which consists of two groups of species with one or multiple types of stamen). In addition, Bentham (1846) divided *Celsia* and *Verbascum* into two sections within the genus *Verbascum* based on the type of stamens: sect.

Thapsus (lower, decurrent, and longer anthers) and sect. *Lychnitis* (reniform anthers) and applied it to both genera. Following this, Franchet (1875) and Boissier (1879) divided *Verbascum* species into two sections based on Bentham's classification and taxonomic distinctions.

Furthermore, Murbeck published the detailed monographs on *Celsia* (Murbeck, 1925) and *Verbascum* (Murbeck, 1933), the first (Murbeck, 1925) divided the genus *Celsia* into the sections *Bothrospermae* and *Aulacospermae* based on the morphology of the seeds, and the former section was further subdivided into subsects *Nefflea* (all anthers reniform) and *Arcturus* (two anterior decurrent anthers). While in the second monograph of *Verbascum* (Murbeck, 1933), species were divided into the sections *Bothrospermae* and *Aulacospermae* based on the morphology of the seeds, and the former was further split into two subsections *Fasciculata* (clusters flowers) and *Singuliflora* (solitary flowers). Later, Ferguson (1971) and Huber-Morath (1973) included *Celsia* L. and *Staurophragma* Fisch. and Mey. in the genus *Verbascum* L. due to the morphological similarity between them and the difficulty in distinguishing their species. Huber-Morath (1978) revised *Verbascum* species in Turkey and grouped the species of sect. *Bothrospermae* Murb. into 13 artificial groups according to the number of stamens, the type of hair on the indumentum, and the number of flowers per bract.

Rhabdotosperma, which was previously split between *Celsia* L. and *Verbascum* L. sect. *Aulacospermae* by Murbeck (1925, 1933), was separated as a distinct genus from *Verbascum* on the basis of seed morphology by Hartl (1977). Use of *Rhabdotosperma* was subsequently followed by Lobin and

Porembski (1994), Fischer (2004, 2006), Ghazanfar, Hepper and Philcox (2008), and Alzahrani *et al*. (2022). Some authors, however, consider *Rhabdotosperma* a synonym of *Verbascum* due to their morphological similarities (Huber-Morath, 1984; Wood, 1997; Collenette, 1999; Chaudhary, 2001). Recent phylogenetic studies on the genus *Verbascum* (Remal, 2014; Ghahremaninejad *et al*., 2015; Sotoodeh, 2015; Dong *et al*., 2022; see Chapter 3) are not consistent with the classifications of Murbeck (1925, 1933) and Huber-Morath (1973) but confirmed the monophyly of the genus and supported the previous inclusion of *Celsia* L., *Staurophragma* Fisch. and Mey., and *Rhabdotosperma* Hartl within the genus *Verbascum* L., which was applied by Ferguson (1971) and Huber-Morath (1973, 1984).

Generally, current taxonomists rely on Murbeck's (1933) classification in terms of seed morphology and split the species between *Bothrospermae* (transversally elongated seeds) and *Aulacospermae* (longitudinally furrowed seeds). Thus, all *Verbascum* species belong to *Bothrosperma* Murb. Sect. *Bothrosperma* and contain about 350 species distributed throughout the world, but mostly in western Asia, whereas *Aulacospermae* Murb. contains eight species found in tropical Africa and the Arabian Peninsula (Murbeck, 1933; Huber-Morath, 1973; Hartl 1977; Fischer, 2004; Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017; Alzahrani *et al*., 2022).

The Middle East, Turkey and Iran are the centre of diversity for *Verbascum*, where about 287 species have been recorded (Murbeck, 1933, 1939; Huber-Morath, 1978; Sharifnia, 2007; Ranjbar and Nouri, 2015; Sotoodeh, 2015) and where the number of described species is increasing rapidly

(Karavelioğulları, Duran and Hamzaoğlu, 2004; Parolly and Tan, 2007; Sharifnia and Assadi, 2007; Parolly and Eren, 2008; Bani, Adigüzel and Karavelioğulları, 2010; Sotoodeh, Civeyrel and Attar, 2015; Çingay, Demir and Cabi, 2018; Ulukuş, Tugay and Sağlam, 2020; Firat, 2022; Sotoodeh *et al*., 2022).

Within the Arabian Peninsula, Deflers (1889) in the book *Voyage au Yemen* described the first two species of *Verbascum* from Yemen. Since then, there have been accounts, checklists, and new species of *Verbascum* added from other countries in the region (Baker, 1894; Deflers, 1896; Blatter, 1921; Murbeck, 1925, 1933; Migahid, 1974; Huber-Morath, 1984; Collenette, 1985, 1998, 1999; Western, 1989; Wood, 1997; AI-Hemaid, 2001; Chaudhary, 2001; Ghazanfar, 1992, 2015; Alzahrani *et al*., 2022). Nevertheless, a comprehensive taxonomic revision is timely for this genus on the Arabian Peninsula given the widespread misidentification, nomenclatural confusion, and absence of useful keys to the Arabian *Verbascum* species. Therefore, this study provides the first detailed revision of *Verbascum* in the Arabian Peninsula.

4.3 Materials and Methods

Verbascum specimens or digital images were studied from the following herbaria: BM, E, K, KSU, MUZ, OBG, ON, RIY, and the JSTOR Global Plants platform (Thiers, continuously updated). All specimens from the Arabian Peninsula were seen and cited unless otherwise stated. In addition to studying protologues and relevant taxonomic literature, fieldwork was conducted in Saudi Arabia and Oman between 2019 and 2021.

Conservation assessments were carried out following the IUCN Red List Categories and Criteria (IUCN, 2012), and the extent of occurrence (EOO) and

area of occupancy (AOO) were calculated using the Geospatial Conservation Assessment Tool (GeoCAT) with a grid size of 2 km^2 (Bachman *et al*., 2011). The distribution map was generated using QGIS software version 3.22. (2022).

4.4 Results and Discussion

4.4.1 Morphological Characters

The following characteristics are useful for identifying and delimiting *Verbascum* species on the Arabian Peninsula.

Habit

All species of *Verbascum* are annual, biennial, or perennial herbs to small shrubs ranging from 30 to 250 cm in height.

Stems

Stems are usually erect and terete but sometimes can be terete to angular (e.g. *V. bottae*). The branching can be a useful character, with simple (e.g. *V. saudiarabicum*), branched from above (e.g. *V. deserticola*), and branched from the base (e.g. *V. transjordanicum*).

Leaves

The leaves of Arabian *Verbascum* are always rosette, except for *V. saudiarabicum*, which has alternate leaves. Basal leaves are mostly oblong to oblong-lanceolate (e.g. *V. transjordanicum*), oblong to oblong-ovate (e.g. V*. sinaiticum*), oblong to obovate-oblong (e.g. *V. schimperianum*), oblong-ovate (e.g. *V. saudiarabicum*), oblanceolate (e.g. *V. virgatum*), lanceolate (e.g. V. *longibracteatum*), elliptic-lanceolate (e.g. *V. sarawaticum*), obovate (e.g. *V. akdarense*), obovate-elliptic to ovate (e.g. *V. shiqricum*), or obovate-oblong (e.g.

V. eremobium). Cauline leaves can be decurrent (e.g. *V. medinecum*), sessile (e.g. *V. longibracteatum*), and sessile or petiole (e.g. *V. sinaiticum*).

Indumentum

The indumentum is comprised of three main types: glandular hairs, simple hairs, and branched hairs of various varieties. One species of *Verbascum* may contain one (e.g. *V. schimperianum*), two (e.g. *V. deserticola*), or all three of these types (e.g. *V. transjordanicum*). This is also applied to the inner and outer surfaces of the corolla, as well as the outer surfaces of calyx, pedicel, ovary, and capsule.

Inflorescence

Arabian *Verbascum* species have racemose (e.g., *V. bottae*), dichasium (e.g., *V. eremobium*), and panicle (e.g., *V. omanense*) inflorescence types. In addition, the number of flowers (one or more accessory flowers) are helpful identification characteristics. Which are single flowers lacking bracteoles (e.g. *V. decaisneanum*), single flowers with bracteoles (e.g. *V. eremobium*), cluster flowers lacking bracteoles (e.g. *V. shiqricum*), and cluster flowers with bracteoles (e.g. *V. longibracteatum*).

Calyx

Calyx lobes are an additional characteristic that can be useful in identifying Arabian *Verbascum*, which are oblong (e.g. *V. sarawaticum*), ovate-elliptic (e.g. *V. schimperianum*), linear (e.g. *V. shiqricum*), lanceolate (e.g. *V. sinaiticum*), oblanceolate (e.g. *V. virgatum*), and ovate-oblong (e.g. *V. akdarense*).

Corolla

The corolla is yellow, sometimes with marks on the throat (e.g. *V. shiqricum*), the upper side (e.g. *V. melhanense*), or both (e.g. *V. saudiarabicum*), with five petals

rarely six or four in some individuals (e.g. *V. yemense* and *V. sinaiticum*). Another helpful characteristic of the corolla is the presence of pellucid glands, which can be used to delimit species, especially those that share the same geographical distribution (e.g. *V. sarawaticum*).

Stamens

Verbascum species have four or five stamens (e.g. *V. melhanense* and *V. transjordanicum*, respectively), which is somewhat to be a valid character if it is counted carefully within the species' population. However, this feature can be unstable in some *Verbascum* species due to the presence of four to seven stamens (e.g. V*. longibracteatum*, *V. yemense* and *V. sinaiticum*).

Filaments

The filament hairs of Arabian *Verbascum* species are all hairs up to the anthers (e.g. *V. omanense*), two anterior glabrous near the apex (e.g. *V. medinecum*), and two anterior glabrous (e.g. *V. melhanense*). In addition to the colour of filament hairs can be white (e.g. *V. shiqricum*), yellow (e.g. *V. decaisneanum*), yellow-whitish (e.g. *V. medinecum*), yellowish-red (e.g. V*. saudiarabicum*), red-purple (e.g. V*. eremobium*).

Anthers

In Arabian species, there are three types of anthers: reniform anthers in the majority of *Verbascum* species, two anterior anthers inserted obliquely only in *V. saudiarabicum* and *V. virgatum,* and two anterior anthers inserted decurrent longitudinally only in *V. bottae* and *V. melhanense*.

Capsule

Capsule shapes of Arabian species are ellipsoid-ovoid (e.g. *V. yemense*), globose (e.g. *V. virgatum*), ovoid (e.g. *V. sarawaticum*), globose-subglobose (e.g. *V. eremobium*), globose-ovoid (e.g. *V. transjordanicum*), ellipsoid (e.g. *V. longibracteatum*), and pyriform-ovoid (e.g. *V. melhanense*).

Seeds

Verbascum species are divided into the sections *Bothrosperma* (transversally elongated seeds in most Arabian species) and *Aulacospermae* (longitudinally furrowed seeds only in *V. saudiarabicum* and *V. bottae*) based on the surface morphology of their seeds, which is a distinct and stable characteristic. In both sections, the seeds are oblong or ovoid in shape, brown or black in colour, and around 1 mm in size.

4.4.2 Taxonomic treatment

Verbascum L., Sp. Pl. 1: 177 (1753). – Type species: *Verbascum thapsus* L.

Celsia L., Sp. Pl. 2: 621 (1753). – Type species: *Celsia orientalis* L.

Staurophragma Fisch. & C.A.Mey., Index Seminum (LE, Petropolitanus) 9: 90 (1843). – Type species: *Staurophragma natolicum* Fisch. & C.A.Mey.

Rhabdotosperma Hartl, Beitr. Biol. Pflanzen 53(1): 57 (1977). – Type species: *Rhabdotosperma brevipedicellatum* (Engl.) Hartl.

Annual, biennial, or perennial herbs to small shrubs, simple or branched from the base or above, sometimes with woody base, from 30 to 250 cm tall. *Indumentum* glabrescent, glandular hairs, stellate hairs, or tomentose with stellate hairs. *Stems* erect, simple or many stemmed, robust, terete, or terete to angular. *Basal and Cauline leaves* rosette or rarely alternate, mostly oblong to oblong-lanceolate or oblanceolate, sometimes to obovate, elliptic, or ovate, with entire, dentate,

repand-crenulate, undulate or lobed-crenate, serrate to sinuate, crenate to denticulate, sinuate, dentate, serrate, pinnatifid-lobed margins, sessile or petiole. *Inflorescence* racemose forming panicle or spike; one or with more accessory flowers, panicle, dichasium, or racemose. *Upper and Lower bracts* linear, lanceolate, oblong to lanceolate or elliptic, triangular to ovate, ovate or ovate to lanceolate, cordate- to triangular, or oblanceolate. *Pedicel* hairy or glabrescent, from 2 to 25 mm long. *Bracteoles* absent or present ovate or to oblanceolate, lanceolate, ovate to triangular or lanceolate to triangular, linear, or lanceolate to cordate. *Calyx* lobes linear, oblong, oblong-lanceolate, ovate-oblong, lanceolate, ovate-elliptic, or oblanceolate, apex mucronate, acute, obtuse, or apiculate, hairy or glabrescent. *Corolla* yellow with or without marks in the throat, sometimes on the upper side, with or without pellucid glands, tubeless or up to 2 mm, hairy or glabrous inside and outside. *Stamens* 4 or 5, sometimes unstable. *Filaments* with whitish, yellowish-purple, yellowish-red, yellow, purple-violet to violet-whitish, red-purple, yellowish-white, yellowish-violet to red, violet-whitish, or creamy hairs, with all hairs up to the anthers, two anterior glabrous, or two anterior glabrous near the apex. *Anthers* all reniform, two anterior inserted obliquely, or two anterior inserted decurrent longitudinally. *Ovary* pyriform-ovoid, ellipsoid, ellipsoid to ovoid, ovoid, globose, globose to ovoid, or globose-subglobose, hairy or glabrous. *Style* from 4 to 22 mm long, filiform, green or red. *Stigma* spatulate, capitate, dilated, or disciform. *Capsule* pyriform-ovoid, ellipsoid, ellipsoid to ovoid, ovoid, globose, globose to ovoid, or globose-subglobose, hairy or glabrous. *Seeds* numerous, bothrospermous or aulacospermous.

Distribution. In Asia, Africa, and Europe, but the centre of diversity is in Turkey and Iran.

Key to species of *Verbascum* in the Arabian Peninsula

1a. Seeds aulacospermous _____ 2

1b. Seeds bothrospermous _____ 3

2a. Anthers two anterior inserted decurrent longitudinally _____ **2. V. bottae**

2b. Anthers two anterior inserted obliquely _____ **11. V. saudiarabicum**

3a. Flowers in clusters _____ 4

3b. Flowers solitary _____ 11

4a. Bracteoles present _____ 5

4b. Bracteoles absent _____ 9

5a. Anthers all reniform _____ 6

5b. Anthers two anterior inserted obliquely _____ **16. V. virgatum**

6a. Indumentum sparse glandular and stellate hairs above, and dense tomentose with stellate hairs below _____ **9. V. omanense**

6b. Indumentum dense tomentose with stellate hairs _____ 7

7a. Upper bracts ovate _____ **14. V. sinaiticum**

7b. Upper bracts linear _____ 8

8a. Cauline leaves 4 – 8 cm long, base obtuse; sessile __ **6. V. longibracteatum**

8b. Cauline leaves 3 – 7 cm long, base cuneate; decurrent ___ **7. V. medinecum**

9a. Calyx lobes linear, apex acute, glabrescent or sparse stellate _____ 10

9b. Calyx lobes oblong, apex mucronate, sparse stellate hairs _____ **10. V. sarawaticum**

10a. Basal leaves oblong-lanceolate, base obtuse or truncate, margins repand-crenulate _____ **17. V. yemense**

10b. Basal leaves obovate-elliptic to ovate, base obtuse to cuneate, margins crenate-sinuate _____ **13. V. shiqricum**

11a. Inflorescence racemose _____ 12

11b. Inflorescence dichasium _____ **5. V. eremobium**

12a. Anthers all reniform _____ 13

12b. Anthers two anterior inserted decurrent longitudinally ___ **8. V. melhanense**

13a. Stamens 4 _____ 14

13b. Stamens 5 _____ 16

14a. Capsule globose-ovoid _____ 15

14b. Capsule ovoid-ellipsoid _____ **4. V. deserticola**

15a. Indumentum dense glandular hairs above and pubescent hairs below _____ **1. V. akdarense**

15b. Indumentum dense glandular hairs above and forked hairs below _____ **3. V. decaisneanum**

16a. Indumentum dense glandular hairs with sparse simple and forked hairs above, and dense tomentose with stellate hairs below _____ **15. V. transjordanicum**

16b. Indumentum dense rough yellowish tomentose with stellate hairs _____ **12. V. schimperianum**

4.4.3 Species descriptions

1. Verbascum akdarense (Murb.) Huber-Morath, Bauhinia 5(1): 10 (1973). – *Celsia akdarensis* Murb., in Lunds Univ. Arsskrift, n. f. xxii. No. 1, 123 (1925). – Type: Oman, Muscat, Jabal Akhdar, *P.M.R. Aucher-Eloy* 5044 (lectotype G [G00015116] designated here, isolectotype P [P03287290]) (Figure 4.1).

Annual or biennial herb, pale green, simple or branched from the base, up to 45 cm tall. *Indumentum* dense glandular hairs above and pubescent hairs below. *Stems* erect, terete to angular. *Basal leaves* rosette, obovate, 3 – 10 x 2 – 5 cm, apex rounded, base cuneate, margins crenate-dentate, lamina darkish green with sparse glandular and dense pubescent hairs; petiole 2 – 5 cm, winged with a few small lateral lobes. *Cauline leaves* few or leafless, oblanceolate, 0.5 – 1.6 x 0.1 – 0.4 cm, apex obtuse, base obtuse; sessile. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* lanceolate-linear, 1 – 3.5 mm, acute. *Lower bracts* lanceolate 2 – 5.5 mm, acute. *Pedicel* covered with dense glandular hairs up to 25 mm long. *Bracteoles* absent. *Calyx* 2 – 3 mm, lobes ovate-oblong, mucronate, dense glandular. *Corolla* 8 – 10 mm across, yellow with purple-red spots around the throat, without pellucid glands, tube up to 1 mm, sparse papillose-ciliated hairs inside, sparse glandular hairs outside. *Stamens* 4, 4 – 5 mm long. *Filaments* yellow with yellowish-purple hairs, two anterior glabrous near the apex, two posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* globose, sparse glandular hairs. *Style* up to 6 mm long, filiform, green. *Stigma* capitate. *Capsule* 2 – 3 x 1 – 2 mm, globose-ovoid, sparse glandular hairy. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Oman, which is known from Muscat (Jabal Aswad), Ash Sharqiyah North (Jabal Abyad, Jabal Bani Jabir, and near Tiwi), Ad Dakhiliyah (Jabal Al Akhdar, Wakan Village, Wadi Kamah, and Sakhakhin), and Al Batinah South (Wadi Bani Awf, Wadi Sahtan, An Nid, Wadi Haslah, and near Rustaq), northeast Oman (Figure 4.2).

Habitat and ecology. It grows in rocky slopes, rocks and fine soil, edge of wadis and gardens, and gravelly wadi beds at altitudes ranging from 200 to 2000 m. There are no records of associated plants.

Global IUCN threat status. Least Concern. LC. (see Chapter 5).

Phenology. Flowering and fruiting from March to May.

Etymology. The named is derived from Akhdar, the local Arabic name of Jabal Akhdar.

Specimens examined. OMAN. **Muscat:** Jabal Aswad, above Siya, 21 iii 1992, *I.S. Collenette* 7994 (ON, E [E00046311]); Northern, E of Hajar mountains, Siya at foot of Jabal Aswad, 30 ix 1989, *A.G. Miller & J.A. Nyberg* 9571 (E [E00066912]). **Al Batinah South:** Vicinity of An Nid, 09 iv 1975, *J.P. Mandaville* 6403 (BM); Vicinity of An Nid, 08 iv 1975, *J.P. Mandaville* 6303 & 6317 (BM); Wadi Sahtan, 05 iv 1975, *J.P. Mandaville* 6248 (BM); Wadi Haslah, SW of Awabi, 13 iii 1978, *R.P. Whitcombe* 150 (E [E00066911]); Al-Rustaq, 18 iii 1975, *T.G. Rubens* 94 (E [E00219516]); Northern mountains, Wadi between Nakhl and Rustaq, 17 iv 2001, *A. Patzelt* 907 (K). **Ad Dakhiliyah:** Wakan village, Northern Hajar mountains, 18 iv 2007, *A. Patzelt* 2441 (OBG); Wadi Kamah trail, 20 iii

1972, *J.P. Mandaville* 3663 (BM); Upper end of Sakhakhin Gorge near Jabal Akhdar, 21 iii 1976, *A. Radcliffe-Smith* 3980 (BM, ON, K, E [E00066951]); Jabal Akhdar, *P.M.R. Aucher-Eloy* 5044 (G [G00015116], P [P03287290]). **Ash Sharqiyah North:** Jabal Bani Jabir, Eastern Hajar mountains, 23 iii 2009, *A. Patzelt* 3771 (OBG); S of Tiwi, 25 iii 1992, *I.S. Collenette* 8026 (E [E00046276]).

Verbascum akdarense can be easily distinguished from other species in the Arabian Peninsula by its indumentum covered with glandular hairs and sparse pubescent hairs, basal leaves obovate with usually a few small lateral lobes, and globose-ovoid capsule. Recent phylogenetic research (see Chapter 3) confirms that it is a distinct species.

Figure 4.1. *Verbascum akdarense*. A, habit; B, flower and pedicel with glandular hairs (white arrow); C, leaf. PHOTOS: A, SALIM AL RAHBI; B and C, SAIF AL HATMI.

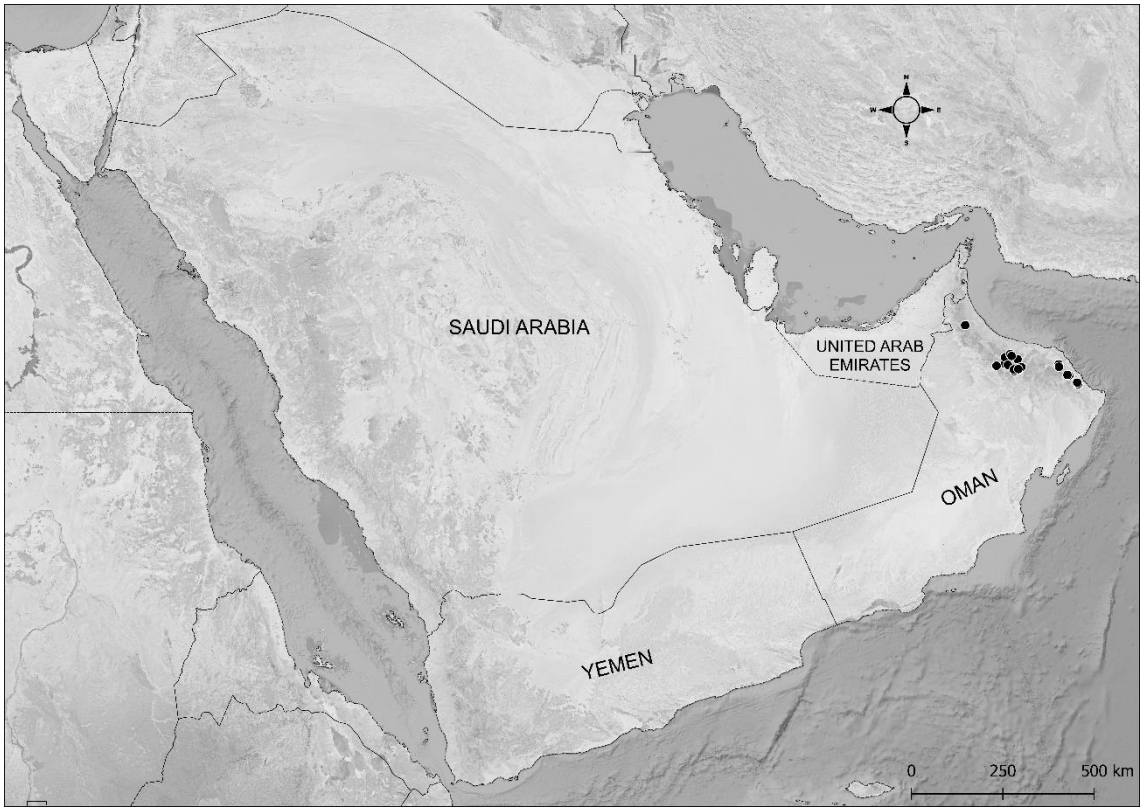

Figure 4.2. Distribution of *Verbascum akdarense* in the Arabian Peninsula.

2. Verbascum bottae (Defl.) Huber-Morath, Bauhinia 5(1): 11 (1973). – *Rhabdotosperma bottae* (Defl.) D.Hartl, Beitr. Biol. Pflanzen 53(1): 58 (1977). – *Celsia bottae* Defl., Voyage au Yemen, p. 178 (1889). – Type: Yemen, Ad fauces jugi Hadhûr, prope Bauân, 30 vi 1887, *A. Deflers* 615 (lectotype MPU [MPU020118] designated here, isolectotype P [P03287260]) (Figure 4.3).

Biennial herb, dark green to purple, simple or branched from above, woody at the base, up to 85 cm tall. *Indumentum* dense glandular hairs. *Stems* erect, robust, terete to angular. *Basal leaves* rosette, oblong to oblong-lanceolate, 4 – 15 x 1 – 5 cm, apex acute or obtuse, base subcordate-truncate, margins crenate-denticulate, lamina dark green with dense simple hairs on the veins below; petiole 2 – 6.5 cm, winged with 1 – 3 small lateral lobes. *Cauline leaves* lanceolate, 2 –

4.9 x 0.5 – 1 cm, apex acute, base subcordate-truncate; sessile. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* lanceolate, 5 – 8 mm, acuminate. *Lower bracts* triangular-ovate, 14 – 45 mm, acuminate. *Pedicel* covered with dense glandular hairs up to 20 mm long. *Bracteoles* absent. *Calyx* 4 – 5.5 mm long, lobes oblong, mucronate, dense glandular hairs. *Corolla* 15 – 20 mm across, yellow with purple-red spots around the throat, without pellucid glands, tubeless, sparse papillose hairs inside, dense glandular hairs outside. *Stamens* 4, 7 – 8 mm long. *Filaments* red with yellowish-red hairs, two anterior glabrous near the apex, two shorter posteriors with hairs up to anthers. *Anthers* two anterior inserted decurrent longitudinally on filaments, two shorter posteriors with reniform anthers. *Ovary* pyriform-ovoid, glabrous. *Style* up to 15 mm long, filiform, green. *Stigma* dilated. *Capsule* 6 – 8 x 4 – 6 mm, pyriform-ovoid, glabrous. *Seeds* aulacospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Yemen, which is known from Ibb (Jabal Taqar, Sumara Pass, Jabal Sumara, and Jiblah town), Al Mahwit (Bait Albeshari), Sana'a (Khawlan, Jabal An Nabi Shu’ayb, and Jabal Shibam), Taizz (Turbah, Algaheli Park, and Jabal Sabr), Al-Bayda (Qarn Al-Wa'al), Hajjah (Kuslan town), and Raymah (Jabal Raymah), southwestern Yemen (Figure 4.4).

Habitat and ecology. It grows on rocky slopes, limestone cliffs, terrace walls, granite crevices, and wadi banks at altitudes ranging from 1800 to 3100 m. There are no records of associated plants.

Global IUCN threat status. Near Threatened. NT. (see Chapter 5).

Phenology. Flowering and fruiting from May to December.

Etymology. The name is derived from Paul Émile Botta (1802-1870), an international naturalist.

Specimens examined. YEMEN. Ad fauces jugi Hadhûr, prope Bauân, 30 vi 1887, *A. Deflers* 615 (MPU [MPU020118]). **Ibb:** roadside S. of Ibb, 27 vii 1973, *M. Brunt* 2528 (K); On terrace walls, Jabal Taqar, 28 vii 1977, *J.R.I Wood* 1707 (K); Sumara Pass, 26 iii 1974, *J.J. Lavranos* 11288 (ON, E [E00066917]); Jiblah, environs of town, 16 x 1978, *A.G. Miller* 536 (E [E00066921]); Sumara Pass, 09 x 1978, *A.G. Miller* 462 (E [E00066918]); Jabal Sumara, 21 vi 1979, *J.R.I Wood* 2869 (BM, E [E00066922]). **Al Mahwit:** Near Bait Albeshari, 14 xii 1979, *J.R.I Wood* 3108 (K). **Sana'a:** By a water lake above Khawlan, 17 ii 1978, *J.R.I Wood* 2251 (K); Jabal An Nabi Shu'ayb, 30 ix 1972, *J.R.I Wood* 71 (BM); Jabal Shibam, 40 km N.E. of Sana'a, 17 x 1975 *F.N. Hepper* 5768 (K); Jabal Shibam above Menacha, 05 x 1978, *A.G. Miller* 377 (E [E00066914]); Shibam, 01 iv 1981, *A.G. Miller & D.G. Long* 3369 (E [E00066926]). **Taizz:** Near Turbah, Algaheli, 10 xi 1995, *M. Thulin, M. Ghebrehiwet & A.N. Gifri* 9282 (K); Jabal Sabir, above and to the SE of Taizz, 03 viii 1977, *A. Radcliffe-Smith & S.J. Henchie* 4399 (K); West facing slopes of Jabal Sabir, 15 Km S of Taizz, 11 vi 1982, *K.J. Gordon* 1 (E [E00066923]); Turbah, 24 x 1974, *J.R.I Wood* Y/74/155 (BM); Turbah, Jabal Sabir, 20 x 1974, *J.R.I Wood* Y/74/166 (BM). **Al-Bayda:** Qarn Al-Wa'al, 29 ix 1976, *J.J. Lavranos & L.E. Newton* 13045 (E [E00066916]). **Hajjah:** Kuslan, 19 iii 1979, *D. Wood* Y1100 (E [E00066920]). **Raymah:** Jabal Raymah, road from Al Jabin to Suq Ar Ribat, 22 iii 1984, *A.G. Miller & R.A. King* 5391 (E [E00687344]).

Verbascum bottae is easily confused with the closely related species *V. melhanense* due to their similar morphology and habitats, but it can be distinguished by its two anterior glabrous filaments and aulacospermous seeds, whereas *V. melhanense* has two anterior glabrous filaments and transversally elongated seeds. Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species.

Figure 4.3. *Verbascum bottae*. A, habit, calyx (white arrow), and stems with glandular hairs (white arrow); B, leaf; C, filaments with two anterior anthers inserted decurrent longitudinally and glabrous near the apex (white arrow). PHOTOS: ABDUL WALI ALKHULAIDI.

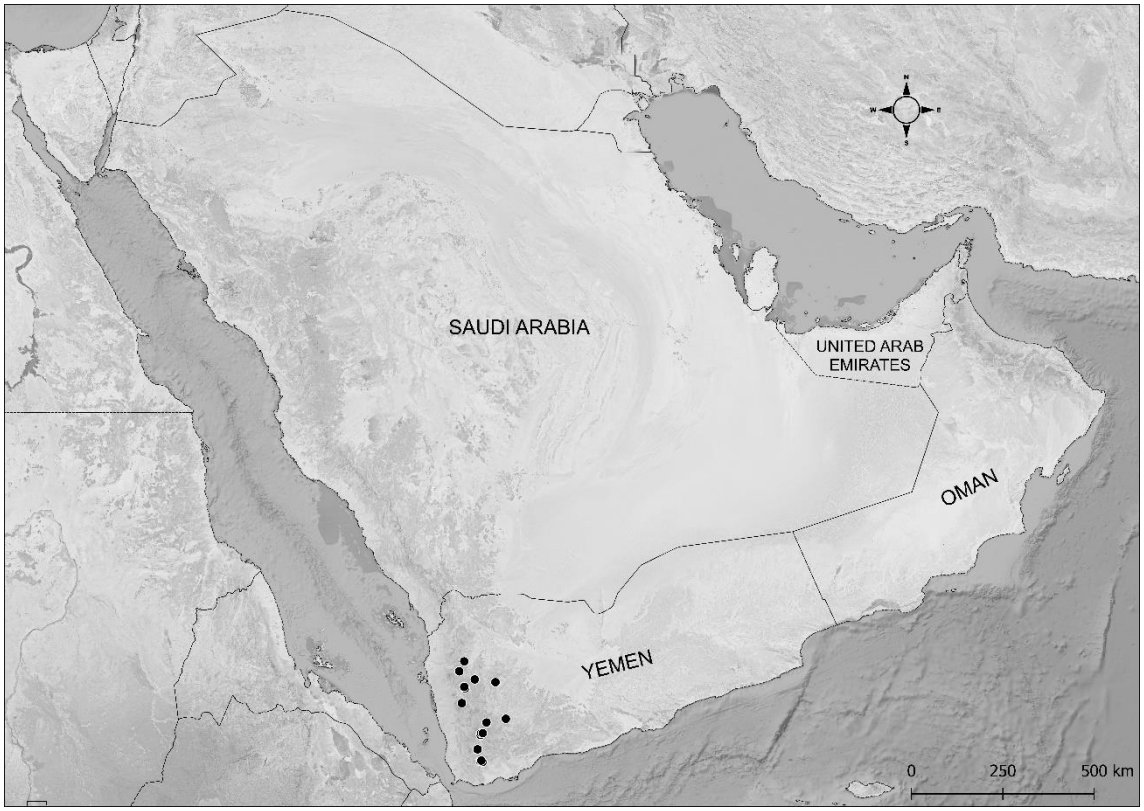

Figure 4.4. Distribution of *Verbascum bottae* in the Arabian Peninsula.

3. Verbascum decaisneanum O. Kuntze, Revis. Gen. Pl. 2: 468 (1891). – *Celsia parviflora* Decne., Ann. Sci. Nat., Bot. sér. 2, 2: 254 (1834). – Type: Egypt, ad latus septentrionale montis St. Catharinae, 20 vi 1835, *W. Schimper* 282 (lectotype HBG [HBG511640] designated here, isolectotype HBG [HBG511642]) (Figure 4.5).

Perennial herb, brownish green, very branched from the base, many-stemmed, woody at the base, up to 60 cm tall. *Indumentum* dense glandular hairs above and forked hairs below. *Stems* erect, terete. *Basal leaves* rosette, oblong-lanceolate, 3 – 5 x 1.5 – 2 cm, apex acute, base attenuate, margins entire or dentate, lamina yellowish green with sparse glandular and dense forked hairs; petiole 0.5 – 1.5 cm. *Cauline leaves* few or leafless, linear-lanceolate, 0.5 – 0.7 x 0.1 – 0.2 cm, apex acute, base attenuate; sessile. *Inflorescence* racemose;

flowers single in the axil of bracts. *Upper bracts* linear-lanceolate, 0.5 – 1.8 mm, acute. *Lower bracts* linear-lanceolate, 0.5 – 2 mm, acute. *Pedicel* covered with dense glandular and sparse forked hairs up to 10 mm long. *Bracteoles* absent. *Calyx* 1 – 3 mm, lobes lanceolate, acute, dense glandular and sparse forked. *Corolla* 8 – 10 mm across, yellow with a red spot around the throat, without pellucid glands, tube up to 2 mm, sparse papillose-ciliated hairs inside, sparse glandular and forked hairs outside. *Stamens* 4, 4 – 6 mm long. *Filaments* yellow with yellow hairs, two anterior glabrous near the apex, two posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* globose-ovoid, sparse glandular and forked hairs. *Style* up to 7 mm long, filiform, green. *Stigma* capitate. *Capsule* 2 – 3 x 1.5 – 2 mm, globose-ovoid, sparse glandular and forked hairy. *Seeds* bothrospermous.

Distribution. Lebanon, Jordan, Syria, Palestine, Egypt (Sinai), and Saudi Arabia.

Distribution in the Arabian Peninsula. It is a native species to Saudi Arabia, which is known from two locations in Tabuk province (Jabal Al-Lawz and Jabal Dabbagh), northwest Saudi Arabia (Figure 4.6).

Habitat and ecology. It grows in granite crevices of cliffs and rocky slopes at altitudes ranging from 1500 to 1900 m. Associated plants include *Pistacia khinjuk* Stocks, *Dianthus sinaicus* Boiss., *Phlomis brachyodon* (Boiss.) Zohary ex Rech.f., *Lactuca orientalis* (Boiss.) Boiss., *Pterocephalus sanctus* Decne., *Hypericum sinaicum* Hochst. ex Boiss., *Verbascum sinaiticum* Benth., and *Kickxia collenetteana* D.A.Sutton.

Regional IUCN threat status. Endangered. EN. (see Chapter 5).

Phenology. Flowering and fruiting from April to June.

Etymology. The name is derived from Joseph Decaisne (1807-1882), the French botanist and plant illustrator.

Specimens examined. EGYPT. **Ad latus** septentrionale: montis St. Catharinae, 20 vi 1835, *W. Schimper* 282 (HBG [HBG511640] & [HBG511642]). SAUDI ARABIA. **Tabuk**: North Hijaz, Jabal Dabbagh, 04 v 1978, *I.S. Collenette* 717 (K); Jabal Al-Lawz, south of Aqaba, 05 v 1992, *I.S. Collenette* 8204 (K, E [E01000561]); Jabal Dabbagh, 100 km SW of Tabuk, 11 iv 1985, *I.S. Collenette* 5260 (E [E00066909]).

Verbascum decaisneanum is a distinct specie by its indumentum dense glandular hairs above and forked hairs below, basal leaves oblong-lanceolate, four stamens, and filaments yellow with yellow hairs. Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species.

Figure 4.5. *Verbascum decaisneanum*. A, habit and showing woody base (white arrows); B, flowers with four stamens (white arrow). PHOTOS: A, TONY MILLER; B, SHEILA COLLENETTE.

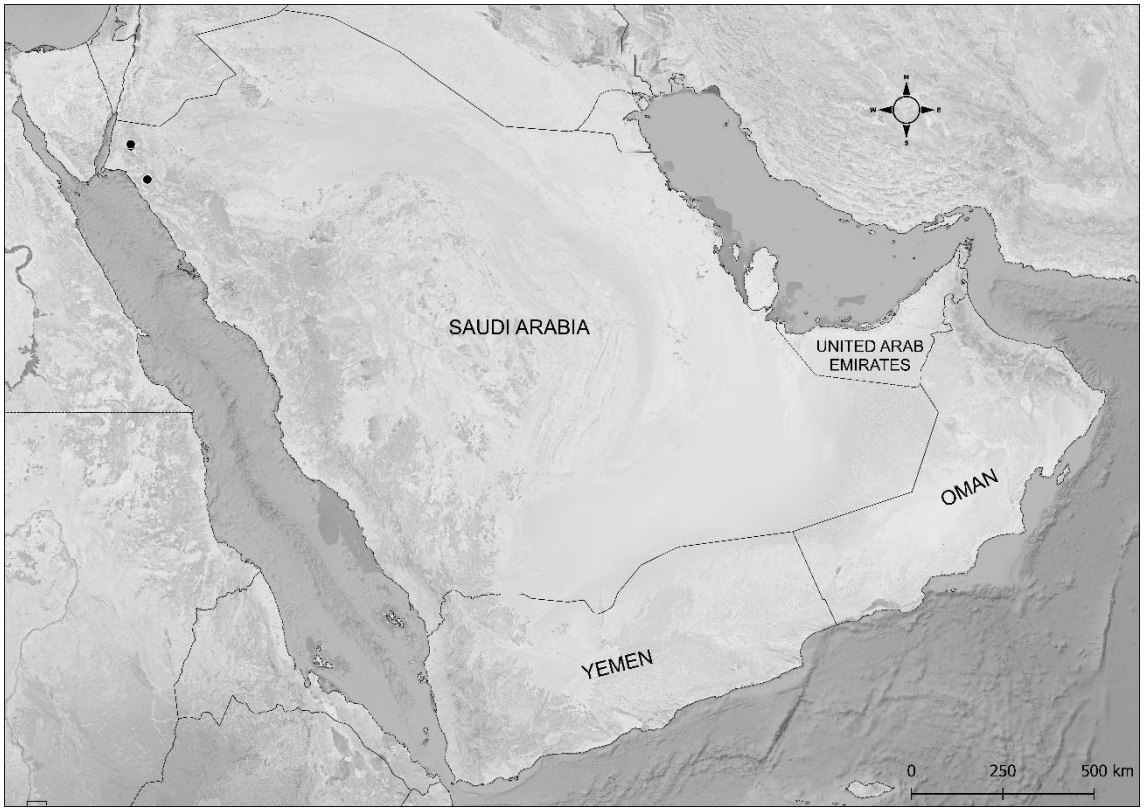

Figure 4.6. Distribution of *Verbascum decaisneanum* in the Arabian Peninsula.

4. Verbascum deserticola (Murb.) Huber-Morath, Bauhinia 5(1): 12 (1973). – *Celsia deserticola* Murb., in Lunds Univ. Arsskrift, n. f. xxii. No. 1, 92 (1925). – Type: Saudi Arabia, Bir Neghile bei Moileh, vii 1825, *Ehrenberg*, s.n. (B†). Saudi Arabia, 75 km E of Duba to Shiqri road, 01 iv 1989, *I.S. Collenette* 7060 (neotype E [E00066907] designated here, isoneotype K).

Key to the varieties

1a. Basal leaves ovate-obovate to lanceolate, apex acute or mucronate, base rounded or obtuse, margins serrate to sinuate, lamina yellowish or grey green with rough tomentose with stellate hairs; petiole 1 – 6.5 cm _____ **4a. deserticola**

1b. Basal leaves oblong-lanceolate, apex acute, base obtuse, margins deep crenate to sinuate, lamina yellowish green with dense stellate hairs; petiole 0.5 – 1.5 cm _____ **4b. sheilae**

4a. Verbascum deserticola var. **deserticola (**Figure 4.7).

Biennial herb, yellowish or greyish green, branched from above, woody at the base, up to 65 cm tall. *Indumentum* dense glandular hairs above, and dense tomentose with stellate hairs below. *Stems* erect, terete. *Basal leaves* rosette, ovate-obovate to lanceolate, 3 – 15 x 1.5 – 6 cm, apex acute or mucronate, base rounded or obtuse, margins serrate to sinuate, lamina yellowish or grey green with rough tomentose with stellate hairs; petiole 1 – 6.5 cm. *Cauline leaves* oblong-lanceolate or lanceolate, 2 – 4.9 x 0.5 – 1 cm, apex acute, base semi-amplexicaul; sessile or petiole up to 1 cm. *Inflorescence* racemose, a single flower in the axil of the bract. *Upper bracts* lanceolate, 1.6 – 2.8 mm, acute. *Lower bracts* ovate or ovate-lanceolate, 6 – 17 mm, acute or mucronate. *Pedicel* covered with glandular hairs, up to 8 mm long. *Bracteoles* absent. *Calyx* 1.5 – 3 mm, lobes oblong to oblong-lanceolate, obtuse, mucronate to apiculate, glandular hairs. *Corolla* 8 – 10 mm across, yellow with a purple-red spot around the throat, without pellucid glands, tube up to 1 mm, sparse papillose-ciliated hairs inside, glandular hairs outside. *Stamens* 4, 5 – 8 mm long. *Filaments* red with purple-violet to violet-whitish hairs, two anterior glabrous near the apex, two posteriors with hairs up to anthers, all reniform anthers. *Ovary* ovoid, sparse glandular hairs. *Style* up to 8 mm long, filiform, green or violet. *Stigma* capitate. *Capsule* 2.8 – 3 x 2 – 2.7 mm, ovoid-ellipsoid, glabrous. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Saudi Arabia, which is known from several locations in Tabuk province (Tabuk road between Duba and Shigry, and near Jabal Shar), northwest Saudi Arabia, and as well from several locations in Medina province (Jabal Radwa, Road to Jabal Al-Figrah, Wadi Buwat, and between Al Wajh and Al-Ula), western Saudi Arabia (Figure 4.8).

Habitat and ecology. It grows on rocky black hillsides, rocky slopes, roadsides, and among fallen rocks in Wadis at altitudes ranging from 400 to 1300 m. Associated plants include *Vachellia tortilis* subsp. *tortilis*, *Vachellia tortilis* subsp. *raddiana* (Savi) Kyal. & Boatwr., *Plocama calycoptera* (Decne.) M.Backlund & Thulin, *Kickxia aegyptiaca* (L.) Nábělek, *Reichardia tingitana* (L.) Roth, *Cleome droserifolia* (Forssk.) Delile, and *Nerium oleander* L.

Global IUCN threat status. Least Concern. LC. (see Chapter 5).

Phenology. Flowering and fruiting from March to November.

Etymology. The name is derived from inhabiting deserts.

Specimens examined. SAUDI ARABIA. **Tabuk:** 75 km E of Duba to Shiqri road, 03 viii 1989, *I.S. Collenette* 7237 (K, E [E00066908]); 75 km E of Duba to Shiqri road, 01 iv 1989, *I.S. Collenette* 7060 (K, E [E00066907]); Tabuk road between Duba and Shigry, near Ras Al-Khuraytah primary school, 02 iii 2021, *A. Alzahrani* 147 (MUZ). **Medina:** Jabal Radwa, 01 i 1983, *D. Lickfold* 8752 (RIY); Jabal Radwa, 100 km N of Yanbo, wadi on N side, 15 viii 1982, *I.S. Collenette* 3802 (K, E [E00066910]); Jabal Radwa, N of Yanbo, 10 x 1981, *I.S. Collenette* 2908 (K, E

[E00687348]); Somewhere N of Al Wajh to Al-Ula, dirt track, 18 iii 1986, *I.S. Collenette* 5767 (RIY, K, E [E00066965]); Wadi Buwat, between Medina and Yanbo Al-Nakal, 06 v 1992, *I.S. Collenette* 8215 (K); Road to Jabal Al-Figrah, 07 iii 2021, *A. Alzahrani* 152 (MUZ).

Verbascum deserticola is an extremely variable species found in the western and northwest regions of Saudi Arabia. Due to its high variation, Al-Hemaid (2001) distinguished *V. sheilae* as a distinct species from *V. deserticola*. However, recent phylogenetic research (see Chapter 3) indicates that both are similar species. In addition to a study of the type specimens of *V. sheilae* and its comparison with *V. deserticola*, as well as thorough examination of the important morphological characteristics of both type specimens, it is proposed here that *V. sheilae* is a variety of *V. deserticola* as both species have a woody base, dense glandular hairs above, and dense tomentose with stellate hairs below, four stamens, racemose inflorescence, single flower, filaments hairs purple-violet to violet-whitish, and capsule glabrous ovoid-ellipsoid.

4b. Verbascum deserticola var. **sheilae** (Hemaid) A.Alzahrani, **stat. nov.** – *Verbascum sheilae* Hemaid, Pakistan J. Bot. 33(4): 324 (2001). – Type: Saudi Arabia, Tabuk, Headwater of wadi Qaraqir, E of Duba, 17 iii 1994, *I.S. Collenette* 9072 (holotype K, isotype E [E00092232] & [E00092213]) (Figure 4.7).

Biennial herb, yellowish or greyish green, branched from above, woody at the base, up to 65 cm tall. *Indumentum* dense glandular hairs above, and dense tomentose with stellate hairs below. *Basal leaves* rosette, oblong-lanceolate, 3 –

10 x 1.5 – 6 cm, apex acute, base obtuse, margins deep crenate to sinuate, lamina yellowish green with dense stellate hairs; petiole 0.5 – 1.5 cm. *Cauline leaves* oblong-lanceolate or lanceolate, 2 – 4.9 x 0.5 – 1 cm, apex acute, base semi-amplexicaul; sessile or petiole up to 1 cm. *Inflorescence* as for var. *deserticola*.

Distribution in the Arabian Peninsula. It is known from one location in Tabuk province (Wadi Al-Disah), northwest Saudi Arabia (Figure 4.8).

Global IUCN threat status. Critically Endangered. CR. (see Chapter 5).

Etymology. The name is derived from Sheila Collenette (1927-2017), the British botanist and plant collector, who made a significant contribution to scientific knowledge in the study of the flora of Saudi Arabia.

Specimens examined. SAUDI ARABIA. **Tabuk:** Wadi Al-Lawz off wadi Qaraqir, E of Duba, 25 viii 1994, *I.S. Collenette* 9154 (K, E [E00095075]); Wadi Ghamrah off wadi Qaraqir, E of Duba, 25 viii 1994, *I.S. Collenette* 9153 (K, E [E00095076]); Headwater of wadi Qaraqir, E of Duba, 17 iii 1994, *I.S. Collenette* 9072 (K, RIY, E [E00092232] & [E00092213]); Wadi Disah, wadi Qaraqir, 08 iii 2013, *J. Thomas* 23970 (KSU); Wadi Disah, SW of Tabuk, 01 iv 2014, *J. Thomas* 23742 (KSU); Wadi Al-Disah, 21 viii 2020, *A. Alzahrani* 86 (MUZ); Wadi Al-Disah, 21 viii 2020, *A. Alzahrani* 85 (MUZ).

This variety can be distinguished from var. *deserticola* by its oblong-lanceolate leaves, deeply crenate to sinuate margins, yellowish-green lamina with dense

stellate hairs, and 0.5 – 1.5 cm petiole. In addition to its distribution in Wadi Al-Disah in Tabuk province, northwest Saudi Arabia.

Figure 4.7. *Verbascum deserticola* var. *deserticola.* A, habit; B, flowers with four stamens; C, leaf. *V. deserticola* var. *sheilae*. D, habit; E, flowers with four stamens; F, leaf. PHOTOS: ALI ALZAHRANI.

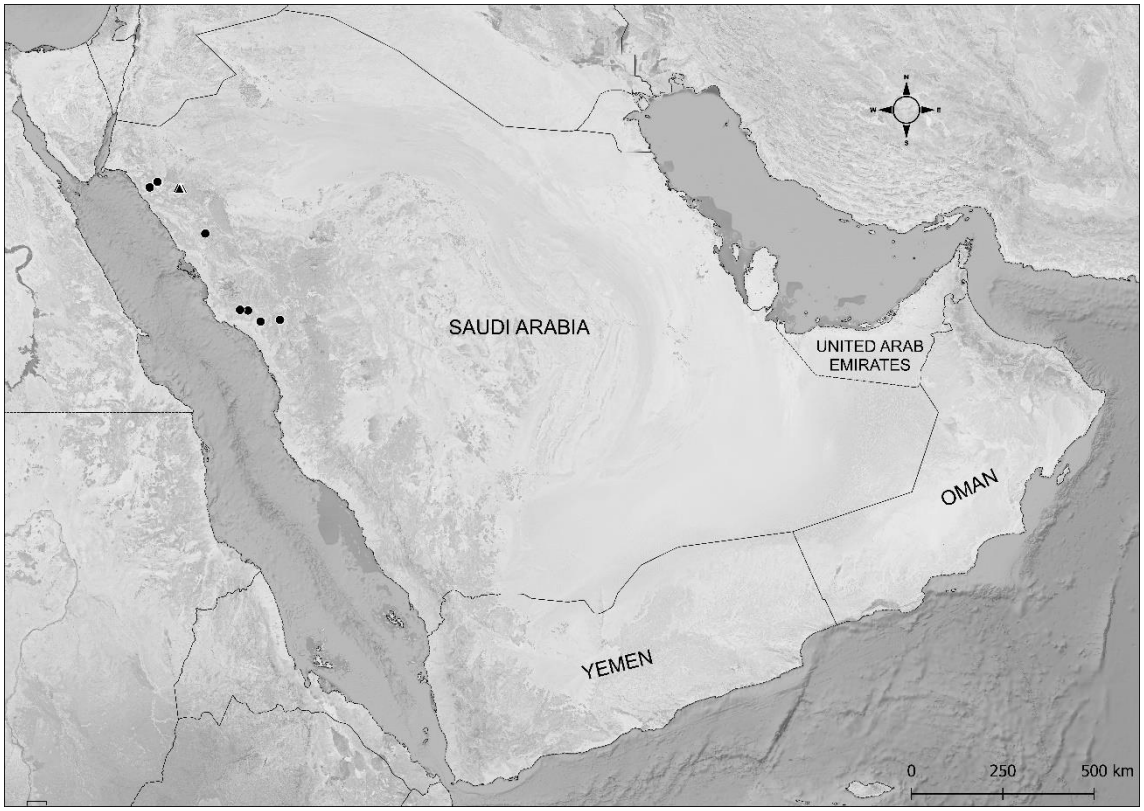

Figure 4.8. Distribution of *Verbascum deserticola* var. *deserticola* (black circles) and *V. deserticola* var. *sheilae* (black triangles) in the Arabian Peninsula.

5. Verbascum eremobium Murb. in Lunds Univ. Arsskrift, N. F. xxix. No. 2 p. 458 (1933). – Type: Syria, Palmyre, 30 iv 1928, *R. Gombault* 462 (lectotype P [P03787920] designated here).

Verbascum tabukum Hemaid, Pakistan J. Bot. 33(4): 327 (2001), **synon. nov. –** Type: Saudi Arabia, Tabuk, Duba road, 28 iv 1994, *I.S. Collenette* 9115 (holotype K) (Figure 4.9).

Perennial herb, yellowish or greyish green, very branched from the base, woody at the base, up to 75 cm tall. *Indumentum* dense rough tomentose with stellate hairs. *Stems* erect, terete. *Basal leaves* rosette, obovate-oblong, 5 – 10 x 2 – 5 cm, apex obtuse, base obtuse to cuneate, margins undulate or lobed-crenate, lamina yellowish or grey green with dense yellowish or greyish green tomentose

with stellate hairs; petiole 2 – 5 cm. *Cauline leaves* oblong-obovate to ovate, 3 – 6 x 2 – 3 cm, apex acute, base semi-amplexicaul; sessile. *Inflorescence* dichasium; three-flowered, or one flowered, peduncle in the axil of bracts. *Upper bracts* lanceolate, 2 – 3 mm, acute. *Lower bracts* cordate-triangular or triangular, 20 – 50 mm, acute. *Pedicel* covered with dense tomentose with stellate hairs up to 5 mm long. *Bracteoles* present, lanceolate-cordate, acute. *Calyx* 5 – 8 mm, lobes lanceolate, acute, dense tomentose with stellate. *Corolla* 15 – 20 mm across, yellow with red blotches around the throat, with pellucid glands, tube up to 1 mm, glabrous inside, dense tomentose with stellate hairs outside. *Stamens* 5, 4 – 6 mm long. *Filaments* red with red-purple hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* globose, dense tomentose with stellate hairs. *Style* up to 6 mm long, filiform, green. *Stigma* capitate. *Capsule* 3 – 4 x 3 – 5 mm, globose-subglobose, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution. Lebanon, Jordan, Syria, Jordan, Palestine, Egypt (Sinai), and Saudi Arabia.

Distribution in the Arabian Peninsula. It is a native species to Saudi Arabia, which is known from several locations in Tabuk province (Jabal Thaghb, near Jabal Al-Lawz road, Jalah, near Wadi Sadrr, near Duba, and Wadi Aba Al-Hinshan), northwest Saudi Arabia (Figure 4.10).

Habitat and ecology. It grows on rocky black hillsides, barren rocky wadis, and roadsides at altitudes ranging from 915 to 1420 m. Associated plants include *Vachellia gerrardii* (Benth.) P.J.H.Hurter, *Diplotaxis harra* (Forssk.) Boiss.,

Fagonia mollis Delile, *Argyrolobium crotalarioides* Jaub. & Spach, *Linaria haelava* (Forssk.) Delile, *Morettia canescens* Boiss., and *Onopordum ambiguum* Fresen.

Vernacular name. Desert mullein (English).

Regional IUCN threat status. Near Threatened. NT. (see Chapter 5).

Phenology. Flowering and fruiting from April to November.

Etymology. The name is derived from living in deserts.

Specimens examined. SYRIA. **Palmyre**: 30 iv 1928, *R. Gombault* 462 (P [P03787920]). **Transjordanien**: 9 iv 1932, *R. Gombault* 19 (P [P03285763]). SAUDI ARABIA. **Tabuk**: Duba road, 28 iv 1994, *I.S. Collenette* 9115 (K, E [E00092230 & E00092231]); Near Shiqri, Tabuk road, 20 iv 1983, *I.S. Collenette* 4347 (E [E00066929]); Near Jabal Al-Lawz, 28 iii 1989, *I.S. Collenette* 7048 (K, E [E00066928]); 8 Km south of Jabal Al-Lawz, 2 viii 1989, *I.S. Collenette* 7227 (K, E [E00066930]).

Verbascum tabukum was described by Al-Hemaid (2001) principally on the four stamens, sessile flowers, and ovate leaves. However, phylogenetic studies (see Chapter 3) indicate that this species is *V. eremobium*. In addition to a study of the type specimens of *V. tabukum* and its comparison with *V. eremobium*, as well as thorough examination of the important morphological characteristics of both type specimens, it is proposed here that *V. tabukum* is a synonym of *V. eremobium* as both species have a woody base, dense rough tomentose with stellate hairs, basal leaves obovate-oblong, five stamens, dichasium inflorescence, one or three flowers, filaments hairs red-purple, and capsule globose-subglobose.

Furthermore, the similarity of its geographical distribution in Saudi Arabia and adjacent countries strengthens the case for this new synonymy.

Figure 4.9. *Verbascum eremobium*. A, habit and dichasium inflorescence (one and three flowered, white arrows); B, flowers with five stamens; C, calyx and stems with dense rough tomentose with stellate hairs. PHOTOS: ALI ALZAHRANI.

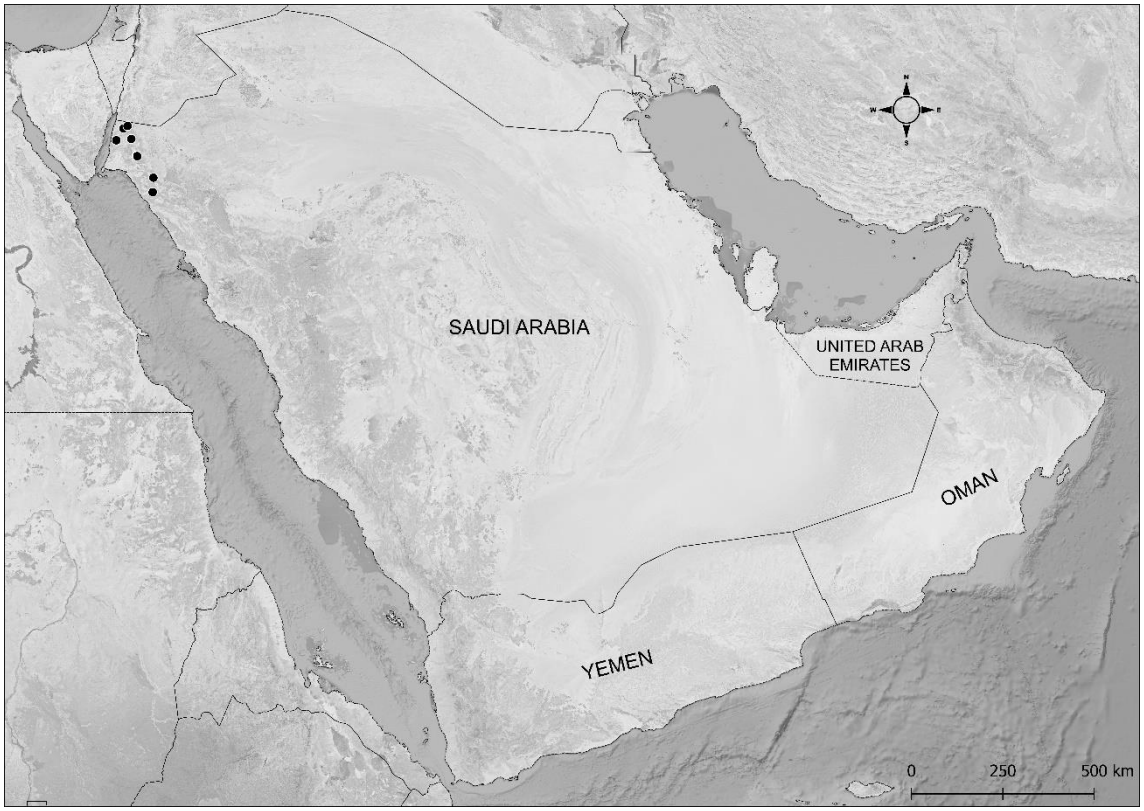

Figure 4.10. Distribution of *Verbascum eremobium* in the Arabian Peninsula.

6. Verbascum longibracteatum Defl., Bull. Soc. Bot. France 43: 218 (1896). – Type. Yemen, Bilad Fodhli, ad fauces australes montis el-'Areys, circa Serrya, 24 iv 1893, *A. Deflers* 868 (lectotype G [G00343570] designated here, isolectotypes MPU [MPU020131] & [MPU020130]).

Verbascum luntii Baker, Bull. Misc. Inform. Kew (93): 337 (1894), **synon. nov.** – Type. Yemen, Hillsides at Alrail, 28 xii 1893, *W. Lunt* 119 (lectotype K [K000975903] designated here) (Figure 4.11).

Perennial herb, yellowish green, simple or usually branched from above, up to 2 m tall. *Indumentum* dense tomentose with stellate hairs. *Stems* erect, robust, terete. *Basal leaves* rosette, lanceolate, 10 – 20 x 3 – 8 cm, apex acute, base obtuse, margins crenate, lamina yellowish green with densely tomentose with stellate hairs; petiole 2 – 4 cm. *Cauline leaves* lanceolate, 4 – 8 x 1 – 3 cm, apex

acute, base obtuse; sessile. *Inflorescence* panicle; with clusters of 2-8 flowers in the axil of bracts. *Upper bracts* linear, 5 – 15 mm, acute. *Lower bracts* linear, 30 – 50 mm, acute. *Pedicel* covered with densely tomentose with stellate hairs up to 6 mm long. *Bracteoles* present, linear, acute. *Calyx* 4 – 7 mm, lobes linear, acute, densely tomentose with stellate hairs. *Corolla* 15 – 20 mm across, yellow, without pellucid glands, tube up to 2 mm, densely tomentose with stellate hairs outside. *Stamens* 4 – 5 or 7 (unstable), 5 – 6 mm long. *Filaments* orange to yellow with yellowish-white hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid, dense tomentose with stellate hairs. *Style* up to 8 mm long, filiform, green. *Stigma* spatulate. *Capsule* 4 – 8 x 3 – 4 mm, ellipsoid, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to the Arabian Peninsula, which is known from Yemen in Abyan (Jabal Areys) and Hadhramaut (Alrail), and from Saudi Arabia in Taif (Red Mountain and near Al-Hada), Al-Baha (Al-Abna Road, Heznah Road, and near Wadi Shora), Abha (Jabal Al-Soudah, Wadi Namra, and near Tanomah), and Jizan (Jabal Al-Qahar), southwestern the Arabian Peninsula (Figure 4.12).

Habitat and ecology. It grows in roadsides, rocky slopes, and edge of wadis at altitudes ranging from 300 to 2750 m. Associated plants include *Juniperus procera* Hochst. ex Endl., *Vachellia origena* (Hunde) Kyal. & Boatwr., *Rumex nervosus* Vahl, *Anagyris foetida* L., *Pentas lanceolata* (Forssk.) Deflers, *Plectranthus asirensis* J.R.I.Wood, *Astragalus atropilosulus* (Hochst.) Bunge,

Vachellia johnwoodii (Boulos) Ragup., Seigler, Ebinger & Maslin, and *Rumex vesicarius* L.

Vernacular name. Zohara (Arabic).

Global IUCN threat status. Near Threatened. NT. (see Chapter 5).

Phenology. Flowering and fruiting from March to May.

Etymology. The named is derived from long bracts; it is a distinct characteristic of the species.

Specimens examined. YEMEN. **Abyan:** Jabal Areys, 11 ii 1989, *A.G. Miller, L. Guarino, N. Obadi, M. Hassan & N. Mohammed* 8103 (E [E00066963]); Bilad Fodhli, ad fauces australes montis el-'Areys, circa Serrya, 24 iv 1893, *A. Deflers* 868 (isosyn. MPU [MPU020130]); Bilad Fodhli, in Wadi el-'Areys (6 km ad orient. urb. Schughra), 23 iii 1890, *A. Deflers* 441 (isosyn. MPU [MPU020132]). **Hadhramaut:** Hillsides at Alrail, 28 xii 1893, *W. Lunt* 119 (K [K000975903]). SAUDI ARABIA. **Abha:** Jabal Soudah, northwest of Abha, 10 iii 1980, *I.S. Collenette* 2049 (K); Near Al Hasane, 98 km from the Abha to Najran road, 22 xi 1985, *I.S. Collenette* 5525 (E [E00066946]); Near Tanomah, 02 v 1985, *I.S. Collenette* 7170 (K); between Abha and Jabal Soudah, 17 x 1981, *I.S. Collenette* 2964 (E [E00066947]); Wadi Namra, 23 iv 1982, *A.C. Podzorski* 1068 (E [E00687345]). **Al-Baha:** Al-Abna Road, 7 km S of Baljurashi, 24 ii 1994, *I.S. Collenette* 9015 (K); Al-Abna Road, 5 km S of Baljurashi, 17 iv 1983, *I.S. Collenette* 4330 (K); between Baljurashi and Maquas, 08 viii 1982, *P. König & H. Kürschner* 82/2125 (E [E00687346]); Heznah road between Al-Makhwah and

Baljurashi, 15 iii 2021, *A. Alzahrani* 170 (MUZ); Al-Abna road between Al-Awamer and Baljurashi, 15 iii 2021, *A. Alzahrani* 171 (MUZ); Al-Baha - Abha road, near Wadi Shora, Baljurashi, 13 iii 2021, *A. Alzahrani* 167 (MUZ). **Jizan:** Jabal Al-Qahar, 07 v 1990, *I.S. Collenette* 7544 (K); Jabal Al-Qahar, 5500 ft, 29 iv 1989, *I.S. Collenette* 7157 (K); Jabal Al-Qahar, 12 ii 2021, *A. Alzahrani* 144 (MUZ). **Taif:** 5 km southwest of Al-Hada, 26 iii 1979 *I.S. Collenette* 1090 (K); Al-Hada, 20 iii 1980 *I.S. Collenette* 2169 (K); Third way of Jeddah Taif Road, 19 ii 1980 *I.S. Collenette* 1891 (K); Red Mountain, near Al-Hada, 10 ii 1982, *I.S. Collenette* 3222 (K, E [E00066945]).

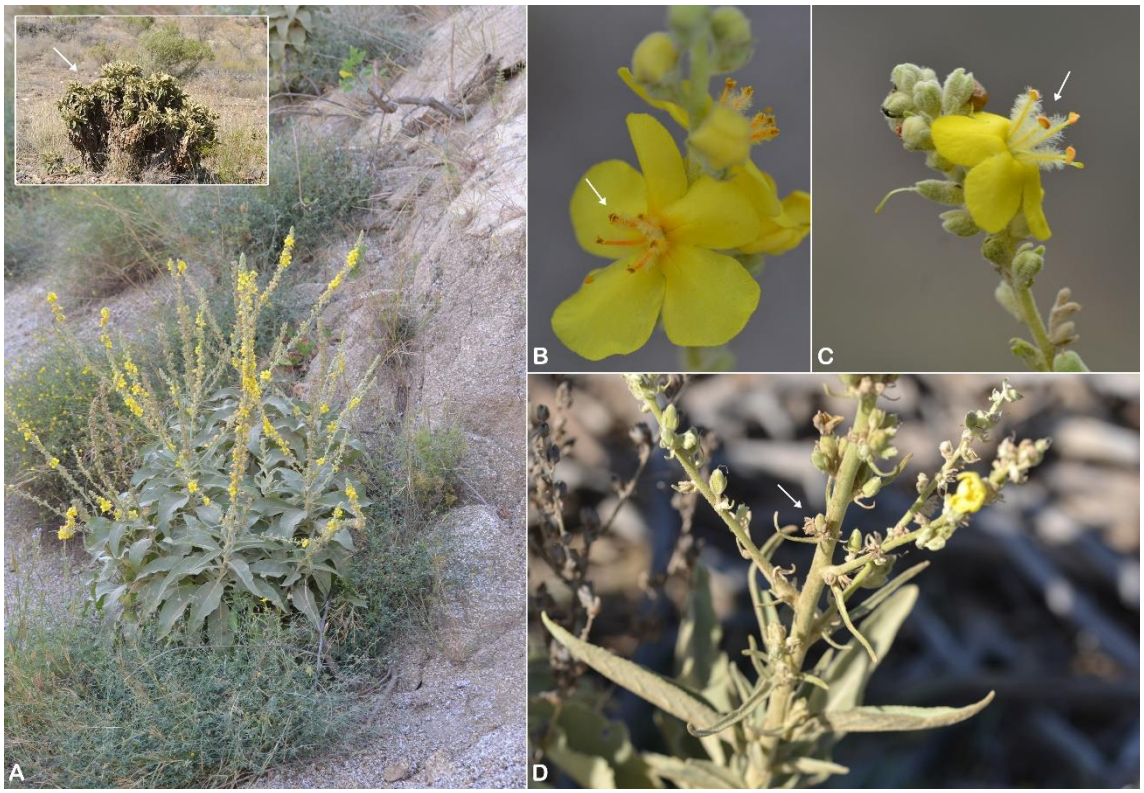

Figure 4.11. *Verbascum longibracteatum*. A, habit and showing massive growth (white arrow); B & C, flowers with five and four stamens, respectively; D, bracts and capsules (white arrow). PHOTOS: ALI ALZAHRANI.

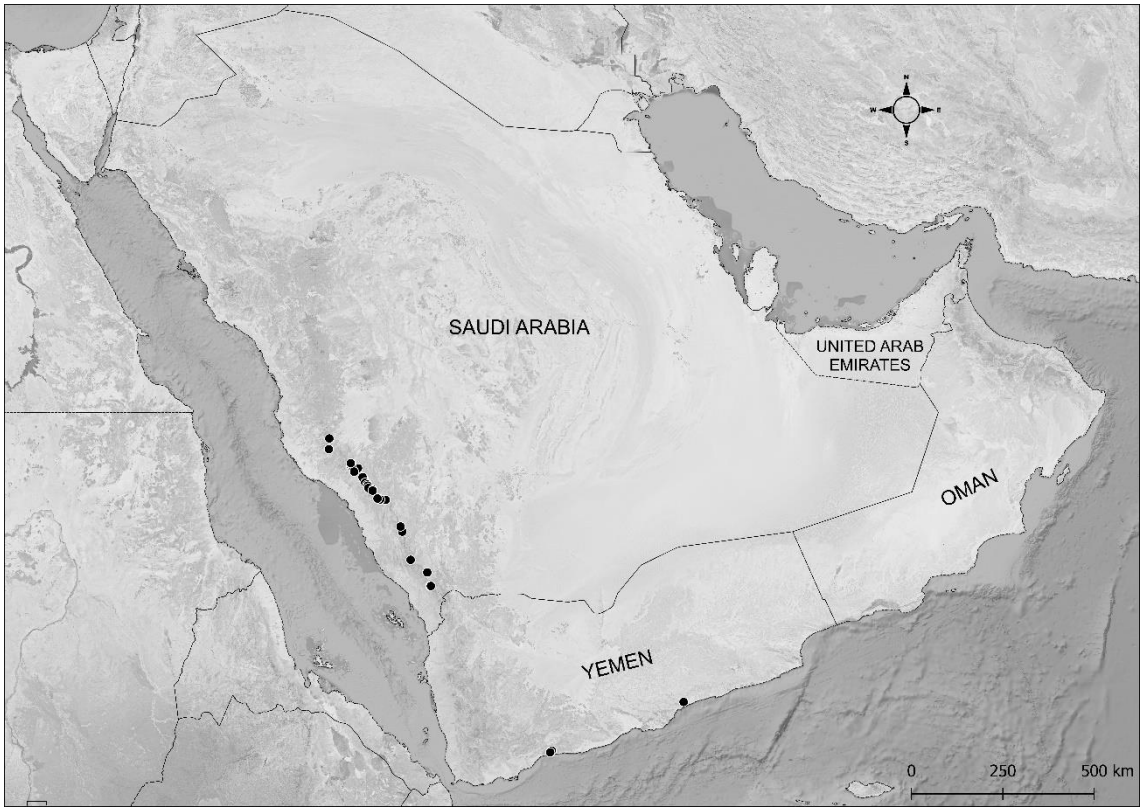

Figure 4.12. Distribution of *Verbascum longibracteatum* in the Arabian Peninsula.

7. Verbascum medinecum Hemaid, Pakistan J. Bot. 33(4): 321 (2001). – Type: Saudi Arabia, Hema Al-Figrah, 60 km W of Medina, 20 iv 1989, *I.S. Collenette* 7116 (holotype K, isotype E [E00066952]).

Verbascum hema-figranum Hemaid, Pakistan J. Bot. 33(4): 321 (2001), **synon. nov.** – Type: Saudi Arabia, Hema Al-Figrah, Medina, 02 iii 1989, *I.S. Collenette* 6977 (holotype E [E00066970]) (Figure 4.13).

Perennial herb, yellowish or greyish green, simple or few short branched above, up to 1.5 m tall. *Indumentum* dense tomentose with stellate hairs. *Stems* erect, robust, terete. *Basal leaves* rosette, oblong-lanceolate, 10 – 25 x 3 – 6 cm, apex acute, base cuneate, margins crenate-sinuate, lamina yellowish or greyish green with dense tomentose with stellate hairs; petiole 3 – 7 cm. *Cauline leaves*

lanceolate, 3 – 7 x 1 – 3 cm, apex acute, base cuneate; decurrent. *Inflorescence* panicle; one or clusters of 2-8 flowers in the axil of bracts. *Upper bracts* linear, 5 – 10 mm, obtuse. *Lower bracts* lanceolate to lanceolate-linear, 20 – 30 mm, acute-attenuate. *Pedicel* covered with dense tomentose with stellate hairs up to 2 mm. *Bracteoles* present, linear, acute. *Calyx* 5 – 6 mm, lobes linear, acute, dense tomentose with stellate. *Corolla* 15 – 20 mm across, yellow, with pellucid glands, tube up to 2 mm, sparse papillose-ciliated hairs inside, dense tomentose with stellate hairs outside. *Stamens* 4-5 or 6 (unstable), 4 – 6 mm long. *Filaments* yellow with yellow-whitish hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid, dense tomentose with stellate hairs. *Style* up to 7 mm long, filiform, green. *Stigma* capitate. *Capsule* 8 – 9 x 2 – 3 mm, ellipsoid, sparse stellate hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Saudi Arabia, which is known from three locations in Medina province (Jabal Al-Figrah, Jabal Radwa, and Jabal Odks), western Saudi Arabia (Figure 4.14).

Habitat and ecology. It grows on rocky slopes, gravelly or sandy wadis, roadsides, and abandoned old gardens at altitudes ranging from 1730 to 1981 m. Associated plants include *Vachellia gerrardii* (Benth.) P.J.H.Hurter, *Juniperus phoenicea* L., *Helianthemum lippii* (L.) Dum.Cours., *Nepeta deflersiana* Schweinf. ex Hedge, *Asparagus aphyllus* L., *Teucrium polium* L., *Lepidium draba* L., *Malva parviflora* L., and *Rumex vesicarius* L.

Vernacular name. Aithnah, *Albusira, Bousira* (Arabic).

Global IUCN threat status. Endangered. EN. (see Chapter 5).

Phenology. Flowering and fruiting from January to August.

Etymology. The name is derived from Medina, the local Arabic name of the holy city "Medina".

Specimens examined. SAUDI ARABIA. **Medina**: Jabal Radwa, 72 km N of Yanbu, 10 ii 1987, *I.S. Collenette* 5999 (RIY, K, E [E00066950]); Home Al-Figrah, 60 km W of Medina, 20 iv 1989, *I.S. Collenette* 7116 (K, E [E00066952]); Home Al-Figrah, 50 km W of Medina, 02 iii 1989, *I.S. Collenette* 6977 (E [E00066970]); Jabal Radwa, 95 km S of Medina, 31 x 1986, *I.S. Collenette* 5889 (E [E00066948]); Jabal Radwa, 70 km N of Yanbu, 10 x 1981, *I.S. Collenette* 2899 (E [E00066942]); Between Al-Akhal and Umm Al Iyal, new Medina to Jeddah highway, 23 i 1986, *I.S. Collenette* 5559 (E [E00066960]); Jabal Al-Figrah, Medina, 07 iii 2021, *A. Alzahrani* 153 (MUZ).

Al-Hemaid (2001) described *Verbascum hema-figranum* and *V. medinecum* from Jabal Al-Figrah in Medina province, western Saudi Arabia. *V. hema-figranum* was distinguished by its four stamens, several flowers with paired opposite bracts, and lanceolate leaves. However, phylogenetic studies (see Chapter 3) indicate that this species is *V. medinecum*. In addition to a study of the type specimens of *V. hema-figranum* and its comparison with *V. medinecum*, and careful examination of the important morphological characteristics of both type specimens, *V. hema-figranum* is proposed here as a synonym of *V. medinecum* as both species have 4-5 (or 6) stamens with yellow-whitish filaments hairs, basal leaves oblong-lanceolate, decurrent cauline leaves with shape lanceolate, and

capsule ellipsoid. Additionally, the resemblance of its geographical distribution in Jabal Al-Figrah supports this new synonymy.

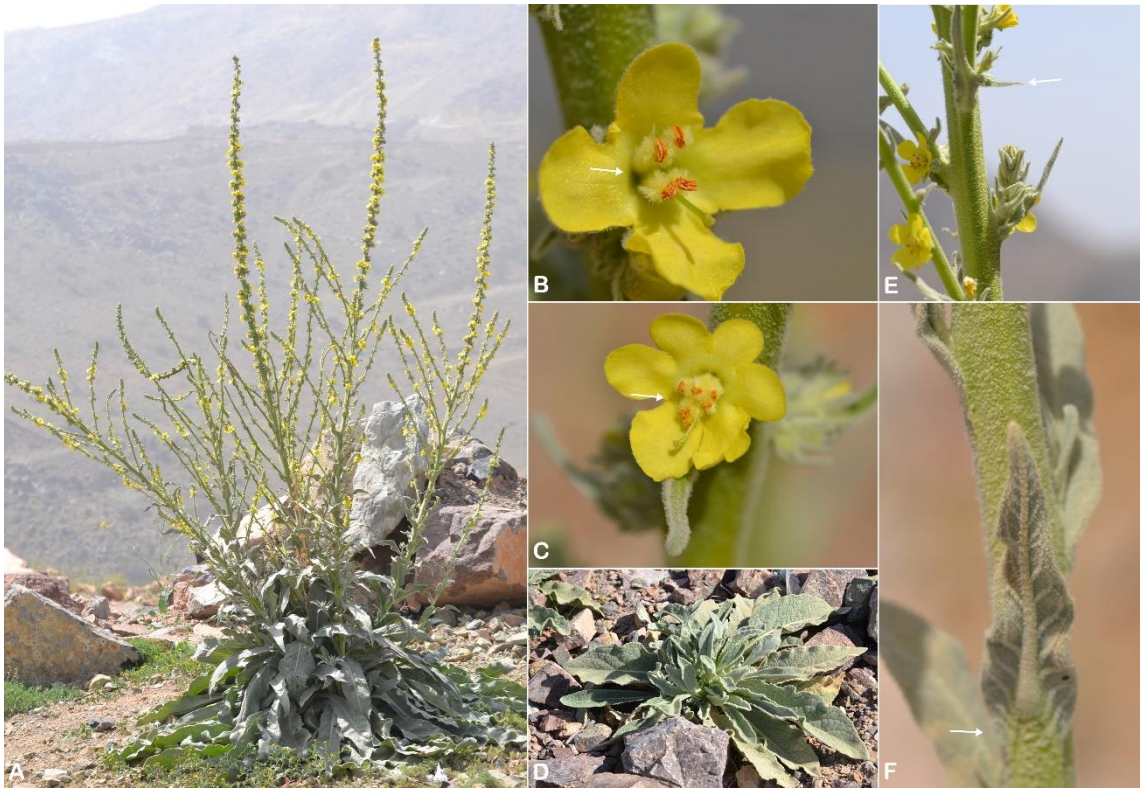

Figure 4.13. *Verbascum medinecum*. A, habit; B & C, flowers with four and six stamens, respectively; D, leaf; E, upper bracts (white arrow); F, cauline leaf decurrent (white arrow). PHOTOS: ALI ALZAHRANI.

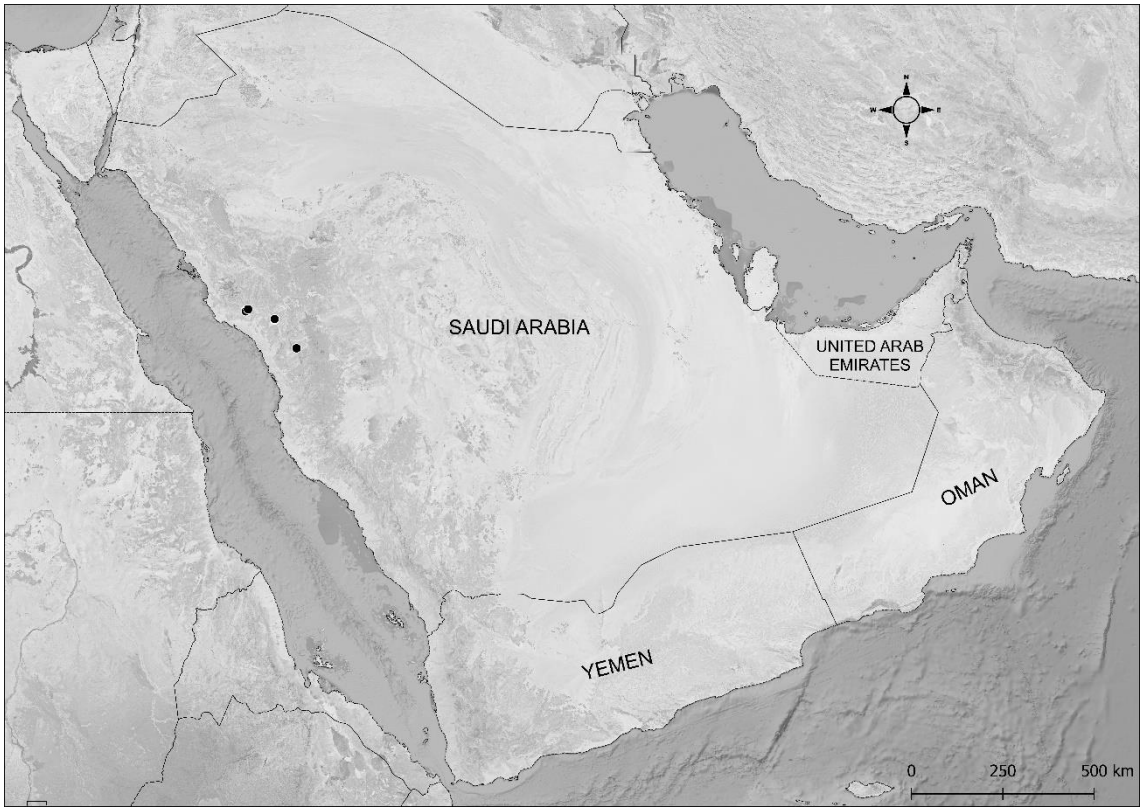

Figure 4.14. Distribution of *Verbascum medinecum* in the Arabian Peninsula.

8. Verbascum melhanense (Murb.) Huber-Morath, Bauhinia 5(1): 14 (1973). - *Celsia melhanensis* Murb. in Lunds Univ. Arsskrift, n. f. xxii. No.1, 155 (1925). – Type: Yemen, Über Menacha, 23 ii 1889, *G. Schweinfurth* 1561 (lectotype K designated here) (Figure 4.15).

Biennial herb, dark green to purple, simple or branched from above, up to 90 cm tall. *Indumentum* sparse glandular hairs. *Stems* erect, terete to angular. *Basal leaves* rosette, oblong-ovate, 4 – 15 x 2 – 5 cm, apex obtuse, base cordate-truncate, margins crenate-serrate, lamina shiny green with sparse simple hairs on the veins below; petiole 2 – 6 cm, winged with a few lateral lobes. *Cauline leaves* oblong-ovate, 2 – 6 x 1 – 3 cm, apex obtuse, base cordate-truncate; sessile or petiole up to 1 cm. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* lanceolate or triangular-ovate, 3 – 5.2 mm, acute. *Lower*

bracts triangular-ovate, 10 – 25 mm, acute-attenuate. *Pedicel* covered with sparse glandular hairs up to 20 mm long. *Bracteoles* absent. *Calyx* 4 – 5 mm, lobes oblong, mucronate, sparse glandular. *Corolla* 20 – 25 mm across, yellow with dark-red streaks on the upper side, without pellucid glands, tube up to 1 mm, sparse papillose hairs inside, sparse glandular hairs outside. *Stamens* 4, 10 – 12 mm long. *Filaments* yellow to red with yellowish-violet to red hairs, two anterior glabrous, two shorter posteriors with hairs up to the anthers. *Anthers* two anterior inserted decurrent longitudinally on filaments, two shorter posteriors with reniform anthers. *Ovary* pyriform-ovoid, sparse glandular hairs. *Style* up to 22 mm long, filiform, green. *Stigma* capitate. *Capsule* 5 – 8 x 4 – 6 mm, pyriform-ovoid, sparse glandular hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to the Arabian Peninsula, which is known from Saudi Arabia in Al-Baha (King Khalid Road between Qilwah and Al-Baha, Heznah road between Al-Makhwah and Baljurashi, and Wadi Turbah), Abha (Jabal Mna'a Tanomah, Al-Samma Road, Sinan Road between Al-Namas and Al-Majaradah, Raidah Sanctuary, Near Mahyar Park Tanomah, and Borma'a Road between Tanomah and Bariq), and Jizan (Jabal Fayfa, Jabal Habbes, and Jabal Al-Hasher), and from Yemen in Saada (Jabal Razih and Jabal Marran), Amran (Shaharah), Al-Mahwit (Jabal Melhan), Sana'a (Jabal Masar), and Hajjah (Jabal Nasira), southwestern the Arabian Peninsula (Figure 4.16).

Habitat and ecology. It grows on mountain cliffs, terrace walls, rocky slopes, granite crevices, and wadi banks at altitudinal ranges from 1600 to 2600 m.

Associated plants include *Pelargonium multibracteatum* Hochst. ex A.Rich., *Oxalis corniculata* L., *Ocimum serpyllifolium* Forssk., *Commelina forskaolii* Vahl, *Coleus barbatus* (Andrews) Benth. ex G.Don, *Selaginella yemensis* (Sw.) Spring, *Crassula schimperi* Fisch. & C.A.Mey., *Erigeron bonariensis* L., *Cyperus cruentus* Rottb., *Withania somnifera* (L.) Dunal, *Dodonaea viscosa* subsp. *angustifolia* (L.f.) J.G.West, and *Solanum incanum* L.

Global IUCN threat status. Near Threatened. NT. (see Chapter 5).

Phenology. Flowering and fruiting throughout year.

Etymology. The name is derived from Melhan, the local Arabic name of Jabal Melhan.

Specimens examined. YEMEN. **Sana'a:** Über Menacha, 23 ii 1889, *G. Schweinfurth* 1561 (K); Jabal Masar, Haraz, 08 vi 1979, *J.R.I. Wood* 2835 (BM, K, E [E00066924]). **Al-Mahwit:** Jabal Melhan, 15 vi 1979, *J.R.I. Wood* 2864 (K). **Amran:** Shaharah, 13 xi 1981, *J.R.I. Wood* 3384 (BM, K). **Saada:** Jabal Marran, 31 x 1979, *J.R.I. Wood* 3036 (K). **Hajjah:** Jabal Nasira, 08 x 1982, *K. Muller-Hohenstein & U. Deil* 705 (E [E00066913]). SAUDI ARABIA. **Abha:** Tanomah, about 15 km south of Al-Namas, 10 iv 1977, *I.S. Collenette* 250 (K); Tanomah, 15 km south of Al-Namas, Abha, 13 iv 1979, *I.S. Collenette* 1360 (K); Between Al-Namas and Tanomah, Tanomah, 07 vi 2000, *Taku Miyazaki* 000607II34 (E [E00614718]); Aqabat Al-Samma to Wadi Al-Ouse, NW of Abha, 06 i 1981, *A.K. Nasher* IH153 (E [E00066915]); Wadi Al-Ouse, Abha, 13 v 1981, *I.S. Collenette* 2692 (E [E00066925]); Raidah Sanctuary, Abha, 09 ii 2001, *Taku Miyazaki* 010209RI (E [E00614685]); Asir, above Abha, 06 1946, *W. Thesiger* s.n. (BM);

Wadi Al-Ouse, 01 xi 1987, *S. Chaudhary* 12315 (RIY); Raidah Sanctuary, 21 vi 1996, *S. Chaudhary* 15523 (RIY); Raidah Sanctuary, 29 iv 1998, *T. Al-Turki* & *I.S. Collenette* 2610 & 2550 (KSU); Raidah Sanctuary, 21 v 1998, *A. Alfarhan* & *J. Thomas* 4840 (KSU); Raidah Sanctuary, 06 vii 2007, *A. Alfarhan* & *J. Thomas* 6272 (KSU); Raidah Sanctuary, 21 v 1998, *A. Alfarhan* & *J. Thomas* 6013 (KSU). **Jizan:** Jabal Fayfa, about 100 km NE of Jizan, 20 xi 1981, *I.S. Collenette* 3164 (K, E [E00066919]); Jabal Fayfa, 20 xi 1981, *S. Chaudhary* 998 (RIY); Jabal Fayfa, Jizan, 06 iii 1979, *S. Chaudhary* 6778 (RIY); Jabal Habbes, near Bani Malik, Jazan, 26 i 2002, *T. Al-Turki* & *J. Thomas* 20383 (KSU); Jabal Fayfa, 19 i 1995, *M. Ibrahim* 1827 (KSU). **Al-Baha:** King Khalid Road, NW of Al-Baha, 15 v 1992, *I.S. Collenette* 8227 (K, E [E01000559]); King Khalid Road between Qilwah and Al-Baha, 13 iii 2021, *A. Alzahrani* 164 (MUZ).

Verbascum melhanense is closely related to the very similar *V. bottae*, see under the latter. Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species from *V. bottae*.

Figure 4.15. *Verbascum melhanense*. A, habit; B, filaments with two anterior anthers inserted decurrent longitudinally and glabrous throughout their length (white arrow); C, flowers and capsules (white arrow); D, pedicel with glandular hairs (white arrow); E, leaf. PHOTOS: ALI ALZAHRANI.

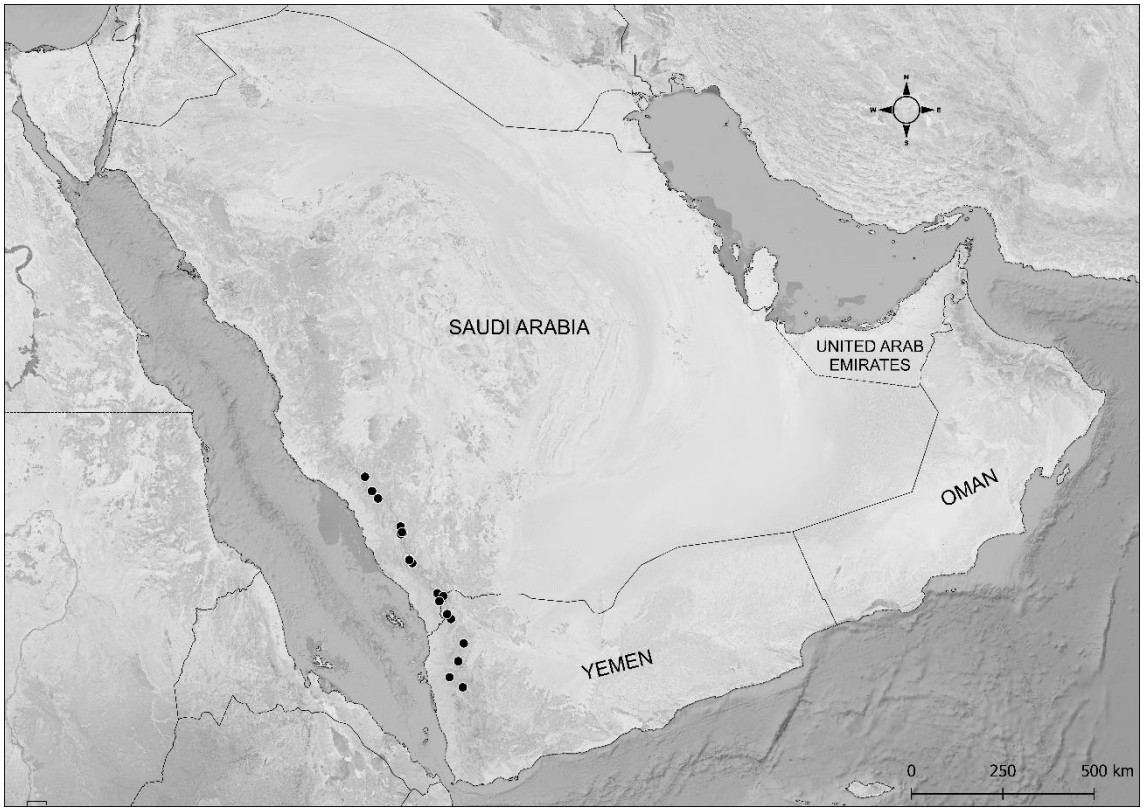

Figure 4.16. Distribution of *Verbascum melhanense* in the Arabian Peninsula.

9. Verbascum omanense Huber-Morath, Candollea 39(1): 320 (1984). – Type: Oman, Bitinah, Hibra, 10 km N of Nakhl, 2 iii 1980, *J.R. Edmondson* 3202 (holotype E [E00066934], isotype ON) (Figure 4.17).

Biennial herb, yellowish green, simple or usually branched from above, up to 1.5 m tall. *Indumentum* sparse glandular and stellate hairs above, and dense tomentose with stellate hairs below. *Stems* erect, robust, terete. *Basal leaves* rosette, oblong to obovate-oblong, 10 – 20 x 2 – 6 cm, apex acute or obtuse, base obtuse, margins undulate or lobed-crenate, lamina darkish or yellowish green with sparse stellate hairs above and dense tomentose with stellate hairs below; petiole 1.5 – 6 cm. *Cauline leaves* obovate-oblong, 3 – 6 x 1 – 3 cm, apex acute, base cordate; sessile or petiole up to 0.5 cm. *Inflorescence* panicle; one or clusters of 2 – 4 flowers in the axil of bracts. *Upper bracts* ovate, 2 – 3 mm,

acute or acuminate. *Lower bracts* ovate-triangular to lanceolate-triangular, 10 – 40 mm, acute or mucronate. *Pedicel* covered with sparse glandular and stellate hairs up to 5 mm long. *Bracteoles* present, ovate-triangular to lanceolate-triangular, acute. *Calyx* 3 – 4 mm, lobes ovate-oblong, acute, sparse glandular and stellate. *Corolla* 15 – 20 mm across, yellow, with pellucid glands, tubeless, glabrous inside, sparse glandular and stellate hairs outside. *Stamens* 5, 4 – 6 mm long. *Filaments* orange with violet-whitish hairs, with hairs up to anthers. *Anthers* all reniform. *Ovary* globose-ovoid, dense tomentose with stellate hairs. *Style* up to 7 mm long, filiform, green. *Stigma* capitate. *Capsule* 4 – 5 x 2 – 3 mm, globose-ovoid, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to the Arabian Peninsula, which is known from Oman in Muscat (Wadi Al Khawd), Al Batinah South (Al Khadra, Hibra, Nakhl, Wadi Abyad, and Wadi Beni Auf), Ash Sharqiyah North (Wadi Dawqah), Ad Dakhiliyah (Jabal Al Halla, Wadi Al Mahil, and Wadi Samail), Al Buraymi (Wadi Rayy), Al Batinah North (Wadi Fizh), and from United Arab Emirates in Hatta (Wadi Jeema), northeast Oman and the UAE (Figure 4.18).

Habitat and ecology. It grows in abandoned or date gardens, roadsides, and rocky wadis bed at altitudes ranging from 100 to 800 m. Associated plants include *Dodonaea viscosa* subsp. *angustifolia* (L.f.) J.G.West, *Salix acmophylla* Boiss., *Ficus palmata* Forssk., and *Zygophyllum indicum* (Burm.f.) Christenh. & Byng.

Global IUCN threat status. Least Concern. LC. (see Chapter 5).

Phenology. Flowering and fruiting from February to September.

Etymology. The name is derived from its occurrence in Oman.

Specimens examined. OMAN. **Al Batinah South:** Al Khadrah, Oasis NE of Buraimi, 23 vi 1984, *R.A. Western* 655 (E [E00066932]); Hibra, 14 ii 1979, *R.P. Whitcombe* 472 (ON, E [E00219515]); Hibra, near Nakhl, 05 iv 1985, *M.D. Gallagher* 7487/11 (ON, E [E00066935]); Bitinah, Hibra, 10 km N of Nakhl, 02 iii 1980, *J.R. Edmondson* 3202 (ON, E [E00066934]); 1.7 km before Al Thowarah Garden on main road through Nakhl, 23 v 1992, *H.D.V. Prendergast* 522 (ON, K); between Al Khod and Nakl, 20 ii 2006, *A. Patzelt* 2350 (OBG); Wadi Abyad, 24 iii 1995, *D. Coshey* 274 (ON); Hamiyat al mand, Zammah, Wadi Beni Awf, 20 km S of Rustaq, 11 iii 1997, *DHI* 278 (ON); Nakhl, 16 iii 1995, *D. Coshey* 154 (ON); Near Wadi Taww to Nakhal Village, 29 vi 2021, *A. Alzahrani* 191 (MUZ). **Ash Sharqiyah North:** Northern, Wadi Dawqah, Sharqiyah, 16 iv 1993, *I. McLeish* 1750 (ON, E [E00128420]). **Ad Dakhiliyah:** W. Hajar mts, 12 km from Kahanat to Rahbah, E. side of Jabal Al Halla, 14 iii 1980, *J.R. Edmondson* 3399 (E [E00066931]); Wadi Mahil, below Jabal Mahil, S of Sumail, 03 iii 1976, *A. Radcliffe-Smith* 3766 (ON, K); Wadi Sumail, 03 ii 1985, *R.E. Ash* 213 (ON); Vicinity of Samail, 20 iv 1975, *J.P. Mandaville* 6694 (BM); Vicinity of Samail, 20 iv 1975, *J.P. Mandaville* 6693 (BM); *Mrs Bovey* 69 (BM). **Al Buraymi:** Wadi Rayy, between Mahdah and Hatta, NE of Buraimi, 04 iv 1990, *R.A. Western* 1197 (E [E00066933]). **Al Batinah North:** Wadi Fizh, near Zaymi in mountains NW of Sohar, 08 iv 1994, *K. & CJN. Roberts & M.D. Gallagher* 8598 (ON, E [E00712454]). **Muscat:** Wadi Al Khawd, 14 vii 2021, *A. Alzahrani* 193 (MUZ). UNITED ARAB EMIRATES. **Hatta:** Wadi Jeema, Hatta Town, 17 iii 1986, *J.N.B. Brown* 905 (E [E00066936]).

Verbascum omanense is restricted to the foothills of the Hajar mountains in Oman and the UAE. It is a very variable leaf, bract, bracteole, and margin shapes, which could be confused with the closely related *V. sinaiticum*. In contrast to *V. sinaiticum*, *V. omanense* has glandular hairs and less dense tomentose with stellate hairs above, a glabrous corolla with glandular-stellate hairs on the outer, and a globose-ovoid capsule. Recent phylogenetic research (see Chapter 3) confirms that it is a distinct species.

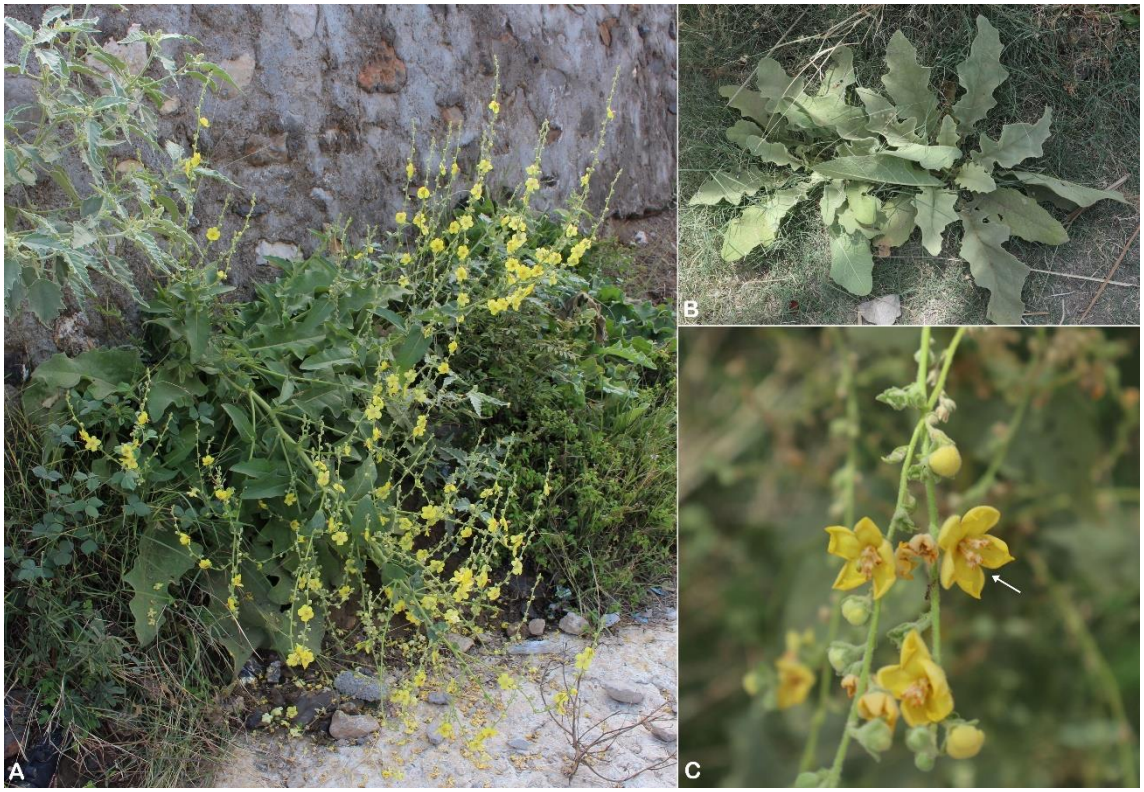

Figure 4.17. *Verbascum omanense*. A, habit; B, leaf; C, flowers with five stamens (white arrow). PHOTOS: A, SAIF AL HATMI; B and C, SALIM AL RAHBI.

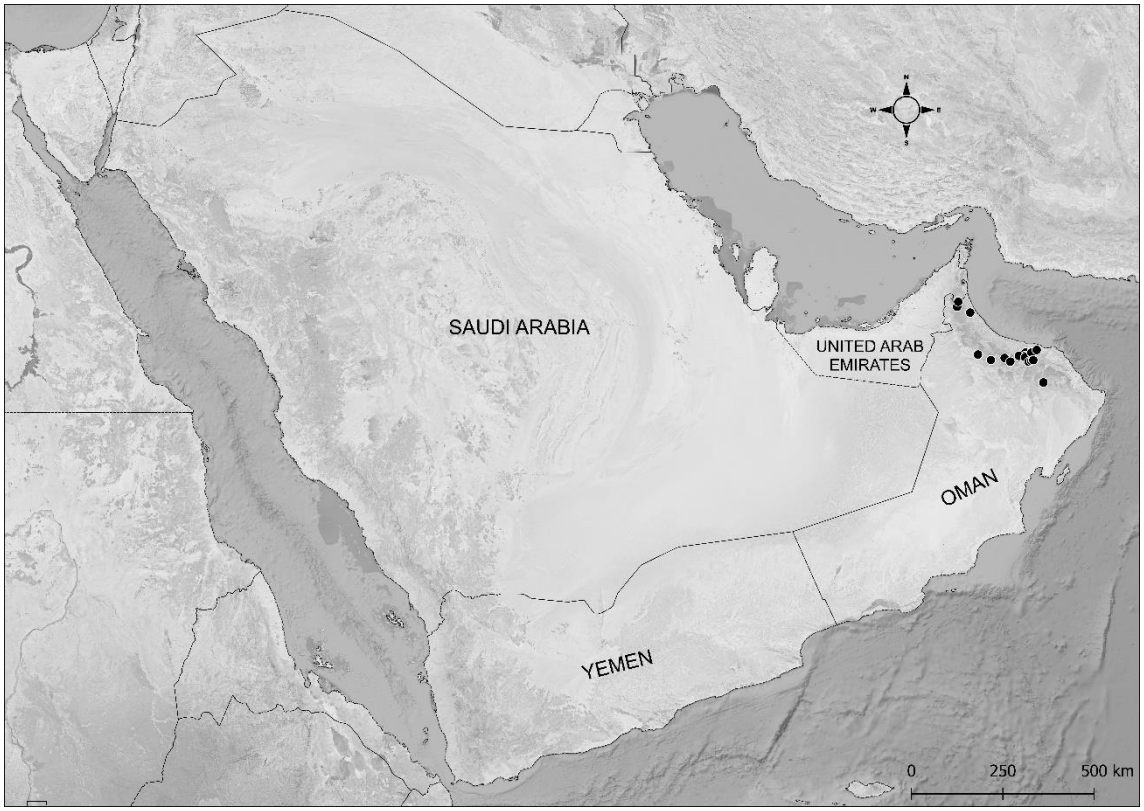

Figure 4.18. Distribution of *Verbascum omanense* in the Arabian Peninsula.

10. Verbascum sarawaticum A.Alzahrani, **sp. nov.**

Verbascum sarawaticum resembles *V. yemense* by its indumentum glabrescent or sparse stellate hairs above, and dense stellate hairs below, but differs in its growth life biennial (versus perennial), many-branched stems from the base (versus branched from above), basal leaves elliptic-lanceolate (versus oblong to oblong-lanceolate), calyx lobes oblong (versus linear), corolla with pellucid glands (versus without pellucid glands), corolla with sparse ciliated hairs inside (versus glabrous inside), filaments with whitish hairs (versus yellowish hairs), and capsule ovoid (versus ellipsoid-ovoid). – Type: Saudi Arabia, Al-Baha, Red Mountain, 50 km S of Baljurashi, 10 v 1981, *I.S. Collenette* 2650 (holotype K) (Figures 4.19, 4.20).

Biennial herb, yellowish green, simple or very branched from the base, up to 1 m tall. *Indumentum* glabrescent or sparse stellate hairs above, and dense stellate hairs below. *Stems* erect, terete. *Basal leaves* rosette, elliptic-lanceolate, 2 – 15 x 1.5 – 6 cm, apex obtuse, base obtuse or cuneate, margins crenate-repand, lamina whitish green with dense stellate hairs; petiole 2 – 5 cm. *Cauline leaves* lanceolate, 1.5 – 2 x 0.5 – 1 cm, apex acute, base cuneate; sessile. *Inflorescence* racemose forming panicle; one or clusters of 2-3 flowers in the axil of bracts. *Upper bracts* linear, 2 – 3 mm, mucronate. *Lower bracts* lanceolate, 10 – 15 mm, acute. *Pedicel* glabrescent or sparse stellate hairs up to 3 mm long. *Bracteoles* absent. *Calyx* 3 – 4 mm, lobes oblong, mucronate, sparse stellate hairs. *Corolla* 15 – 20 mm across, yellow with red marks in the throat, with pellucid glands, tube up to 1 mm, sparse ciliated hairs inside, sparse stellate hairs outside. *Stamens* 5, 3 – 5 mm long. *Filaments* orange with whitish hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ovoid, dense stellate hairs. *Style* up to 7 mm long, filiform, green. *Stigma* spatulate. *Capsule* 4 – 6 x 2 – 4 mm, ovoid, sparse stellate hairs. *Seeds* 0.7 – 0.8 × 0.4 – 0.5 mm, brownish, oblong, bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Saudi Arabia, which is known from Al-Baha (Red Mountain in Baljurashi), and Taif (Near Al-Hada palm, Al-Hada), southwestern Saudi Arabia (Figure 4.21).

Habitat and ecology. It grows on granite rubbles and roadsides at altitudinal ranges from 1600 to 1980 m. Associated plants include *Juniperus procera* Hochst. ex Endl., *Commicarpus grandiflorus* (A.Rich.) Standl., *Osteospermum*

vaillantii (Decne.) Norl., *Aizoon canariense* L., *Blepharis edulis* (Forssk.) Pers., *Rumex vesicarius* L., *Fumaria abyssinica* Hammar, *Solanum incanum* L., and *Campanula edulis* Forssk.

Global IUCN threat status. Endangered. EN. (see Chapter 5).

Phenology. Flowering and fruiting from March to August.

Etymology. The name is derived from Sarawat, the local Arabic name of the Sarawat mountains.

Specimens examined. SAUDI ARABIA. **Al-Baha:** Red Mountain, 50 km S of Baljurashi, 10 v 1981, *I.S. Collenette* 2650 (holo. K). **Taif:** Al-Hada, 22 iii 2005, *A. Alfarhan, T. Al-Turki* & *J. Thomas* 4610 (KSU); Near Al-Hada palm, Al-Hada, 10 iii 2021, *A. Alzahrani* 155 (MUZ).

Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species from related species *V. yemense.*

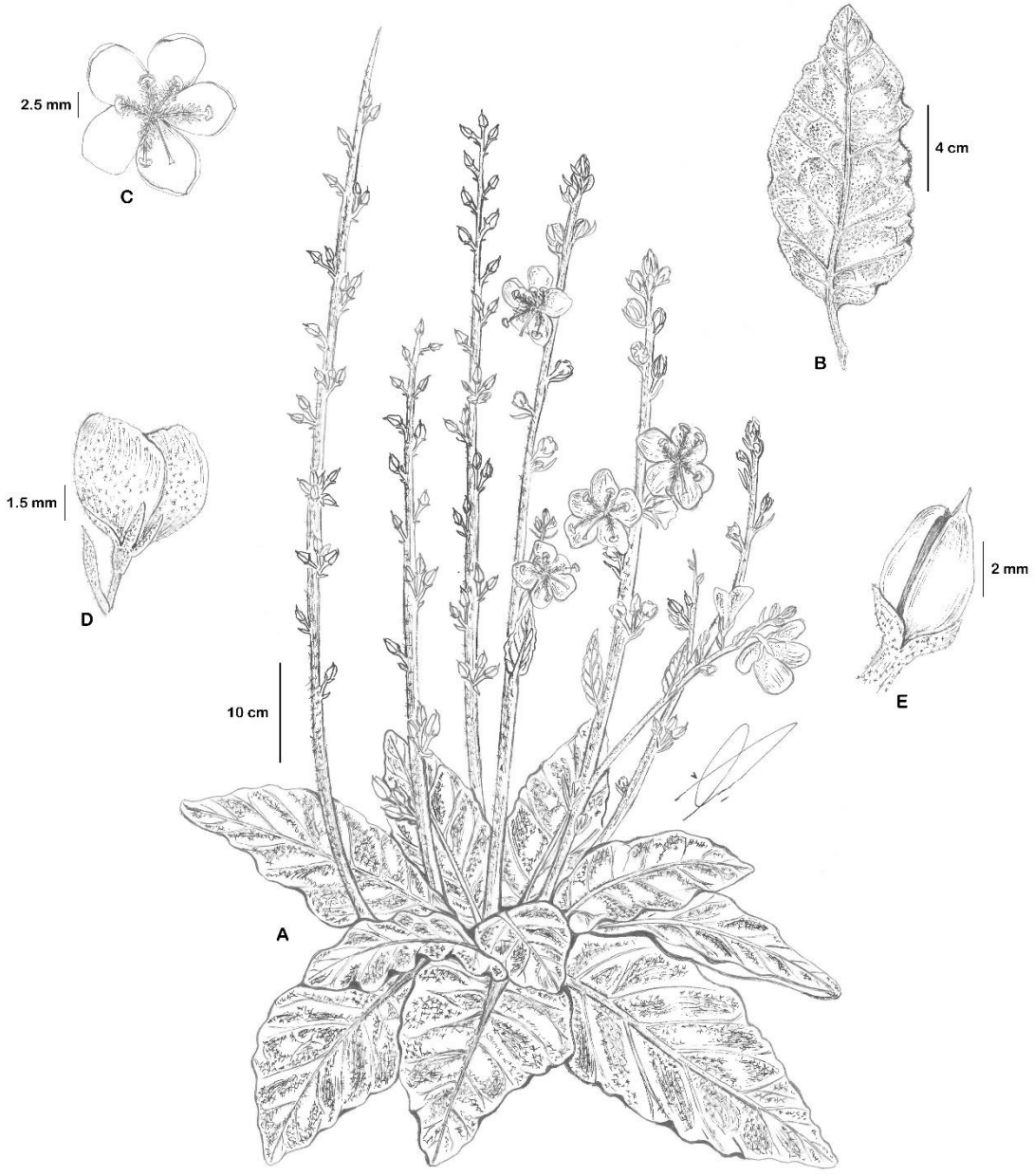

Figure 4.19. *Verbascum sarawaticum*. A, habit (many-branched stems from the base); B, flower with five stamens (filaments with two anterior glabrous near the

apex); D, flower, calyx, and upper bract (covered with sparse stellate hairs); E, capsule. All parts from *I.S. Collenette* 2650. DRAWN BY SUHAIR ALMALKI.

Figure 4.20. *Verbascum sarawaticum*. A, habit and capsule (white arrow); B, flowers with five stamens and filaments with whitish hairs; C, leaf; D, sparse stellate hairs outside the calyx and corolla (white arrows). PHOTOS: ALI ALZAHRANI.

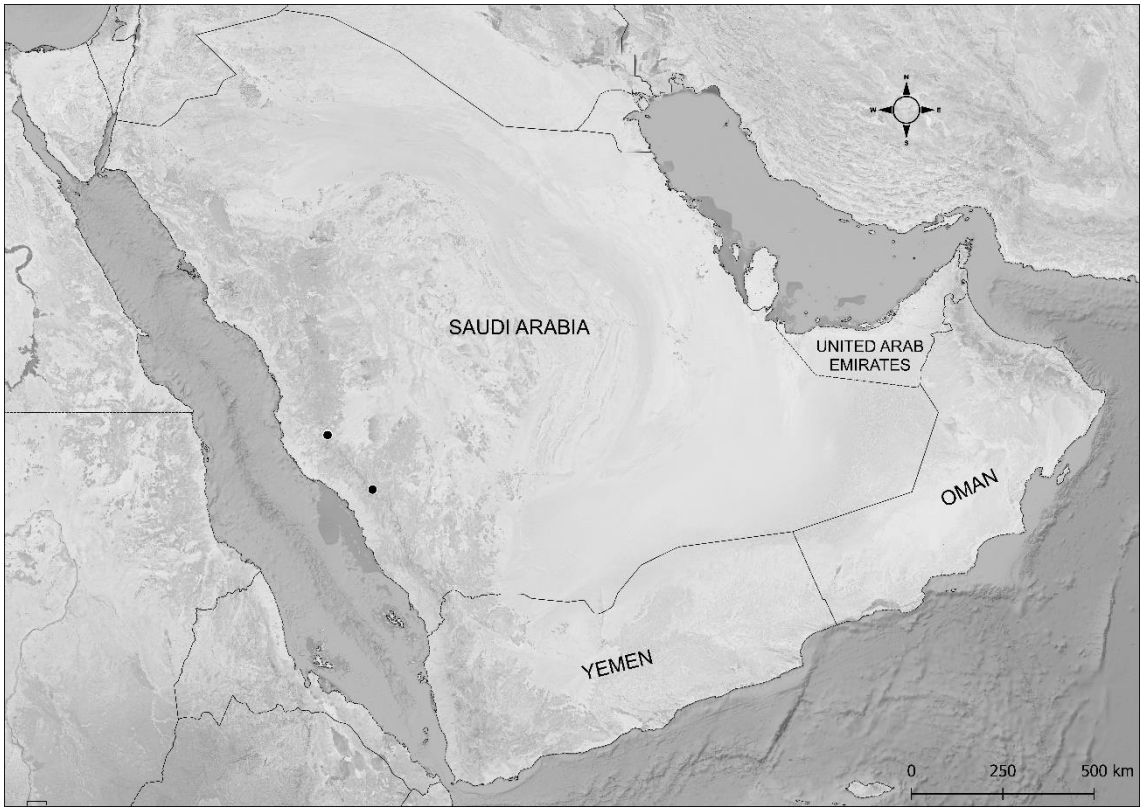

Figure 4.21. Distribution of *Verbascum sarawaticum* in the Arabian Peninsula.

11. Verbascum saudiarabicum (A.Alzahrani) A.Alzahrani*,* **comb. nov.** – *Rhabdotosperma saudiarabicum* A.Alzahrani, Kew Bull. 77(4): 987 (2022). – Type: Saudi Arabia, Abha, Jabal Al-Soudah, Al-Soudah, 25 km NW of Abha, 22 ii 1982, *I.S. Collenette* 3316 (holotype K).

Alzahrani *et al*. (2022) described *Rhabdotosperma saudiarabicum* as new species from Saudi Arabia; however, recent phylogenetic research (see Chapter 3) confirms and supports the inclusion of *Rhabdotosperma* within *Verbascum*.

For detailed information, see Alzahrani *et al*. (2022; see Chapter 2).

12. Verbascum schimperianum Boiss. Diagn. Pl. Orient. ser. 1, 12: 11 (1853). – *Verbascum crispum* Ehrenb. ex Boiss., Fl. Orient. 4(2): 341 (1879). – Type:

Inter Tor et Sinam, *Ehrenberg* 300 (lectotype K designated here, isolectotype P [P03285813]) (Figure 4.22).

Perennial herb, yellowish green, very branched from the base, woody at the base, up to 80 cm tall. *Indumentum* dense rough yellowish tomentose with stellate hairs. *Stems* erect, terete. *Basal leaves* rosette, oblong to obovate-oblong, 3 – 10 x 2 – 5 cm, apex obtuse, base obtuse, margins sinuate to lobed-crenate, lamina yellowish green with dense yellow-grey tomentose with stellate hairs; petiole 0.5 – 2 cm. *Cauline leaves* oblong-ovate, 3 – 5 x 1 – 2 cm, apex obtuse, base cordate, sessile or petiole up to 1 cm. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* ovate, 2 – 3 mm long, acute. *Lower bracts* ovate-triangular, 20 – 50 mm long, acute. *Pedicel* covered with dense tomentose with stellate hairs up to 3 mm long. *Bracteoles* absent. *Calyx* 3 – 4 mm, lobes ovate-elliptic, acute, dense tomentose with stellate. *Corolla* 15 – 20 mm across, yellow, with pellucid glands, tubeless, sparse ciliated hairs inside, dense tomentose with stellate hairs outside. *Stamens* 5, 3 – 6 mm long. *Filaments* yellow with yellow hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid-ovoid, dense tomentose with stellate hairs. *Style* up to 6 mm long, filiform, green. *Stigma* capitate. *Capsule* 4 – 5 x 2 – 3 mm, ellipsoid-ovoid, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution. Jordan, Palestine, Egypt (Sinai), and Saudi Arabia.

Distribution in the Arabian Peninsula. It is a native species to Saudi Arabia, which is known from two locations in Tabuk province (Wadi Sawawin, Ain Al-Shayatei and surrounding areas), northwest Saudi Arabia (Figure 4.23).

Habitat and ecology. It grows on among rocks in wadis edge and granite sand in lava at altitudes ranging from 600 to 1280 m. Associated plants include *Retama raetam* (Forssk.) Webb & Berthel., *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Ochradenus baccatus* Delile, *Fagonia mollis* Delile, *Scrophularia deserti* Delile, *Stachys aegyptiaca* Pers., and *Zilla spinosa* (L.) Prantl.

Regional IUCN threat status. Critically Endangered. CR. (see Chapter 5).

Phenology. Flowering from March to November.

Etymology. The name is derived from Georg Wilhelm Schimper (1804-1878), the German botanist and plant collector.

Specimens examined. SAUDI ARABIA. **Tabuk:** Wadi Sawawin, 26 iii 1978, *I.S. Collenette* 527 (K).

Verbascum schimperianum is closely related to *V. eremobium* by its dense rough tomentose with stellate hairs, branched from the base, woody base, five stamens, and all anthers reniform, but differs in having racemose inflorescence without bracteoles, calyx lobes ovate-elliptic, filaments yellow with yellow hairs, and ellipsoid-ovoid capsule.

Figure 4.22. *Verbascum schimperianum*. A, habit and capsule (white arrow). PHOTO: ABDUL WALI ALKHULAIDI.

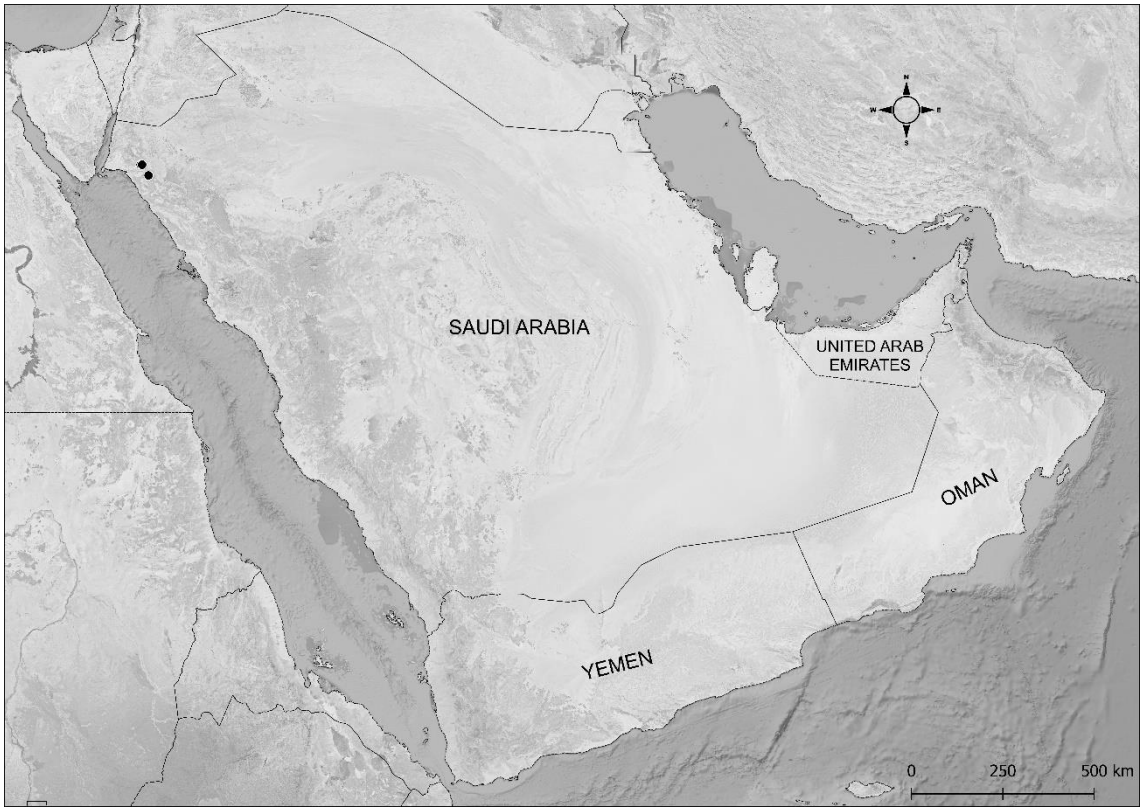

Figure 4.23. Distribution of *Verbascum schimperianum* in the Arabian Peninsula.

13. Verbascum shiqricum Hemaid, Pakistan J. Bot. 33(4): 324 (2001). – Type: Saudi Arabia, Tabuk, between Sawawin and Shiqri, 12 iv 1985, *I.S. Collenette* 5277 (holotype E [E00066964]).

Verbascum abyadicum Hemaid, Pakistan J. Bot. 33(4): 316 (2001), **synon. nov.** – Type: Saudi Arabia, Harrat Khaybar, 125 Km N of Medina, 10 viii 1982, *I.S. Collenette* 3757 (holotype E [E00066949], isotype K) (Figure 4.24).

Biennial herb, yellowish green, simple or usually branched from the base, up to 1 m tall. *Indumentum* glabrescent or sparse stellate hairs above, and dense tomentose with stellate hairs below. *Stems* erect, robust, terete. *Basal leaves* rosette, obovate-elliptic to ovate, 5 – 15 x 2 – 10 cm, apex acute, base obtuse to cuneate, margins crenate-sinuate, lamina white or grey greenish with dense white-grey tomentose with stellate hairs; petiole 2-10 cm. *Cauline leaves*

lanceolate, 3 – 5 x 1.5 – 2 cm, apex acuminate, base obtuse-cuneate, sessile or petiole up to 2 cm. *Inflorescence* racemose forming panicle; one or clusters of 2-6 flowers in the axil of bracts. *Upper bracts* linear, 5 – 10 mm, acute. *Lower bracts* oblong-elliptic, 15 – 20 mm, acuminate. *Pedicel* glabrescent or sparse stellate hairs up to 3 mm long. *Bracteoles* absent. *Calyx* 5 – 6 mm, lobes linear, acute, glabrescent or sparse stellate. *Corolla* 15 – 20 mm across, yellow with red marks in the throat, with pellucid glands, tube up to 2 mm, sparse ciliated hairs inside, sparse stellate hairs outside. *Stamens* 5, 4 – 5 mm long. *Filaments* orange with whitish hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid, dense tomentose with stellate hairs. *Style* up to 8 mm long, filiform, green. *Stigma* capitate. *Capsule* 5 – 6 x 3 – 4 mm, ellipsoid, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to Saudi Arabia, which is known from several locations in Tabuk province (Alaqan near Jordan borders, between Duba and Shiqri near Shiqri, and Jabal Qaraqir), and in Medina province (Harrat Khaybar near Jabal Abyad, Al-Ula near Bir Al-Qurr, and Harrat Uwayrid), northwest to western Saudi Arabia (Figure 4.25).

Habitat and ecology. It grows in crevices of black lava, roadsides, and rocky sandstone at altitudes ranging from 915 to 1680 m. Associated plants include *Vachellia gerrardii* (Benth.) P.J.H.Hurter, *Ononis natrix* L., *Rumex vesicarius* L., *Nanorrhinum acerbianum* (Boiss.) Betsche, *Solenostemma oleifolium* (Nectoux) Bullock & E.A.Bruce ex Maire, *Matthiola longipetala* (Vent.) DC., *Forsskaolea*

tenacissima L., *Euphorbia dracunculoides* Lam., and *Pseudodictamnus undulatus* (Benth.) Salmaki & Siadati.

Global IUCN threat status. Near Threatened. NT. (see Chapter 5).

Phenology. Flowering from March to August.

Etymology. The name is derived from the type locality Shiqri.

Specimens examined. SAUDI ARABIA. **Tabuk:** between Sawawin and Shiqri, 12 iv 1985, *I.S. Collenette* 5277 (E [E00066964]); North Hijaz, Wadi Qaraqir, 10 iii 1979, *I.S. Collenette* 1013 (K); Jabal Hisma ranges, 26 iii 1989, *I.S. Collenette* 7028 (E [E00066957]); Tabuk road between Duba and Shigry, near Shigry, 16 vi 2021, *A. Alzahrani* 180 (MUZ). **Medina:** Harrat Khaybar, 125 Km N of Medina, 10 viii 1982, *I.S. Collenette* 3757 (K, E [E00066949]); Near Bir Al-Qurr, Al-Ula, 05 iii 2021, *A. Alzahrani* 149 (MUZ); Harrat Khaybar, near Jabal Abyad, 06 iii 2021, *A. Alzahrani* 150 (MUZ).

Verbascum shiqricum a very distinctive and variable species in Saudi Arabia. However, phylogenetic studies (see Chapter 3) indicate that this species is *V. shiqricum*. In addition to a study of the type specimens of *V. abyadicum* and its comparison with *V. shiqricum*, as well as thorough examination of the important morphological characteristics of both type specimens, it is proposed here that *V. abyadicum* is a synonym of *V. shiqricum* as both species have glabrescent or sparse stellate hairs above, and dense tomentose with stellate hairs below, basal leaves obovate-elliptic to ovate, five stamens, racemose forming panicle; one or clusters of 2 – 6 flowers, filaments hairs whitish, and capsule ellipsoid.

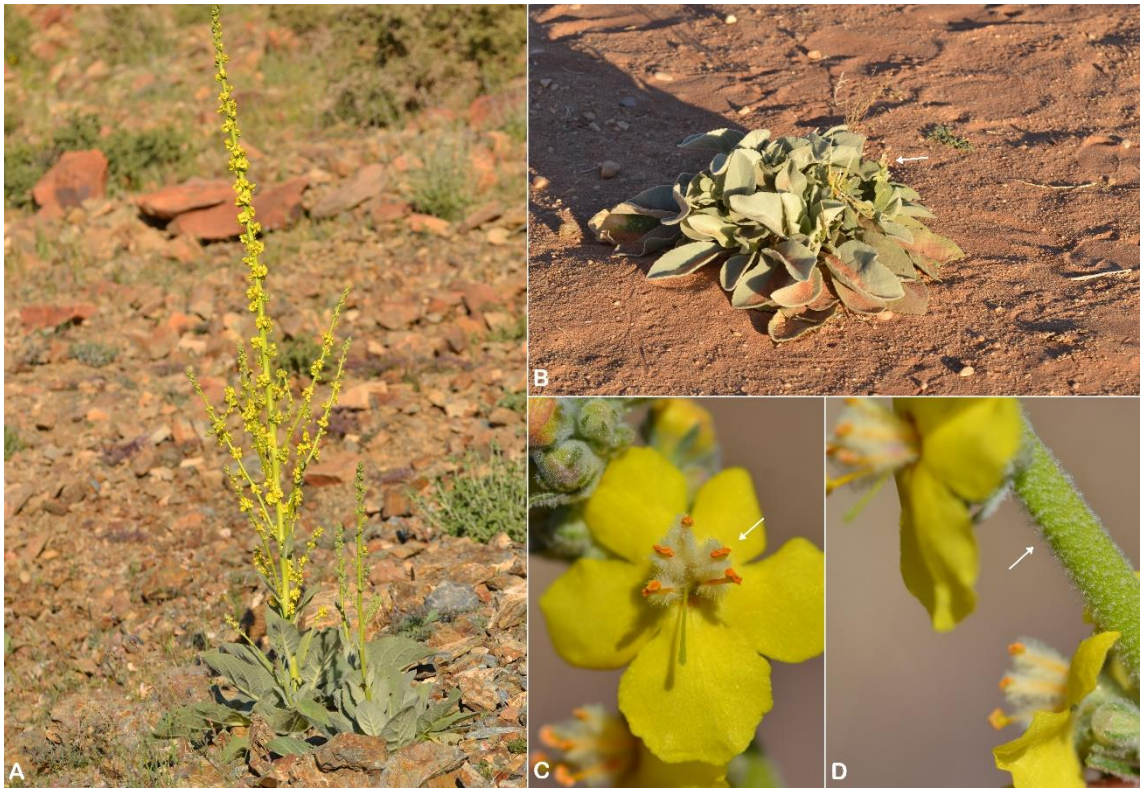

Figure 4.24. *Verbascum shiqricum*. A, habit; B, leaf (stems were grazed, white arrow); C, flowers with five stamens and filaments with whitish hairs (white arrow); D, stems with sparse stellate hairs (white arrow). PHOTOS: ALI ALZAHRANI.

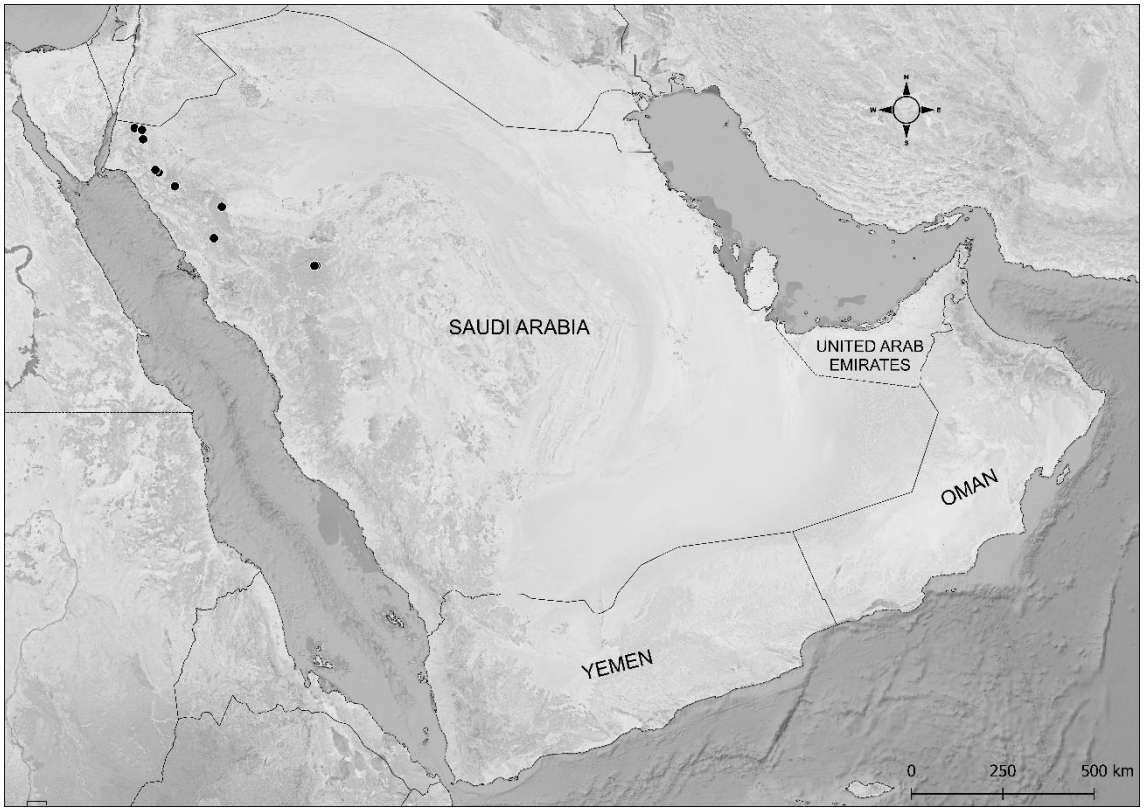

Figure 4.25. Distribution of *Verbascum shiqricum* in the Arabian Peninsula.

14. Verbascum sinaiticum Benth. in DC., Prodr., X, p. 236 (1846). – Type: Egypt, ad fontes montis Sinai Peninsula, 30 v 1835, *W. Schimper* 357 (lectotype HBG [HBG512118] designated here, isolectotype HBG [HBG512120]).

Verbascum fasciculatum Ehrenb. ex Sweet, Hort. Brit., ed. II. p. 381 (1830). – Type: Egypt, Mount Sinai 1829, s.n. (not seen).

Verbascum ternacha Hochst. In: A. Rich. Tent. Fl. Abyss. II: 108. (1851). – Type: Ethiopia, Prope Dscheladscheranne 1852, *W. Schimper* 621 (isotype M [M0106186]).

Verbascum barradense Boiss., Fl. Orient. 4(2): 318 (1879). – Type: Syria, Damascus, prés au bord du Barrada, gorge de Doumar, 20 vi 1853, *C. Gaillardot* s.n. (Hskn.?, not seen).

Verbascum somaliense Baker, Bull. Misc. Inform. Kew 1895(105): 222 (1895). – Type: Somalia, Golis range, Balamha, *E. Cole & E. Lort Phillips* 296 (lectotype K [K000411058] designated here).

Verbascum nubicum Murb., in Lunds Univ. Arsskrift, n. f. xxix. No. 2. 293 (1933). – Type: Red Sea Hills, Erkowit, *L. Maffey* 5 (lectotype K [K000411062] designated here) (Figure 4.26).

Biennial herb, yellowish green, usually simple large or branched above, up to 2 m tall. *Indumentum* dense rough tomentose with stellate hairs. *Stems* erect, robust, terete. *Basal leaves* rosette, oblong to oblong-ovate, 10 – 30 x 3 – 10 cm, apex acute, base obtuse to cuneate, margins crenate-dentate, lamina yellowish green with dense yellow-grey tomentose with stellate hairs; petiole 2 – 13 cm. *Cauline leaves* oblong-ovate, 4 – 10 x 3 – 5 cm, apex acute-acuminate, base obtuse; sessile or petiole up to 1 cm. *Inflorescence* panicle; clusters of several flowers in the axil of bracts. *Upper bracts* ovate, 5 – 8 mm, acute or acuminate. *Lower bracts* ovate to ovate-triangular, 15 – 40 mm, acuminate. *Pedicel* covered with dense tomentose with stellate hairs up to 8 mm long. *Bracteoles* present, ovate to ovate-lanceolate, acute. *Calyx* 4 – 5 mm, lobes lanceolate, acute, dense tomentose with stellate. *Corolla* 15 – 20 mm across, yellow, with pellucid glands, tube up to 2 mm, glabrous or sparse ciliated hairs inside, dense tomentose with stellate hairs outside. *Stamens* 4-5 or 7 (unstable), 4 – 6 mm long. *Filaments* orange with violet-whitish hairs, with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid-ovoid, dense tomentose with stellate hairs. *Style* up to 8 mm long, filiform, green. *Stigma* capitate. *Capsule* 4.5 – 7.5 x 4 – 6 mm, ellipsoid-ovoid to globose, dense tomentose with stellate hairs. *Seeds* bothrospermous.

Distribution. Eritrea, Ethiopia, Kenya, Somalia, Sudan, Niger, Egypt, Iraq, Jordan, Lebanon, Syria, Palestine, and the Arabian Peninsula.

Distribution in the Arabian Peninsula. It is a native species to Saudi Arabia, which is known from Tabuk province (Jabal Al-Lawz, Wadi Al-Disah, Harrat Raha) northwest Saudi Arabia, but it is an introduced species from Yemen, which is known from Sana'a (Haima Al Kharajia, and between Sayyan and Qaidun), Raymah (Jibal Raymah), and Ibb (Near Dhi Sufal and Sumara Pass) southwestern Yemen (Figure 4.27).

Habitat and ecology. It grows in rocky slopes or granite, hillside, beds of sandy wadis, black lava, and roadsides at altitudes ranging from 1500 to 2800 m. Associated plants include *Pistacia khinjuk* Stocks, *Dianthus sinaicus* Boiss., *Phlomis brachyodon* (Boiss.) Zohary ex Rech.f., *Lactuca orientalis* (Boiss.) Boiss., *Pterocephalus sanctus* Decne., *Hypericum sinaicum* Hochst. ex Boiss., *Ononis natrix* L., *Verbascum decaisneanum* O. Kuntze, *Nanorrhinum acerbianum* (Boiss.) Betsche, and *Kickxia collenetteana* D.A.Sutton.

Vernacular name. Qetetina (English); *Aithnah*, *Albusira* (Arabic).

Regional IUCN threat status. Least Concern. LC. (see Chapter 5).

Phenology. Flowering and fruiting from May to August.

Etymology. The name is derived from its occurrence in Sinai, Egypt.

Specimens examined. EGYPT**. Sinai Peninsula:** ad fontes montis Sinai, 30 v 1835, *W. Schimper* 357 (HBG [HBG512118] & [HBG512120]). YEMEN**. Sana'a:**

Haima Al Kharajia, Manakhah to Sana'a, 29 xi 1976, *J.R.I. Wood* 1483 (K); Between Sayyan and Qaidun, 01 v 1977, *J.R.I. Wood* 1579 (BM, K). **Raymah:** Jibal Raymah, path below ridge to S of Al Jabin, 21 iii 1984, *A. G. Miller & R. A. King* 5327 (E [E00066966]). **Ibb:** Near Dhi Sufal, 04 x 1976, *J.R.I. Wood* 1351 (E [E00687347]); The road near Ad Delil at the bottom of the Sumara Pass, 05 v 1975, *J.R.I. Wood* 75/108 (BM, E [E00066959]); Sumara Pass, 10 km S of Yarim, 01 ix 1976, *B. Acres* 14 (K); 35 km N of Taiz around Dhi Sufal, 20 x 1975, *F.N. Hepper & J.R.I. Wood* 5854 (K); Sumara Pass, road summit, 13 x 1975, *F.N. Hepper* 5650 (K). SAUDI ARABIA**. Tabuk:** Jabal Al-Lawz, near Aqaba Gulf, 03 viii 1989, *I.S. Collenette* 7235 (K, E [E00066927]); Harrat Raha, 20 km SE of Badiah, 17 v 1994, *I.S. Collenette* 9144 (K, E [E00092224]); Jabal Al-Lawz, S of Aqaba, Wadi Lakus, 05 v 1992, *I.S. Collenette* 8213 (K); Jabal Al-Lawz, N of Tabuk, 02 vi 2016, *J. Thomas*, *M. El-Sheikh* & *A. Alatar* 24311 (KSU); Wadi Al-Disah, SW of Tabuk, 01 iv 2014, *J. Thomas* 23741 (KSU); Jabal Al-Lawz, Tabuk, 06 v 2016, *M. El-Sheikh* & *M. Al-Shehri* 23366 (KSU); Jabal Al-Lawz, 17 vi 2021, *A. Alzahrani* 181 (MUZ).

Verbascum sinaiticum is native to northwest Saudi Arabia; however, Rathjens introduced this species to Yemen in 1937 (Wood, 1997).

Verbascum sinaiticum is distinct from *V. shiqricum* in its indumentum which is dense rough tomentose with stellate hairs, inflorescence panicle with clusters of several flowers in the axil of bracts, and ellipsoid-ovoid to globose capsule. Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species.

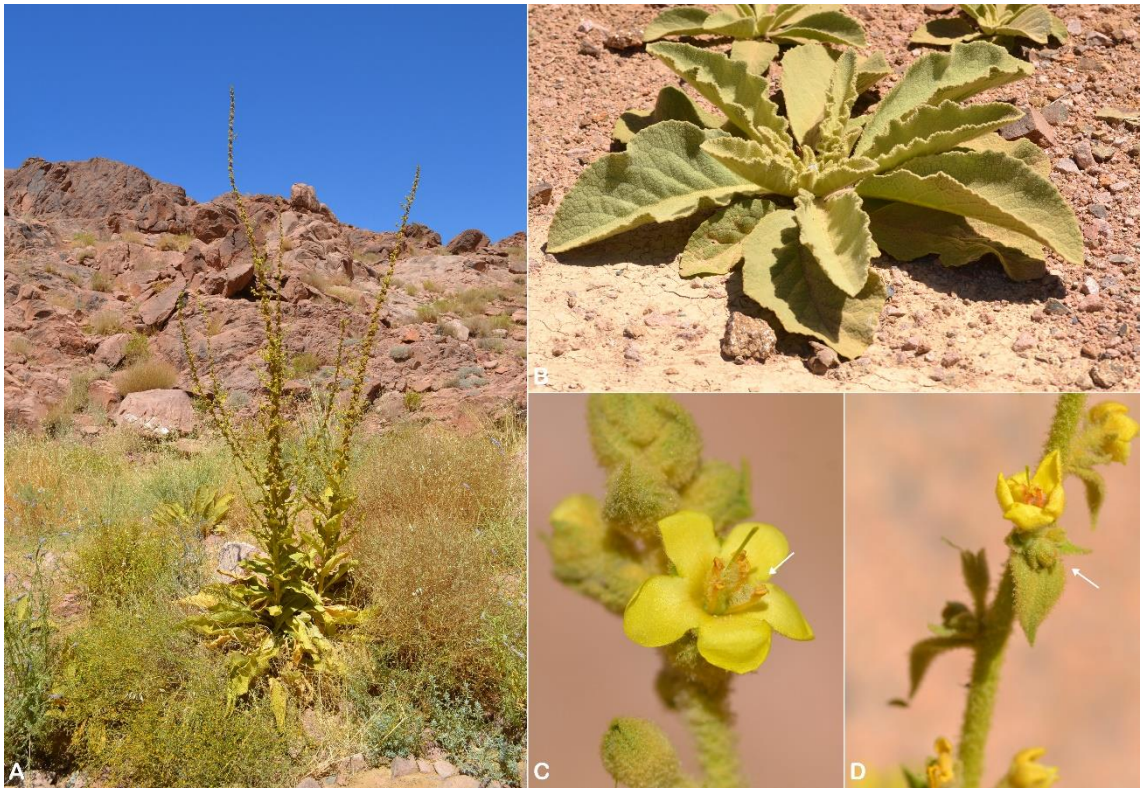

Figure 4.26. *Verbascum sinaiticum*. A, habit; B, leaf; C, flowers with five stamens and filaments with hairs up to anthers (white arrow); D, calyx and upper bracts (white arrow). PHOTOS: ALI ALZAHRANI.

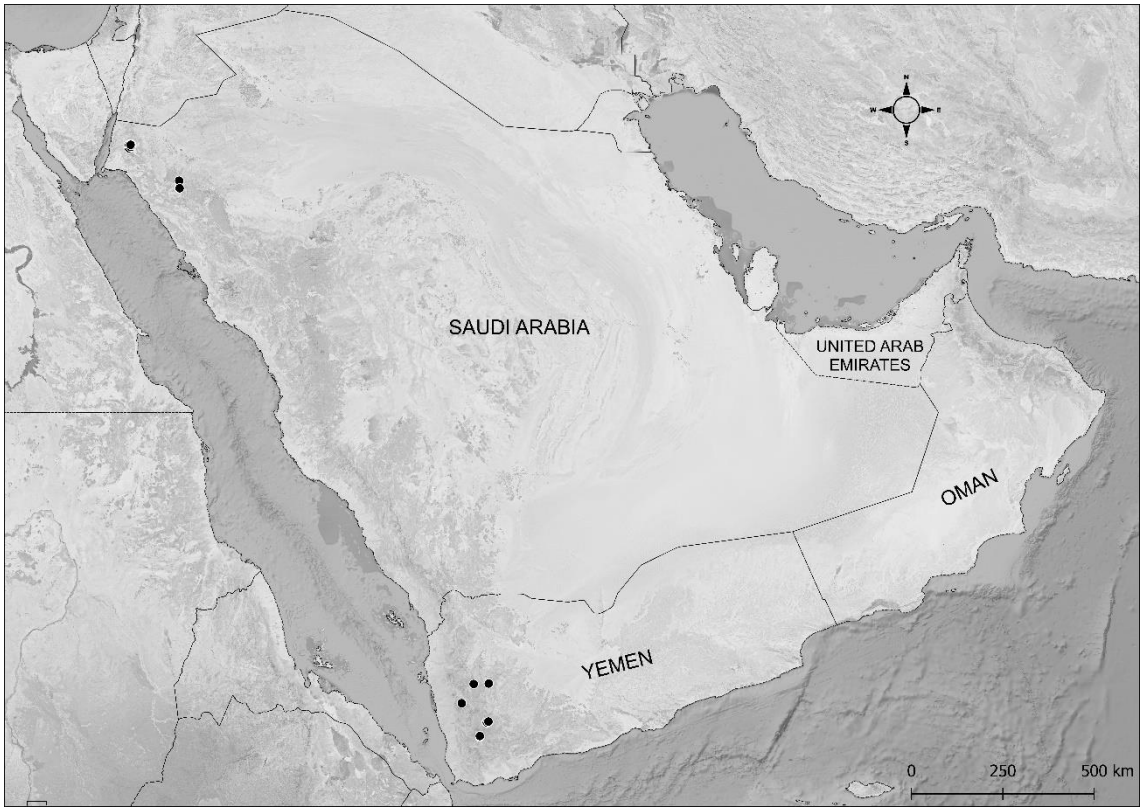

Figure 4.27. Distribution of *Verbascum sinaiticum* in the Arabian Peninsula.

15. Verbascum transjordanicum Murb. in Lunds Univ. Arsskrift, n. f. xxxv. No. 1 54 (1939). – Type: Jordan, Sandy desert, 40 km west of Azrak, 17 iv 1936, *J.E. Dinsmore* 11804 (isotype E [E00327349]) (Figure 4.28).

Annual or biennial herb, pale green, usually branched, many-stemmed from the base, up to 70 cm tall. *Indumentum* dense glandular hairs with sparse simple and forked hairs above, and dense tomentose with stellate hairs below. *Stems* erect, robust, terete to angular. *Basal leaves* rosette, oblong-lanceolate, 2.5 – 12 x 1 – 3.5 cm, apex acute, base obtuse, margins crenate to pinnatifid-lobed, lamina darkish green with sparse stellate hairs above and dense white-grey tomentose with stellate hairs below; petiole 1 – 4 cm. *Cauline leaves* oblong-lanceolate, 1.6 – 5 x 1 – 2 cm, apex acute, base obtuse; sessile. *Inflorescence* racemose; flowers single in the axil of bracts. *Upper bracts* ovate-triangular, 1 – 4 mm, acute. *Lower*

bracts oblong-lanceolate, 4 – 8 mm, acute. *Pedicel* covered with dense glandular hairs up to 20 mm long. *Bracteoles* absent. *Calyx* 3.4 – 4.4 mm, lobes oblong-lanceolate, acute, dense glandular. *Corolla* 20 – 30 mm across, yellow with dark purple-red hairy blotches around the throat, without pellucid glands, tube up to 1 mm, dense papillose hairs inside, spare glandular, simple, and forked hairs outside. *Stamens* 5, 3 – 5 mm long. *Filaments* yellow with creamy hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* globose-ovoid, sparse glandular hairs. *Style* up to 7 mm long, filiform, green. *Stigma* capitate. *Capsule* 4 – 6 x 3 – 4 mm, globose-ovoid, sparse glandular hairs. *Seeds* bothrospermous.

Distribution. Jordan and Saudi Arabia.

Distribution in the Arabian Peninsula. It is a native species to Saudi Arabia, which is known from Turaif province (near Harrat Al-Harrat Reserve), northern of Saudi Arabia (Figure 4.29).

Habitat and ecology. It grows on a limestone plateau with basalt rock at altitudes ranging from 600 to 832 m. Associated plants include *Achillea fragrantissima* (Forssk.) Sch.Bip., *Helianthemum lippii* (L.) Dum.Cours., *Centaurea sinaica* DC., *Hyoscyamus muticus* subsp. *muticus*, and *Cornulaca setifera* (DC.) Moq.

Vernacular name. Transjordan Mullein (English), *Abu Ain* (Arabic).

Regional IUCN threat status. Critically Endangered. CR. (see Chapter 5).

Phenology. Flowering and fruiting from March to June.

Etymology. The name is derived from being located across or beyond Jordan (Transjordan).

Specimens examined. JORDAN. **Azrak**: Sandy desert, 40 km west of Azrak, 17 iv 1936, *J.E. Dinsmore* 11804 (E [E00327349]). SAUDI ARABIA. **Turaif**: 5 km NNW of Turaif Camp, 22 iv 1994, *I.S. Collenette* 9092 (E [E00092227] & [E00092228]); Near Harrat Al-Harrat Reserve, 04 iii 2021, *A. Alzahrani* 148 (MUZ).

Verbascum transjordanicum is a distinct species by its solitary flower, subsessile glands stems, simple and sparsely forked hairs outside the corolla, five stamens with two anterior glabrous near the apex and three posteriors with creamy hairs up to anthers. Recent phylogenetic research (see Chapter 3) confirms that this is a distinct species.

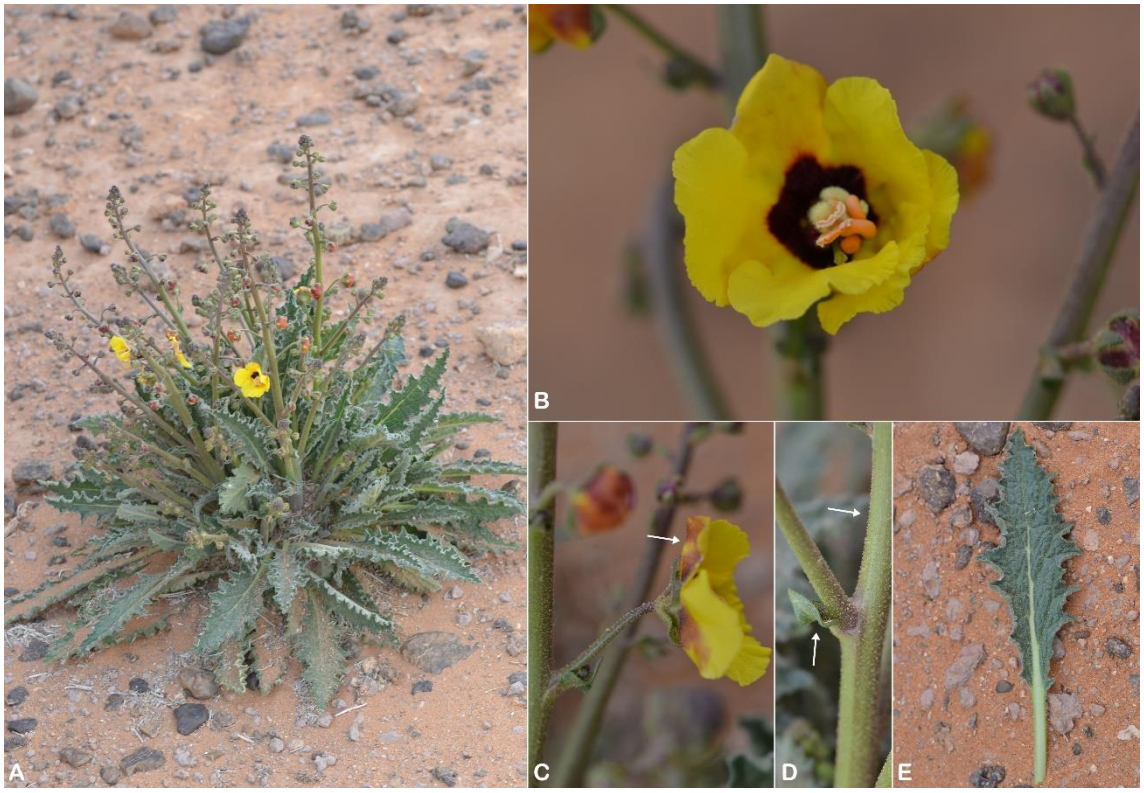

Figure 4.28. *Verbascum transjordanicum*. A, habit; B, flowers with five stamens and filaments with creamy hairs; C, spare glandular, simple, and forked hairs outside the corolla (white arrow); D, stems with subsessile glands hairs and upper bracts (white arrows); E, leaf. PHOTOS: ALI ALZAHRANI.

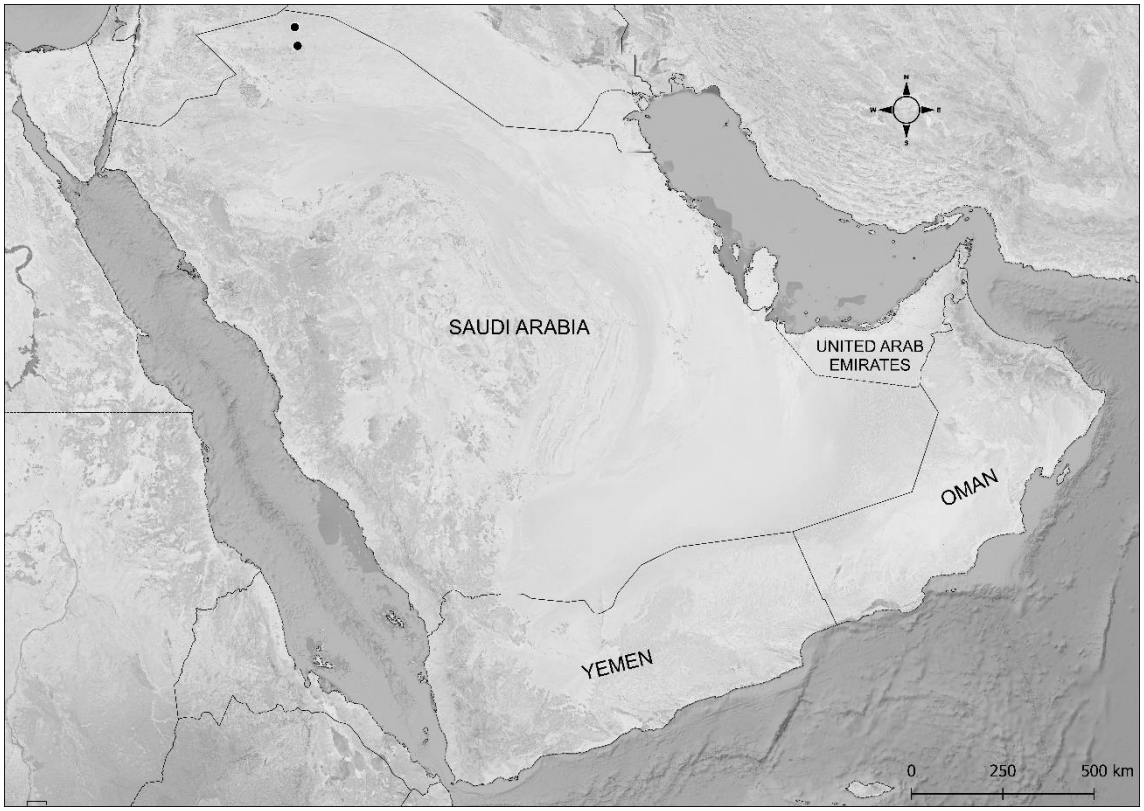

Figure 4.29. Distribution of *Verbascum transjordanicum* in the Arabian Peninsula.

16. Verbascum virgatum Stokes, Bot. Arr. Brit. Pl., ed. 2. 1: 227 (-229) (1787).

Blattaria virgata Fourr., Ann. Soc. Linn. Lyon sér. 2, xvii. (1869) 125.

Verbascum blattarioides var. *lusitanicum* Schrad. in Monogr. Verbasci 2: 45, 47 (1823).

Verbascum virgatum var. lanceolatum Mariz, in Bol. Soc. Brot. 23: 42 (1907)

Verbascum virgatum subsp. *lusitanicum* (Schrad.) Rivas Goday, in Veg. Fl. Guadiana: 752 (1964) (Figure 4.30).

Biennial herb, yellowish to reddish green, simple or branched from above, up to 1.5 m tall. *Indumentum* glabrescent or dense glandular hairs. *Stems* erect, terete. *Basal leaves* rosette, oblanceolate, 8 – 20 x 3 – 6 cm, apex acute, base cuneate or attenuate, margins crenate to dentate, lamina darkish green with glabrescent

or dense glandular hairs and sparse simple hairs; petiole 1 – 4 cm. *Cauline leaves* oblanceolate, 3 – 8 x 1 – 3 cm, apex acute, base cordate; sessile or petiole up to 1 cm. *Inflorescence* racemose forming spik; one or clusters of 2-3 flowers in the axil of bracts. *Upper bracts* triangular-ovate, 3 – 6 mm, acuminate. *Lower bracts* oblanceolate, 15 – 20 mm, acute to acuminate. *Pedicel* glabrescent or dense glandular hairs up to 3 mm long. *Bracteoles* present, ovate to oblanceolate, acuminate. *Calyx* 4 – 8 mm, lobes oblanceolate, acute or mucronate, glabrescent or dense glandular hairs. *Corolla* 20 – 25 mm across, yellow with a purple-red spot around the throat, with pellucid glands, tube up to 1 mm, sparse ciliated hairs inside, sparse or dense glandular hairs outside. *Stamens* 5, 3 – 6 mm long. *Filaments* red with purple-violet to violet-whitish hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* two anterior inserted obliquely on filaments, three posteriors with reniform anthers. *Ovary* globose, glabrescent or dense glandular hairs. *Style* up to 6 mm long, filiform, green. *Stigma* capitate. *Capsule* 6 – 9 x 5 – 8 mm, globose, glabrescent or dense glandular hairs. *Seeds* bothrospermous.

Distribution. Native to Europe and introduced elsewhere.

Distribution in the Arabian Peninsula. It is an introduced species to Oman, which is known from Dhofar (Jabal Qamar) (Figure 4.31).

Habitat and ecology. It grows in roadsides and abandoned gardens at altitudes ranging from 800 to 980 m. There are no records of associated plants.

Vernacular name. twiggy Mullein (English).

Phenology. Flowering and fruiting from June to October.

Etymology. The named is derived from twiggy, which means upright slender twigs.

Specimens examined. OMAN. **Dhofar:** Jabal Qamar, Kezat Amqat, 10 ix 2022, *L. Al-Harthy & A. Al-Hinai* 186 (OBG).

Verbascum virgatum is a recently introduced species to the Dhofar region in Oman, as observed by Al Hatmi *et al*. (in press).

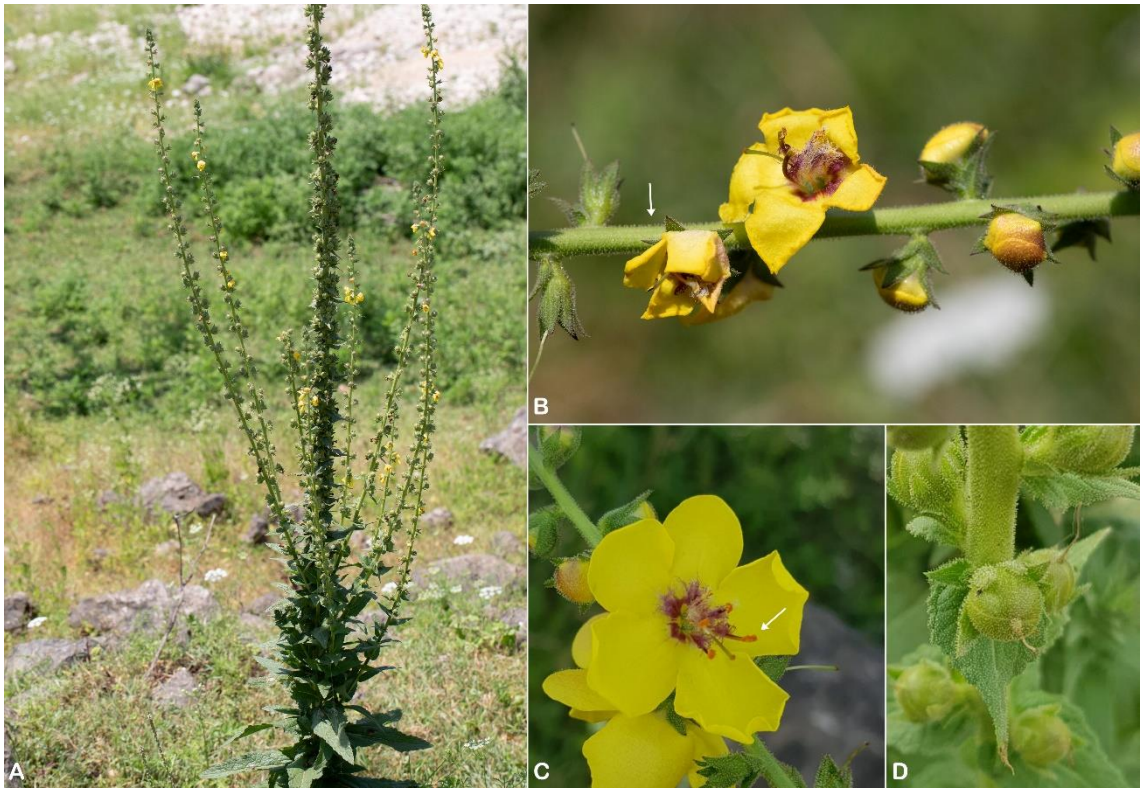

Figure 4.30. *Verbascum virgatum*. A, habit; B, stems with glandular hairs (white arrow); C, filaments with two anterior anthers inserted obliquely (white arrow); D, capsule. PHOTOS: A and B SAIF AL HATMI; C and D, AHMED JABOOB.

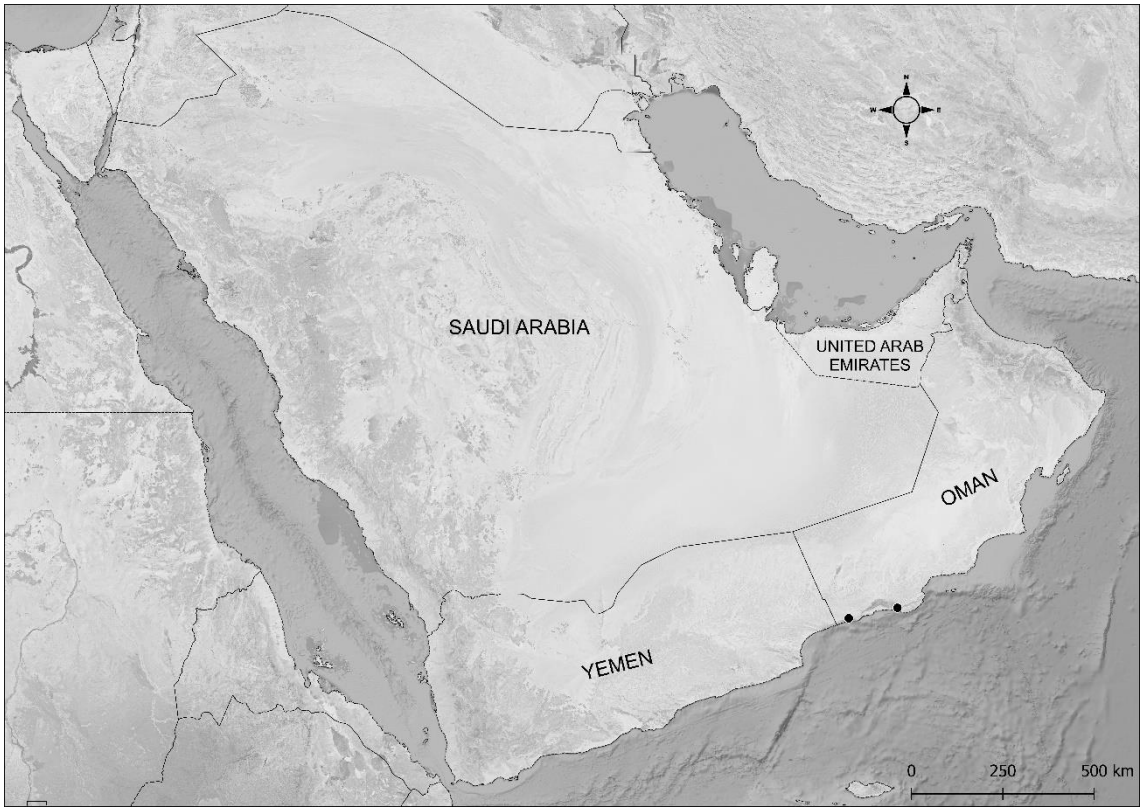

Figure 4.31. Distribution of *Verbascum virgatum* in the Arabian Peninsula.

17. Verbascum yemense Defl. Voyage Au Yemen, p.177 (1889). – Type: Yemen, Ad margines agrorum circa Raudah, 13 vi 1887, *A. Deflers* 492 (isotype MPU [MPU020119]).

Verbascum chaudharyanum Hemaid, Pakistan J. Bot. 33(4): 318 (2001), **synon. nov.** – Type: Saudi Arabia, An Nimas, Taif-Abha Road, Abha, 28 iv 1985, *I.S. Collenette* 5321 (holotype E [E00066941], isotype K).

Key to the varieties

1a. Pedicels up to 5 mm long _____ **17a. yemense**

1b. Pedicels up to 15 mm long _____ **17b. asiricum**

17a. Verbascum yemense var. **yemense** (Figure 4.32).

Perennial herb, yellowish green, simple or branched from above, up to 80 cm tall. *Indumentum* glabrescent or sparse stellate hairs above, and dense stellate hairs below. *Stems* erect, terete. *Basal leaves* rosette, oblong to oblong-lanceolate, 2 – 11 x 3 – 5 cm, apex acute, base obtuse or truncate, margins repand-crenulate, lamina yellowish green with dense stellate hairs; petiole 2 – 6 cm. *Cauline leaves* lanceolate, 1.5 – 4 x 0.5 – 1 cm, apex acute-attenuate, base cuneate; sessile or petiole up to 1 cm. *Inflorescence* racemose forming panicle; one or clusters of 2-4 flowers in the axil of bracts. *Upper bracts* linear, 5 – 7 mm, acute. *Lower bracts* linear-lanceolate, 10 - 15 mm, acute. *Pedicel* glabrescent or sparse stellate hairs up to 5 mm long. *Bracteoles* absent. *Calyx* 3 – 4 mm, lobes linear, acute, glabrescent or sparse stellate. *Corolla* 15 – 20 mm across, yellow, without pellucid glands, tube up to 1 mm, glabrous inside, sparse stellate hairs outside. *Stamens* 4-5 or 6 (unstable), 3 – 5 mm long. *Filaments* orange with yellowish hairs, two anterior glabrous near the apex, three posteriors with hairs up to anthers. *Anthers* all reniform. *Ovary* ellipsoid-ovoid, sparse stellate hairs. *Style* up to 6 mm long, filiform, green. *Stigma* spatulate. *Capsule* 3 – 4 x 1 – 3 mm, ellipsoid-ovoid, sparse stellate hairs. *Seeds* bothrospermous.

Distribution in the Arabian Peninsula. It is an endemic species to the Arabian Peninsula, which is known from Yemen in Sana'a (Shibam, Jabal An Nabi Shu’ayb, between Sana'a and Walan, Dhamar Road, Beit El-Ghofr, and North Haz), Hajjah (Jabal Jabar), Ibb (Yarim), and Amran (south of Khamr), and from Saudi Arabia in Abha (near Al-Jarrah National Park, north of Alaya, Al-Namas, Tanomah, between Tatlith and Khamis Mushayt, Najran Road, Al-Soudah Road, Al-Soudah, Jabal Mna'a, and King Faisal Road between Bani Amr and Al-

Namas), Taif (near Bani Saad, Wadi Thi Ghazal, and Ash Shafa), and Jizan (Jabal Al-Aswad), southwestern the Arabian Peninsula (Figure 4.33).

Habitat and ecology. It grows on roadsides and abandoned gardens at altitudes ranging from 1800 to 2500 m. Associated plants include *Felicia abyssinica* var. *schimperi* (Steud. & Hochst. ex Jaub. & Spach) Mesfin, *Plantago lanceolata* L., *Erica arborea* L., *Maesa lanceolata* Forssk., *Vachellia origena* (Hunde) Kyal. & Boatwr., *Anthemis yemensis* Podlech, and *Lavandula citriodora* A.G.Mill.

Global IUCN threat status. Least Concern. LC. (see Chapter 5).

Phenology. Flowering and fruiting from March to November.

Etymology. The named is derived from its occurrence in Yemen.

Specimens examined. YEMEN. **Sana'a:** Shibam, 01 vi 1977, *J.R.I Wood* 1669 (K, BM); Haddah, 07 xi 1975, *F.N. Hepper* 6299 (K); Jabal An Nabi Shu’ayb, 20 ix 1978, *A.G. Miller* 143 (K, E [E00066954]); Roadside at Kilo 22 between Sana'a and Walan, 14 xii 1977, *J.R.I Wood* 2158 (K, BM); Roadside at Sana'a to Dhamar Road, 10 x 1974, *J.M. Ritchie* 62 (E [E00066953]); Jabal An Nabi Shu’ayb, near Yazil, 07 xii 1979, *J.R.I Wood* 3097 (E [E00066956]); Beit El-Ghofr, North Haz, 04 ii 1938, *H. Scott* & *E.B. Britton* 494 (BM). **Hajjah:** Jabal Jabar, 06 vi 1946, *W. Thesiger* s.n. (BM). **Ibb:** Yarim, 27 ix 1972, *J.R.I Wood* 35 (BM). **Amran:** 1 mile south of Khamr, 27 viii 1975, *J.R.I Wood* 75/600 (BM). SAUDI ARABIA. **Abha:** An Nimas, Taif-Abha Road, Abha, 28 iv 1985, *I.S. Collenette* 5321 (K, E [E00066941]); 40-42 km S of Abha, near Al-Jarrah National Park and Tamniah village, 24 v 1980, *L. Boulos* & *A.S. Ads* 14259 (K); Talha Camp, old mine at Arjh,

02 iv 1974, *I.S. Collenette* 231 (K); Asir Mts. just below summit of ridge, 1972, *I.S. Collenette* 184 (K); 18 km north of Alaya, 23 iv 1990, *I.S. Collenette* 7462 (K, E [E00066961]); 10 miles east of Hamdah camp, between Tatlith and Khamis Mushayt, 25 iii 1977, *I.S. Collenette* 53 (K); Al-Namas, 28 iv 1985, *I.S. Collenette* 5321 (K, E [E00066941]); Tanomah, 13 iv 1979, *I.S. Collenette* 1348 (K); 15 miles east of Hamdah camp, between Tatlith and Khamis Mushayt, 25 iii 1977, *I.S. Collenette* 71 (K); 70 km, S.E. of Abha, on road to Najran, 14 iii 1980, *J.J. Lavranos* & *I.S. Collenette* 18341 (E [E00066937]); 15 km N of Abha, 21 iv 1984, *I.S. Collenette* 4915 (E [E00066938]); Asir above Dhahran, 12 v 1946, *W. Thesiger* s.n. (BM); Soda, 10 viii 1952, *J.D. Tothill* 147 (BM); Al-Soudah Road, Al-Soudah, 20 iii 2021, *A. Alzahrani* 177 (MUZ); Jabal Mna'a, Tanomah, 20 iii 2021, *A. Alzahrani* 179 (MUZ); King Faisal Road between Bani Amr and Al-Namas, 15 iii 2021, *A. Alzahrani* 172 (MUZ).**Taif:** Near Ash Shafa, Wadi Thi Ghazal, 20 iii 1991, *I.S. Collenette* 7716 (K, E [E00090893]); Near Bani Saad, 11 iii 2021, *A. Alzahrani* 161 (MUZ); Wadi Thi Ghazal, Ash Shafa, 10 iii 2021, *A. Alzahrani* 156 (MUZ). **Jizan:** Jabal Al-Aswad, 13 ii 2021, *A. Alzahrani* 145 (MUZ).

Verbascum yemense is a variable species found in southwestern the Arabian Peninsula. Due to its variation, Al-Hemaid (2001) described *V. asiricum* and *V. chaudharyanum* from the same region. However, recent phylogenetic research (see Chapter 3) indicates that they are similar species. In addition to a study of the type specimens of *V. chaudharyanum* and *V. asiricum* and its comparison with *V. yemense*, as well as a thorough examination of the important morphological characteristics of their type specimens, it is proposed here that *V. chaudharyanum* is a synonym to *V. yemense* and *V. asiricum* is a variety of *V.*

yemense as they species have a glabrescent or sparse stellate hairs above, and dense stellate hairs below, racemose forming panicle inflorescence, one or clusters of 2-4 flowers, filaments hairs yellowish, and capsule ellipsoid-ovoid with sparse stellate hairs.

17b. Verbascum yemense var. **asiricum** (Hemaid) A.Alzahrani, **stat. nov.** – *Verbascum asiricum* Hemaid, Pakistan J. Bot. 33(4): 316 (2001). – Type: Saudi Arabia, 70 km, S.E. of Abha, Abha, 14 iii 1980, *I.S. Collenette* 2091 (holotype K) (Figure 4.32).

Pedicel: up to 15 mm long.

Distribution in the Arabian Peninsula. It is an endemic variety to Saudi Arabia, which is known from Abha (Dalagan areas, near Souk Al-Ithnayn, and near Tamniah village), southwestern Saudi Arabia (Figure 4.33).

Global IUCN threat status. Endangered. EN. (see Chapter 5).

Etymology. The named is derived from Asir, the local Arabic name of Asir mountains in Saudi Arabia.

Specimens examined. SAUDI ARABIA. **Abha:** Wadi Dalagan, 27 iii 1980, *A. Nader* 237 (K); 7 km SE Abha, 14 iii 1980, *A. Nader* 214 (K); Dalagan road, 12 km SE of Abha, 15 iv 1995, *I.S. Collenette* 9347 (K, E [E00095077]); 70 km, S.E. of Abha, 14 iii 1980, *I.S. Collenette* 2091 (K); Near Souk Al-Ithnayn, head of wadi Al-Soudah, 50 km S of Abha, 21 viii 1983, *I.S. Collenette* 4478 (E [E00066944]); Dalagan national park, 30 km SE of Abha, 06 iii 1981, *D. Hilesat* 118 (BM);

Dalagan national park, 30 km SE of Abha, 01 iii 1981, *D. Hilesat* 59 (BM); Near Tamniah village, 19 iii 2021, *A. Alzahrani* 175 (MUZ).

This variety can be distinguished from var. *yemense* by its long pedicels which is up to 15 mm long, and its distribution in Dalagan areas, near Souk Al-Ithnayn, and near Tamniah village in Abha province, southwestern Saudi Arabia.

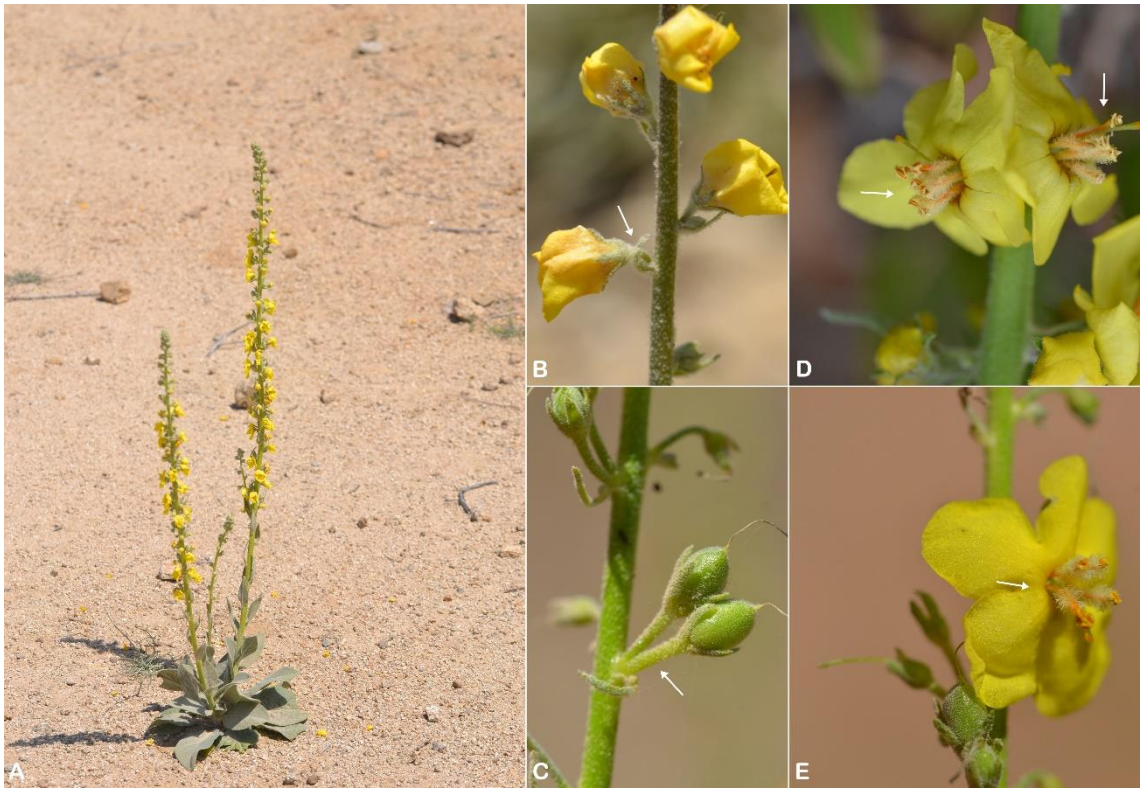

Figure 4.32. *Verbascum yemense* var. *yemense*. A, habit; B, short pedicel; D, flowers with five and six stamens (white arrows). *V. yemense* var. *asiricum*. C, long pedicel; E, flowers with five stamens (white arrow). PHOTOS: ALI ALZAHRANI.

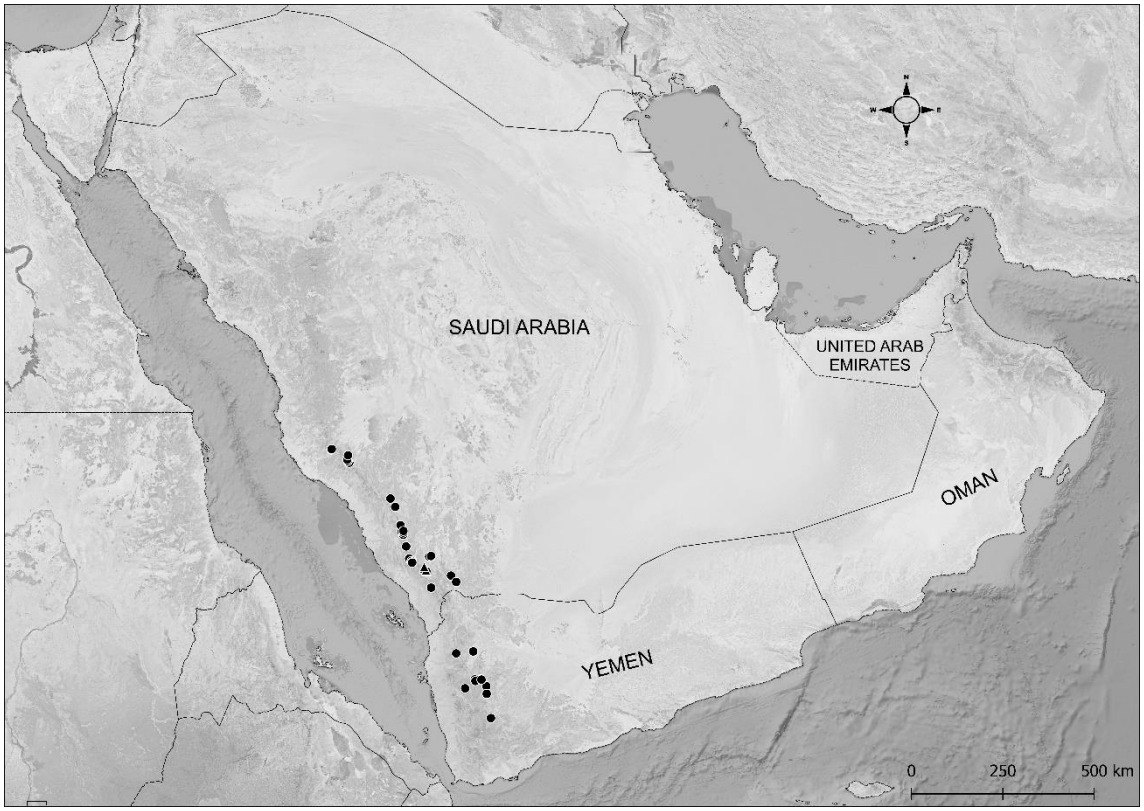

Figure 4.33. Distribution of *Verbascum yemense* var. *yemense* (black circles) and *V. yemense* var. *asiricum* (black triangles) in the Arabian Peninsula.

CHAPTER 5. RED LIST ASSESSMENT OF THE GENUS *VERBASCUM* IN THE ARABIAN PENINSULA

The work presented in this chapter is in preparation for submission.

Alzahrani, A.M., Magos Brehm, J., and Maxted, N. (in prep) Red List assessment of the genus *Verbascum* in the Arabian Peninsula.

Author contribution:

Conceived and designed the study: A.M.A., J.M.B., N.M.

Data collation and preparation: A.M.A.

Performed analysis: A.M.A.

Interpreted results: A.M.A., J.M.B., N.M.

Wrote the paper: A.M.A.

Critically reviewed the paper: A.M.A., J.M.B., N.M.

5.1 Abstract

The aims of this study were to determine the geographical range and habitats of the *Verbascum* species in the Arabian Peninsula and to assess their conservation status at national, regional and global levels by using the International Union for Conservation of Nature (IUCN) Red List categories and criteria. *Verbascum* is represented by 16 species with 4 varieties in the area of the study, and most of these species are endemic to Saudi Arabia, Yemen, Oman and the United Arab Emirates (UAE). This study is based on an ecogeographic survey, which was conducted using herbaria collections, literature sources and fieldwork. The findings showed that the genus is distributed in three main regions in the Arabian Peninsula, which include northern Saudi Arabia, the Asir and Yemen highlands and the Hajar mountains in Oman and the UAE. In addition, most species of *Verbascum* in the region are at high risk of extinction. Eight taxa are threatened, four of which are assessed as critically endangered and four as endangered. Furthermore, five species are assessed as near threatened, while five species are assessed as of least concern. Threats to the *Verbascum* species in the region are overgrazing, suburban and agricultural expansion, climate change, invasive species, recreational activities, tourism and war and civil unrest, and human intrusion and disturbances. Some important strategies for conserving and managing *Verbascum* species on the Arabian Peninsula are recommended here.

Keywords *Verbascum*, ecogeographic survey, IUCN Red List, Arabian Peninsula.

5.2 Introduction

The Arabian Peninsula is a large region, about 2,590,000 km^2, with a unique location between Africa and Asia. It is bordered by the Red Sea to the west, the Indian Ocean to the southeast and the Arabian Gulf and the Gulf of Oman to the northeast. This region contains a unique assemblage of species diversity that is mainly derived from the historical changes in its geology and climate (Ghazanfar and Fisher, 1998; Portik and Papenfuss, 2015). Therefore, the position of the Arabian Peninsula gives a unique character to its vegetation, which is dominated by species of various historical origins represented in three main phytogeographical zones: the Saharo-Sindian regional zone, the Somalia-Masai regional centre of endemism and the Afromontane archipelago-like regional centre of endemism (Ghazanfar and Fisher, 1998).

The Arabian Peninsula contains about 3,418 plant species belonging to 144 families, of which over 600 species are endemic to Yemen, Oman and Saudi Arabia (Al Farhan *et al*., 2008). However, this richness and diversity of plant species faces physical and biological threats, such as desertification, habitat loss as a result of long-term climatic changes, urban and agricultural expansion and uncontrolled grazing, leading to further decline or loss of populations and plant species diversity (Miller and Cope, 1996; Collenette, 1998; Ghazanfar and Fisher, 1998; Brown and Mies, 2012). The Arabian Peninsula has 228 protected areas, which cover 18.07% of Saudi Arabia, 1.24% of Yemen, 4.29% of Oman, 30.83% of the UAE, 18.07% of Qatar, 18.46% of Kuwait and 34.09% of Bahrain (UNEP-WCMC and IUCN 2023).

Since a complete Red List for the Arabian Peninsula has not yet been compiled, lists for individual nations, such as Oman (Patzelt, 2015a) and Yemen (Miller and Al-Khulaidi [unpublished]), have been produced (Hall and Miller, 2011). In Saudi Arabia, the first list of threatened species was compiled by Collenette in her *Checklist of Botanical Species in Saudi Arabia* (1998), and most species are classified as endangered. However, in making her assessments, Collenette did not use the IUCN Red List Categories and Criteria (IUCN, 2012) for assessing the species, and her assessments were mostly based on her subjective but extensive field observations of over 20 years in this region.

Verbascum L. belongs to the *Scrophulariaceae* family, which contains approximately 360 species worldwide (Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017). Turkey and Iran are the main geographic centres for *Verbascum* species, with 243 and 44 species, respectively (Murbeck, 1933, 1939; Huber-Morath, 1978; Sharifnia, 2007; Ranjbar and Nouri, 2015; Sotoodeh, 2015). Despite the large number of *Verbascum* species, according to the IUCN Red List of threatened species databases (IUCN, 2022), only eight species have been assessed, and the majority remain unknown.

Within the Arabian Peninsula, *Verbascum* species are found in Saudi Arabia, Yemen, Oman and the UAE and comprise 16 species, most of which are endemic. In recent years, new species of the genus *Verbascum* have been described and recorded in Saudi Arabia (Al-Hemaid, 2001; Alzahrani *et al*., 2022; see Chapter 4), and these species are likely to be threatened by extinction due to their restricted geographical distribution; each new species is only known from a single or a few localities. Only two species were previously assessed, and both

were from Oman. These species are *V. akdarense* (Murb.) Hub.-Mor. (assessed as near threatened) and *V. omanense* Hub.-Mor. (assessed as data deficient) using the IUCN Red List Categories and Criteria (Patzelt, 2015a). Although the number of endemic species is high in the region, their ecogeographic distribution and current conservation status are mostly unknown due to a lack of information. Therefore, the aims of this study were to ascertain the ecogeographic extent of *Verbascum* species on the Arabian Peninsula and to assess their threat status at national, regional and global levels using the IUCN Red List Categories and Criteria (2012).

5.3 Materials and methods

5.3.1 Ecogeographic survey

Following the methodology proposed by Maxted *et al*. (1995) and Castañeda *et al*. (2011), we conducted an ecogeographic survey of the *Verbascum* species in the Arabian Peninsula (Table 5.1). A range of data was included in this survey, such as taxonomic information, distribution, population, habitat, ecology, threats and conservation actions. For each species, data were gathered from a number of sources. One is existing herbarium specimens deposited at major international, regional and digital herbaria: BM, E, K, KSU, MUZ, OBG, ON, RIY and the JSTOR Global Plants platform (Thiers, continuously updated). Literature references were included to verify the data and provide additional information on the genus *Verbascum* in the Arabian Peninsula in the major floras (Wood, 1997; Collenette, 1999; Chaudhary, 2001; Jongbloed *et al*., 2003; Ghazanfar, 2015), inventories (Ghazanfar, 1992; Collenette, 1998; Al-Khulaidi, 2013) and revision works (Murbeck, 1925, 1933, 1939; Huber-Morath, 1984; Al-Hemaid, 2001; Alzahrani

et al., see Chapter 4). Geographic databases were used from the Global Biodiversity Information Facility (GBIF), and local experts in the Arabian Peninsula were consulted to verify certain distribution data, especially from Yemen.

Due to incorrect details, unclear passport information, duplicated data and insufficient materials, some information and specimens were excluded. Additionally, this survey gathered data to outline the timetable and routes for later field studies.

Table 5.1 List of *Verbascum* species in the Arabian Peninsula.

Species	**Distribution**
V. akdarense (Murb.) Huber-Morath	Endemic to Oman
V. bottae (Defl.) Huber-Morath	Endemic to Yemen
V. decaisneanum O. Kuntze	Native to Saudi Arabia, Lebanon, Jordan, Syria, Palestine and Egypt (Sinai)
V. deserticola (Murb.) Huber-Morath	Endemic to Saudi Arabia
var. *deserticola*	
var. *sheilae* (Hemaid) A.Alzahrani	
V. eremobium Murb.	Native to Saudi Arabia, Lebanon, Jordan, Syria, Palestine and Egypt (Sinai)
V. longibracteatum Defl.	Endemic to Saudi Arabia and Yemen
V. medinecum Hemaid	Endemic to Saudi Arabia
V. melhanense (Murb.) Huber-Morath	Endemic to Saudi Arabia and Yemen
V. omanense Huber-Morath	Endemic to Oman and UAE
V. sarawaticum A.Alzahrani	Endemic to Saudi Arabia
V. saudiarabicum (A.Alzahrani) A.Alzahrani	Endemic to Saudi Arabia
V. schimperianum Boiss.	Native to Saudi Arabia, Jordan, Palestine and Egypt (Sinai)
V. shiqricum Hemaid	Endemic to Saudi Arabia
V. sinaiticum Benth.*	Native to Saudi Arabia, and introduced to Yemen
V. transjordanicum Murb.	Native to Saudi Arabia and Jordan
V. yemense Defl.	Endemic to Saudi Arabia and Yemen
var. *yemense*	Saudi Arabia and Yemen

var. *asiricum* (Hemaid) A.Alzahrani Saudi Arabia

* Observation records of *V. sinaiticum* in Yemen have been excluded from assessments due to its distribution status as introduced species.

5.3.2 Fieldwork

Extensive fieldwork was conducted during the years 2019, 2020 and 2021 in Saudi Arabia and Oman. Throughout the fieldwork, data on distribution and habitat, associated plants, coordinates (GPS), elevation, threat factors, number of mature individuals and population sizes were gathered for each species. Where possible, specimens and seeds were collected for identification and *ex situ* conservation.

5.3.3 Red List assessment

Conservation assessments were carried out according to the IUCN Red List Categories and Criteria (IUCN 2012), and the extent of occurrence (EOO) and area of occupancy (AOO) were calculated using the Geospatial Conservation Assessment Tool (GeoCAT) with a grid size of 2 km^2 (Bachman *et al*. 2011). The distribution maps were generated using QGIS software version 3.22 (2022).

5.4 Results and Discussion

5.4.1 Threat assessment

In this study, a total of 291 records from herbaria, genebanks and fieldwork for 18 taxa from the Arabian Peninsula and their passport data were examined and analysed (Table 5.2). These data were gathered and arranged into an ecogeographic conspectus as a summary of taxonomic information, distribution and threats status (Table 5.3). Sixteen species of Arabian *Verbascum* were assessed using the IUCN Red List Categories and Criteria (IUCN, 2012), of which

11 (69%) are endemic, 3 (19%) are rare nonendemic, and the remaining 2 (12%) are widespread regionally and globally. The threat status of each of these species was assessed in the following sections.

Table 5.2. Number of records for each *Verbascum* taxon from herbaria, genebanks and fieldwork were used in this study.

***Verbascum* taxon**	**Herbarium specimens**	**Genebank accessions**	**Fieldwork records**	**Total**
V. akdarense	14	1	7	22
V. bottae	20			20
V. decaisneanum	3			3
V. deserticola var. *deserticola*	7		2	9
V. deserticola var. *sheilae*	6		8	14
V. eremobium	4		4	8
V. longibracteatum	21		25	46
V. medinecum	7		6	13
V. melhanense	20		23	43
V. omanense	18	1	2	21
V. sarawaticum	3		4	7
V. saudiarabicum	3			3
V. schimperianum	1		2	3
V. shiqricum	6		5	11
V. sinaiticum	7		14	21
V. transjordanicum	1		1	2
V. yemense var. *yemense*	25		13	38
V. yemense var. *asiricum*	6		1	7
Total	172	2	117	291

Verbascum akdarense (Murb.) Huber-Morath

Verbascum akdarense is an endemic species that is widely distributed in the Hajar foothills and mountains northeast of Oman (Figure 5.1). The species was assessed as near threatened (Patzelt, 2015a) due to neither a continuing decline nor threats. Nevertheless, with the new information on its geographic distribution, the species is found near or within protected areas, namely in al-Sareen Nature

Reserve, al-Rustaq Wildlife Reserve, al-Jabal al-Akhdar Scenic Reserve and Western Hajer Stars and Lights Reserve. In addition, its EOO is 14,265 km^2, its AOO is 84 km^2 and it has more than 10 locations. Thus, it is assessed as least concern due to its widespread distribution is not currently experiencing any major threats and no significant future threats have been identified (Table 5.3; Appendix 5.1).

Verbascum bottae (Defl.) Huber-Morath

V. bottae is an endemic species that is widely distributed from the southwestern to southern regions of Yemen, and it is found in close proximity to and within the Haraz Wildlife Sanctuary (Figure 5.1). In addition, its EOO is 20,406 km^2, its AOO is 72 km^2 and it has more than 10 locations. However, its habitat might decline due to human intrusion and disturbances caused by war and civil unrest. Thus, it is assessed as near threatened (Table 5.3; Appendix 5.2).

Verbascum decaisneanum O. Kuntze

This species is found in Saudi Arabia, Lebanon, Jordan, Syria, Palestine and Egypt (Sinai). In Saudi Arabia, the species is known from two locations in the northwest within protected areas, which are Jabal al-Lawz Reserve and Jabal Dabbagh Nature Reserve (Figure 5.1). Despite the distribution of its range within protected areas, its habitat in Jabal Al-Lawz is under threat caused by suburban expansion and by tourism and recreation, also its other location in Jabal Dabbagh is also threaten by tourism and recreation. In addition, its EOO is 93 km^2, its AOO is 12 km^2 and it has less than 5 locations. Thus, it is assessed as endangered (Table 5.3; Appendix 5.3).

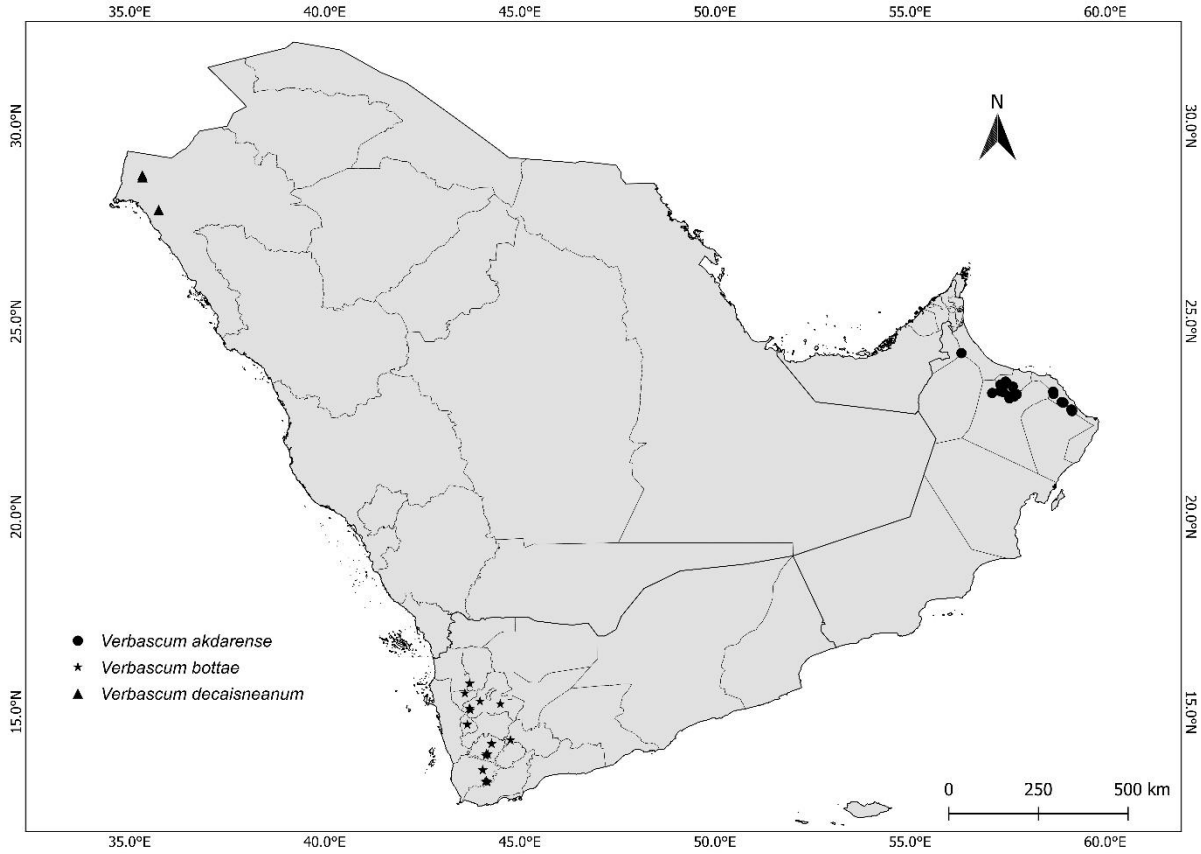

Figure 5.1. Distribution map of *V. akdarense*, *V. bottae*, and *V. decaisneanum* in the Arabian Peninsula.

Verbascum deserticola (Murb.) Huber-Morath

V. deserticola is an endemic species found from northwest to western Saudi Arabia (Figure 5.2). The species has two varieties that were recognised by Alzahrani *et al*. (see Chapter 4), namely var. *deserticola* and var. *sheilae*. The population of var. *deserticola* is located near or within protected areas across its range of Hisma, Harrat 'Uwayrid and Jabal Radwa. In addition, its EOO is 21,906 km^2, its AOO is 36 km^2 and it has more than 10 locations. Thus, it is assessed as least concern due to its stable population and neither faces a continuous decline nor any threats (Table 5.3; Appendix 5.4).

Verbascum deserticola var. *sheilae* is an endemic variety, and it is known from one location in Wadi al-Disah in Tabuk province, northwest Saudi Arabia

(Figure 5.2). In addition, it is observed that the number of mature individuals is less than 50, and its EOO and AOO are 24 km^2. The population of this variety is continuing to decline, and its locality is under threat by agricultural expansion, vehicle tracks and use as a tourism destination and recreation area. Thus, it is assessed as critically endangered due to its continuing decline in EOO, AOO, habitat quality and area, and the number of locations and mature individuals (Table 5.3; Appendix 5.5).

Verbascum longibracteatum Defl.

It is an endemic species that is widely distributed in the southwestern Arabian Peninsula, and it is found near or within protected areas of Asir National Park and Jabal al-Qahar in Saudi Arabia (Figure 5.2). In Yemen, its habitat might decline due to human intrusion and disturbances caused by war and civil unrest. In addition, its EOO is 211,736 km^2, its AOO is 128 km^2 and it has more than 10 locations. Thus, it is assessed as near threatened (Table 5.3; Appendix 5.7).

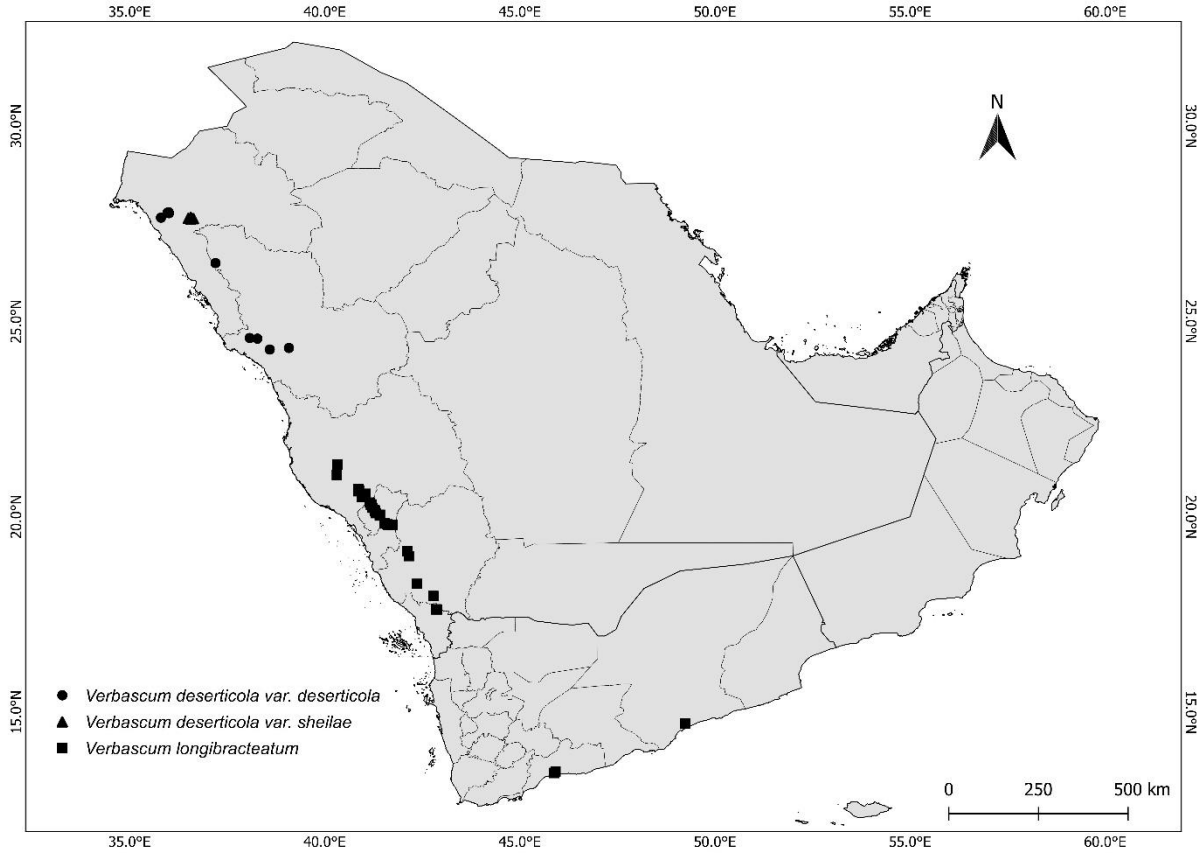

Figure 5.2. Distribution map of *V. deserticola* var. *deserticola, V. deserticola* var. *sheilae*, and *V. longibracteatum* in the Arabian Peninsula.

Verbascum eremobium Murb.

This taxon is found in Saudi Arabia, Lebanon, Jordan, Syria, Palestine and Egypt (Sinai). The species is known from several locations in northwest Saudi Arabia, and it is found near or within protected areas across its range (Hisma and Jabal al-Lawz Reserve) (Figure 5.3). Despite the distribution of its range within protected areas, the locations are under threat from habitat disturbance caused by suburban expansion and use as a tourism destination and recreation area. In addition, its EOO is 5,294 km^2, its AOO is 32 km^2 and it has less than 10 locations. Thus, it is assessed as near threatened (Table 5.3; Appendix 5.6).

Verbascum medinecum Hemaid

This species is endemic to the Hijaz mountains in western Saudi Arabia, and it is found in three locations (Jabal al-Figrah, Jabal Odks and Jabal Radwa), including the type locality (Figure 5.3). In addition, it is found throughout its range within the protected Jabal Radwa area. However, the type locality in Jabal al-Figrah is under threat by suburban and agricultural expansion, overgrazing, vehicle tracks and use as a tourism destination and recreation area, also its other location in Jabal Odks is suffering from extreme drought and overgrazing. Additionally, its EOO is 2,676 km^2, its AOO is 24 km^2 and it has less than 5 locations. Thus, it is assessed as endangered (Table 5.3; Appendix 5.8).

Verbascum melhanense (Murb.) Huber-Morath

V. melhanense is an endemic species that is widely distributed in the southwestern Arabian Peninsula, and it is found near or within protected areas across its range (Wadi Turbah, Raidah Sanctuary, Asir National Park and Ballasmar) in Saudi Arabia (Figure 5.3). In Yemen, its habitat might decline due to human intrusion and disturbances caused by war and civil unrest. In addition, its EOO is 28,882 km^2, its AOO is 92 km^2 and it has more than 10 locations. Thus, it is assessed as near threatened (Table 5.3; Appendix 5.9).

Verbascum omanense Huber-Morath

The species was categorised as data deficient (Patzelt, 2015a) due to its taxonomic status and lack of geographic distribution information. Recent taxonomic revision and phylogenetic studies (Alzahrani *et al*., see Chapter 3) confirmed the taxonomic status of this species, which is a distinct species among the Arabian *Verbascum*. *V. omanense* is an endemic species that is widely distributed in the Hajar foothills and mountains northeast of Oman and the UAE,

and it occurs near or within protected areas across its range of al-Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve, al-Jabal al-Akhdar Scenic Reserve and Hatta Mountain Reserve (Figure 5.3). In addition, its EOO is 19,039 km^2, its AOO is 80 km^2 and it has more than 10 locations. Thus, due to its widespread distribution and neither a continuing decline nor threats, it is assessed as least concern (Table 5.3; Appendix 5.10).

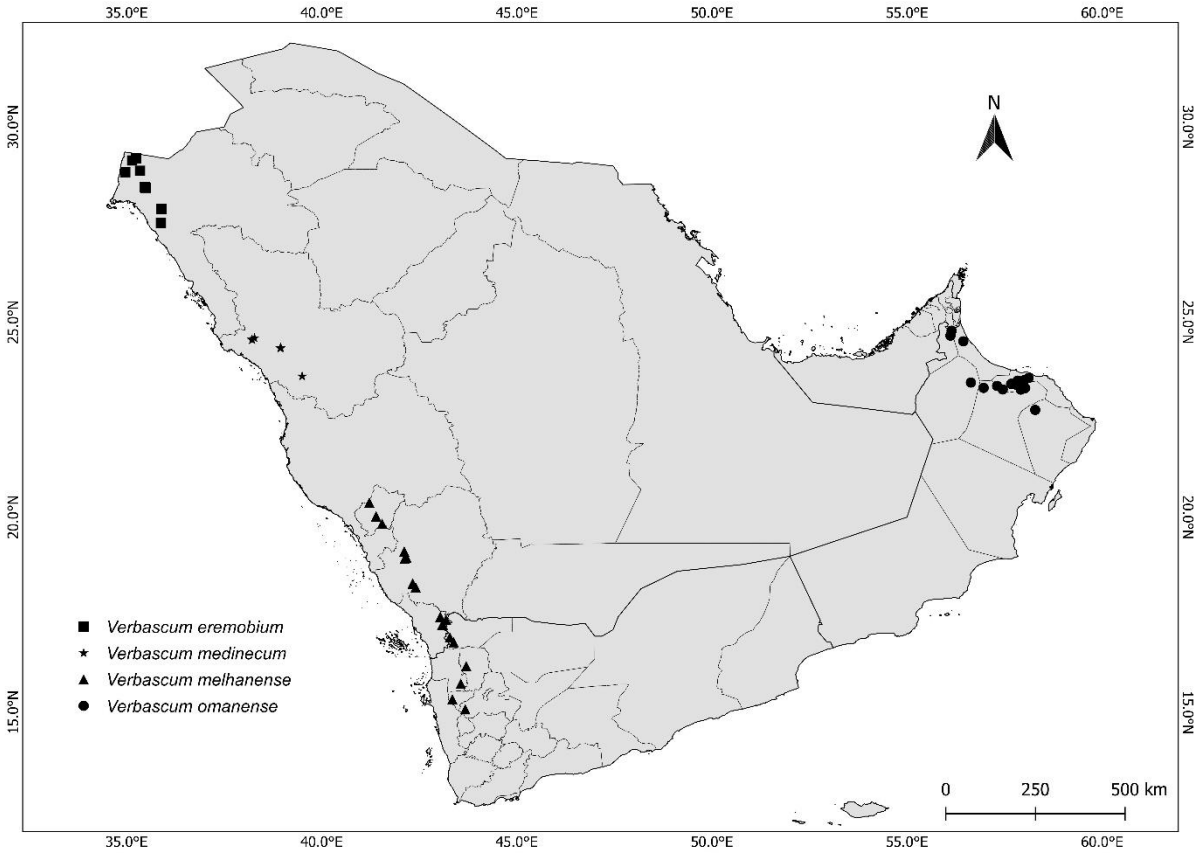

Figure 5.3. Distribution map of *V. eremobium, V. medinecum*, *V. omanense,* and *V. melhanense* in the Arabian Peninsula.

Verbascum sarawaticum A.Alzahrani

V. sarawaticum is endemic to the Sarawat mountains in southwestern Saudi Arabia, and it is found in two locations (Red Mountain Baljurashi in al-Baha and near al-Hada palm in Taif), including the type locality (Figure 5.4). However, the type locality in near Al-Hada palm is under threat caused by recreational

activities, also its other location in Red Mountain is threatened by overgrazing. In addition, its EOO is 165 km^2, its AOO is 16 km^2 and it has less than 5 locations. Thus, it is assessed as endangered (Table 5.3; Appendix 5.11).

Verbascum saudiarabicum (A.Alzahrani) A.Alzahrani

This is an endemic taxon that occurs in al-Soudah of the Asir Mountains in southwestern Saudi Arabia (Figure 5.4). Due to its locality being under threat from suburban and agricultural expansion, colonisation of invasive species and, recently, used as a tourism destination and recreation area. It is assessed as critically endangered as recommended previously by Alzahrani *et al*. (2022) (Table 5.3; Appendix 5.12).

Verbascum schimperianum Boiss.

V. schimperianum is found in Saudi Arabia, Jordan, Palestine and Egypt (Sinai). In Saudi Arabia, the species is known from one location in the northwest and is found close to protected areas across its range (Hisma and Jabal Dabbagh Nature Reserve) (Figure 5.4). This species was collected from one location, Wadi Sawawin, in 1978 by Sheila Collenette; otherwise, it has not been collected since that. Recent observations were made by locals in Ain al-Shayatei and surrounding areas near Wadi Sawawin, but no specimens were collected. However, its habitat is declining due to human intrusion and disturbances caused by recreational activities. In addition, its EOO is 51 km^2, its AOO is 12 km^2 and it has less than 5 locations. Thus, it is assessed as critically endangered (Table 5.3; Appendix 5.13).

Verbascum sinaiticum Benth.

V. sinaiticum is native to Saudi Arabia, Eritrea, Ethiopia, Kenya, Somalia, Sudan, Niger, Egypt, Iraq, Jordan, Lebanon and Syria, and it also has been introduced to other regions. In Saudi Arabia, this species is widespread in the northwest, and it occurs near or within the protected areas of Jabal Qaraqir, Harrat 'Uwayrid, Jabal al-Lawz Reserve and Hisma (Figure 5.4). Its EOO is 2,217 km^2, its AOO is 36 km^2 and it has more than 10 locations. Thus, it is assessed as least concern due to its widespread distribution in Saudi Arabia as well as neighbouring countries and faces neither a continuing decline nor threats (Table 5.3; Appendix 5.15).

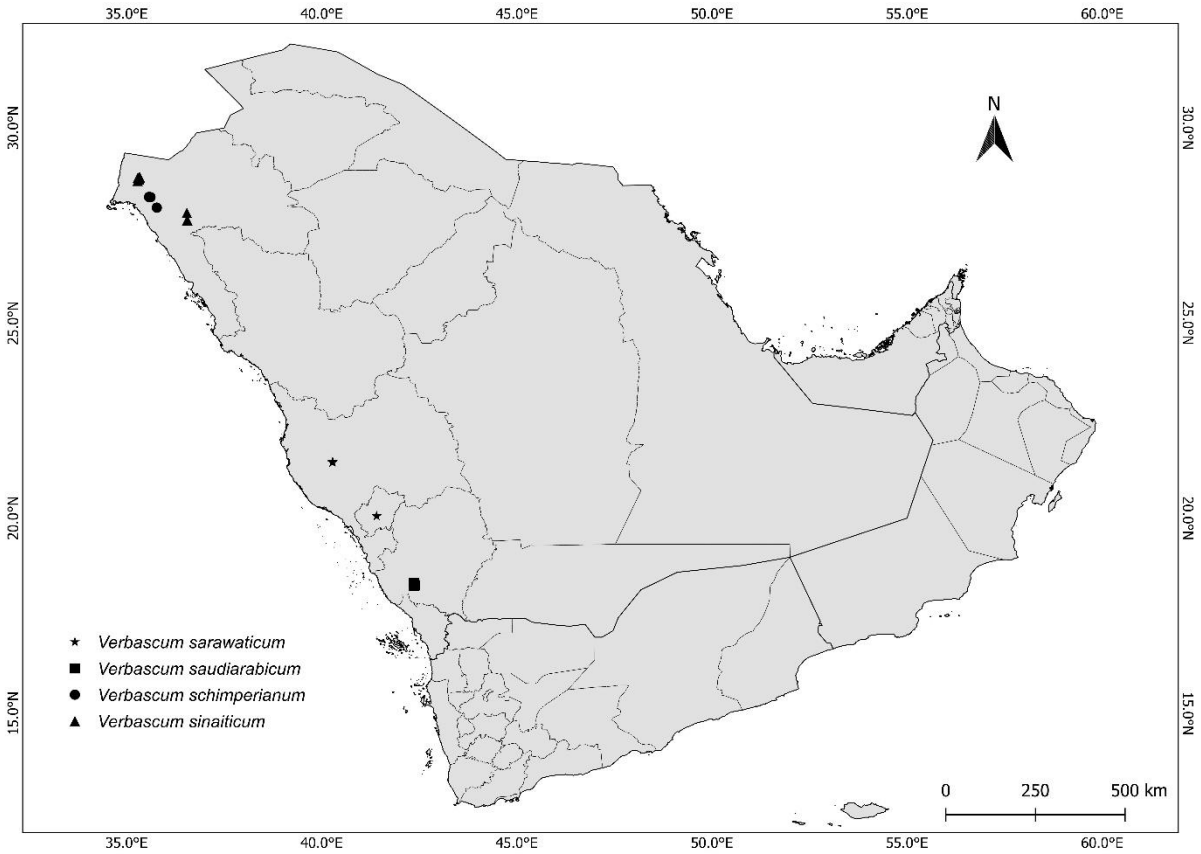

Figure 5.4. Distribution map of *V. sarawaticum, V. saudiarabicum*, *V. schimperianum,* and *V. sinaiticum* in the Arabian Peninsula.

Verbascum shiqricum Hemaid

This species is an endemic species that is widely distributed from northwest to western Saudi Arabia, and it occurs near or within the protected areas of Jabal Qaraqir, Harrat ‘Uwayrid, Hisma and Harrat Khaybar (Figure 5.5). However, most population of this species is stable, except for one subpopulation that is declining due to overgrazing across its range. In addition, its EOO is 39,174 km^2, its AOO is 40 km^2 and it has more than 10 locations. Thus, it is assessed as near threatened (Table 5.3; Appendix 5.14).

Verbascum transjordanicum Murb.

The taxon is found in Jordan and Saudi Arabia. In Saudi Arabia, this species is an exceedingly rare species, and it is known from one location in the north, in close proximity to the protected area of King Salman Bin Abdulaziz Royal Natural Reserve (Figure 5.5). However, its location faces the threat of habitat disturbance from overgrazing and vehicle tracks. In addition, it is observed that the number of mature individuals is less than 50, and its EOO and AOO are 8 km^2. Thus, it is assessed as critically endangered (Table 5.3; Appendix 5.16).

Verbascum yemense Defl.

V. yemense is an endemic species that is widely distributed in the southwestern Arabian Peninsula (Figure 5.5). The species has two varieties that were recognised by Alzahrani *et al*. (see Chapter 4), namely var. *yemense* and var. *asiricum*. The population of var. *yemense* is located near or within protected areas across its range (Jabal al-Balas, Ballasmar, Wadi Tayyah, Asir National Park, Hima Thumalah and Haraz Wildlife Sanctuary). In addition, its EOO is 63,247 km^2, its AOO is 136 km^2 and it has more than 10 locations. However, its habitat might be in decline due to human intrusion and disturbances caused by

war and civil unrest in Yemen, but its population in Saudi Arabia is stable, with neither a continuous decline nor any threats. Thus, it is assessed as least concern (Table 5.3; Appendix 5.18).

Verbascum yemense var. *asiricum* is an endemic variety to Abha province in southwestern Saudi Arabia (Figure 5.5). In addition, its EOO is 23 km^2, its AOO is 20 km^2 and it has less than 5 locations. The population of this variety is continuing to decline, and its locality is under threat by suburban and agricultural expansion and use as a tourism destination and recreation area. Thus, it is assessed as endangered (Table 5.3; Appendix 5.17).

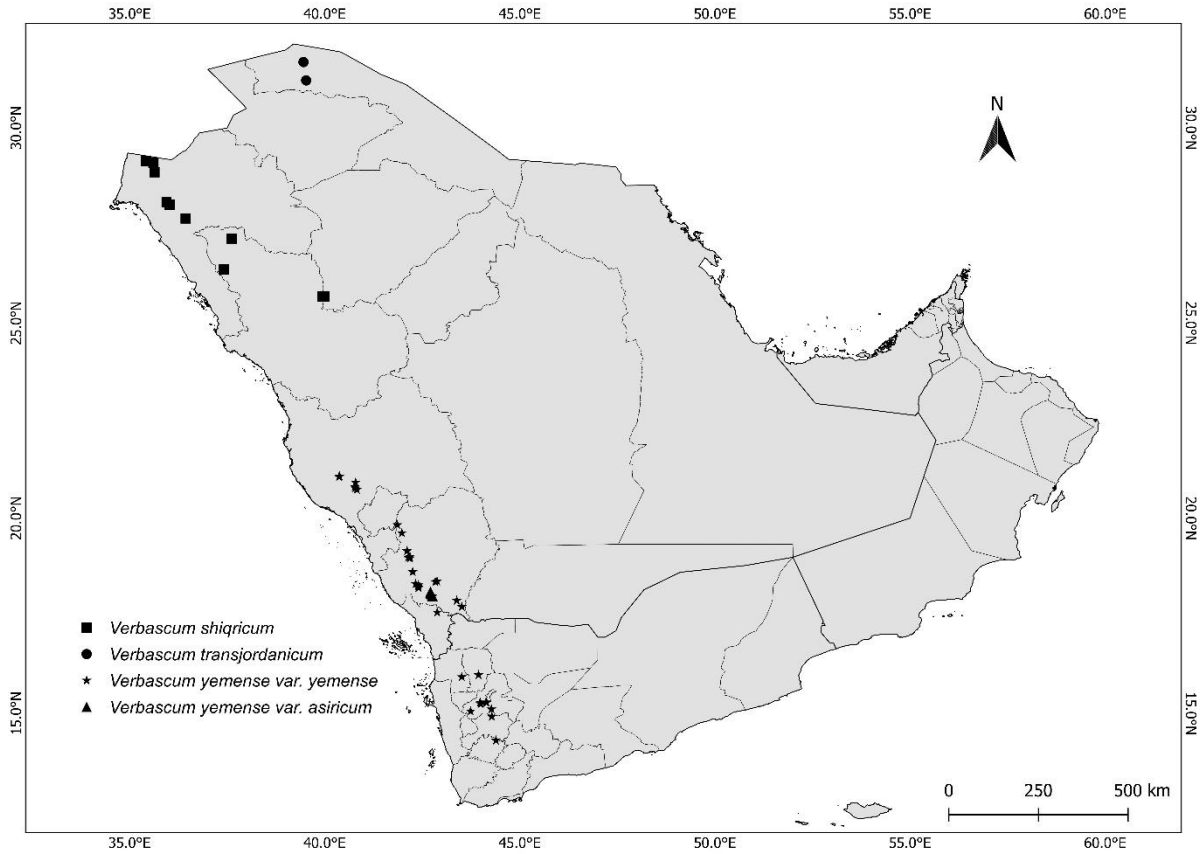

Figure 5.5. Distribution map of *V. shiqricum, V. transjordanicum*, *V. yemense* var. *yemense,* and *V. yemense* var. *asiricum* in the Arabian Peninsula.

Table 5.3. Ecogeographic conspectus of *Verbascum* species in the Arabian Peninsula.

Taxa	Distribution	EOO	AOO	No. locations	Altitude (m)	IUCN Criteria	IUCN Category
V. akdarense	Muscat, Ash Sharqiyah North, Ad Dakhiliyah, and Al Batinah South, northeast Oman	14,265	84	-	200 – 2000	-	LC
V. bottae	Ibb, Al Mahwit, Sana'a, Taizz, Al-Bayda, Hajjah, and Raymah, southwestern Yemen	20,406	72	-	1800 – 3100	B1b(iii)+2b(iii)	NT
V. decaisneanum	Tabuk, northwest Saudi Arabia	93	12	2	1500 – 1900	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv); D	EN
V. *deserticola* var. *deserticola*	Tabuk and Medina, northwest to western Saudi Arabia	21,906	36	-	400 – 1300	B2ab(iii)	LC
V. *deserticola* var. *sheilae*	Medina, western Saudi Arabia	24	24	1	400 – 1300	B1ab(i,ii,iii,iv); C2a(i); D	CR
V. eremobium	Tabuk, northwest Saudi Arabia	5,294	32	-	915 – 1420	B1b(iii)+2b(iii)	NT
V. longibracteatum	Abyan and Hadhramaut in Yemen, and Taif, Al-Baha, Abha, and Jizan in Saudi Arabia, southwestern the Arabian Peninsula.	211,736	128	-	300 – 2750	B1b(iii)+2b(iii)	NT
V. medinecum	Medina, western Saudi Arabia	2,676	24	3	1730 – 1981	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv); D	EN
V. melhanense	Saada, Amran, Al-Mahwit, Sana'a, and Hajjah in Yemen, and Al-Baha, Abha, and Jizan in Saudi Arabia, southwestern the Arabian Peninsula.	28,882	92	-	1600 – 2600	B1b(iii)+2b(iii)	NT

V. omanense	Hatta in the UAE, and Muscat, Al Batinah South, Ash Sharqiyah North, Ad Dakhiliyah, Al Buraymi, and Al Batinah North in Oman, northeast Oman and the UAE	19,039	80	-	100 – 800	-	LC
V. sarawaticum	Taif and Al-Baha, southwestern Saudi Arabia	165	16	2	1600 – 1980	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv); D	EN
V. saudiarabicum	Abha, southwestern Saudi Arabia	11	12	1	2500 – 3000	B1ab(iii)+D	CR
V. schimperianum	Tabuk, northwest Saudi Arabia	51	12	1	600 – 1280	B1ab(i,ii,iii,iv); D	CR
V. shiqricum	Tabuk and Medina, northwest to western Saudi Arabia	39,174	40	-	915 – 1680	B1b(iii)+2b(iii)	NT
V. sinaiticum	Tabuk, northwest Saudi Arabia	2,217	36	-	1500 – 2800	-	LC
V. transjordanicum	Turaif, northern Saudi Arabia	8	8	1	600 – 832	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv); D	CR
V. *yemense* var. *yemense*	Sana'a, Hajjah, Ibb, and Amran in Yemen, and Taif, Abha, and Jizan in Saudi Arabia, southwestern the Arabian Peninsula.	63,247	136	-	1800 – 2500	-	LC
V. *yemense* var. *asiricum*	Abha, southwestern Saudi Arabia	23	20	4	1800 – 2500	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv); D	EN

5.4.2 Threat analysis

Most species were assessed under criteria B, C and D, which are determined by distribution range or restricted distribution, small population size, the number of mature individuals and the number of locations. The findings showed that the *Verbascum* species of the Arabian Peninsula are at high risk of extinction with 44% of *Verbascum* taxa threatened, including 22% critically endangered, 22% endangered and a further 28% that are near threatened. In addition, 28% were assessed as least concern with a stable population and neither a continuous decline nor any threats (Figure 5.6).

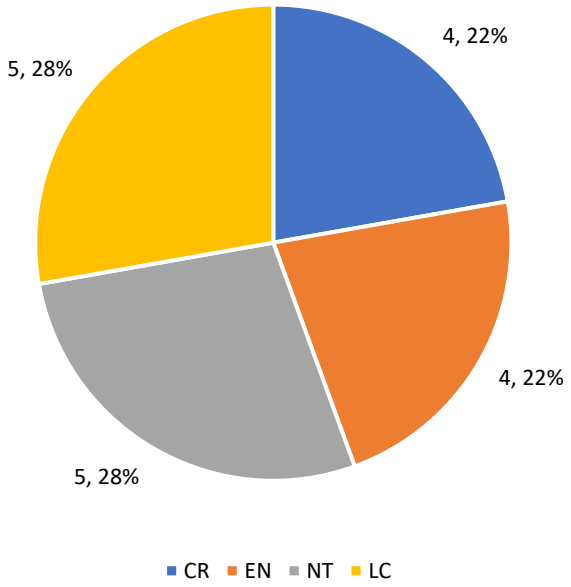

Figure 5.6. Number and percentage of Arabian *Verbascum* taxa assessed under the IUCN Red List categories.

The main threats to the *Verbascum* taxa on the Arabian Peninsula are habitat disturbance and loss resulting from overgrazing (22.2%), suburban and agricultural expansion (49.9%), climatic changes (e.g., drought) (5.5%), invasive species (5.5%), recreational activities (e.g., vehicle tracks) (27.7%), tourism and recreation areas (27.7%) and war and civil unrest caused by human intrusions and disturbances (22.2%) (Table 5.4).

Table 5.4. Threats to *Verbascum* taxa in the Arabian Peninsula.

Threats	Caused by	No. of taxa	Percentage of species
Human intrusions and disturbances	recreational Activities, such as vehicle tracks	5	27.7%
	habitats might be declining due to war and civil unrest	4	22.2%
Residential & commercial development	become tourism destination and recreation area	5	27.7%
	suburban expansion	5	27.7%
Agriculture & Aquaculture	agricultural expansion	4	25%
	overgrazing	4	25%
Climate change and severe weather	drought	1	5.5%
Invasive and other problematic species	invasive species	1	5.5%

Therefore, some recommendations that are needed for the genus *Verbascum* based on these assessments are given:

- Raising public and educational awareness to protect endangered species.
- Conducting further field surveys in search of new populations and potential threats to endangered species.
- Determining and addressing the main threats, including habitat loss and overgrazing.
- Establishing and managing conservation strategies for endangered species, particularly those in protected areas.
- Reintroducing the most endangered species to their former ranges.
- Monitoring populations of the most endangered species.

CHAPTER 6. GAP ANALYSIS AND CONSERVATION PLANNING OF *VERBASCUM* TAXA IN THE ARABIAN PENINSULA

The work presented in this chapter is in preparation for submission.

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6.1 Abstract

Verbascum species have economic value as ornamentals and in traditional medicinal uses. Sixteen species and four taxonomic varieties of *Verbascum* are recognised within the Arabian Peninsula. They are widely distributed throughout Saudi Arabia, Yemen, Oman, and the United Arab Emirates. In this study, *in situ* and *ex situ* conservation gap analyses of 18 *Verbascum* taxa found in the Arabian Peninsula were undertaken based on taxon richness and ecogeographic diversity using complementarity analysis. The results indicate that 30% of the *Verbascum* taxa population was found within protected areas (PAs), while 70% was found outside PAs. *Verbascum* taxa hotspots were identified in the northwest region of Tabuk Province and the southwest region of Asir Province in Saudi Arabia. In 8 out of 26 ELC zones, ecogeographic diversity is observable both in complementary PAs and at complementary sites. The greatest diversity of *Verbascum* taxa was observed in PAs located in ELC Zones 19 and 25. Using complementarity analysis, six complementary PAs and eight complementary sites within PAs were identified that would be conducive to active *in situ* conservation, four of which were located outside PAs, where other effective conservation measures could be implemented. Unfortunately, none of the *Verbascum* taxa from the Arabian Peninsula are presently conserved *ex situ* in international or national genebanks. Therefore, recommendations are provided in this study for active *in situ* and *ex situ* conservation methods that would aid in conserving the diversity of *Verbascum* taxa in the Arabian Peninsula.

Keywords: *Verbascum*, conservation, *in situ*, *ex situ*, complementarity analysis, gap analysis, Arabian Peninsula

6.2 Introduction

The genus *Verbascum* L. belongs to the Scrophularieae tribe of the Scrophulariaceae family (Oxelman *et al*., 2005) and includes approximately 350 species distributed across Asia, Africa, and Europe (Fischer, 2004; Heywood *et al*., 2007; Christenhusz, Fay and Chase, 2017). However, its diversity is focused in Turkey and Iran (Murbeck, 1933, 1939; Huber-Morath, 1978; Sharifnia, 2007; Ranjbar and Nouri, 2015; Sotoodeh, 2015). Several species of *Verbascum* are economically significant as ornamentals and in traditional medicinal uses (Heywood *et al*., 2007; Kell *et al*., 2007; Simpson, 2010). In the Arabian Peninsula, 16 species and 4 varieties of *Verbascum* are recognised, and they have a wide distribution range. Extending from the northern plateau to the northwest Hisma Plateau of Saudi Arabia, this range continues to the western escarpment mountains (the Midian, Hijaz, and Asir Mountains and the Yemen Highlands) and finally to the Hajar Mountains in Oman and the United Arab Emirates (UAE; see Chapters 4 and 5).

The Arabian Peninsula is considered a rich region with a high rate of unique and endemic plant diversity (Ghazanfar and Fisher, 1998). It has around 3,418 plant species, of which over 600 are endemic to the region (Al Farhan *et al*., 2008); more than 400 are crop wild relatives (Rao, 2013), and over 260 are medicinal plants (Ghazanfar, 1994). To conserve these species, strategies have been developed as part of the Arabian Peninsula's plant conservation projects, such as the IUCN Important Plant Area programme (https://www.iucn.org/), which aimed to identify plant diversity hotspots and designate *important plant areas* worthy of increased active conservation (Al-Abbasi *et al*., 2010; Hall and Miller,

2011). This programme culminated in the designation of four important plant areas: Jabal Qaraqir (Llewellyn *et al*., 2010), the Farasan Archipelago (Hall *et al*., 2010), 'Uruq Bani Ma'arid (Hall *et al*., 2011), and Jabal Aja' (Llewellyn *et al*., 2011). In total, 228 protected areas (PAs) have been established in the Arabian Peninsula (UNEP-WCMC and IUCN, 2023).

Gap analysis is an approach used to identify areas in which selected elements of biodiversity are underrepresented or poorly represented at various scales before establishing conservation action priorities *in situ* (Burley, 1988). This approach was developed to incorporate both *in situ* and *ex situ* conservation strategies for promoting genetic diversity by identifying target taxa or areas, assessing natural diversity, evaluating existing complementary *in situ* and *ex situ* conservation strategies, and revising these strategies (Maxted *et al*., 2008a). Subsequently, this method has been widely used as a tool for developing national conservation plans for crop wild relative groups (Maxted *et al*., 2007; Magos Brehm *et al*., 2008; Ng'uni *et al*., 2019; Mponya *et al*., 2021; Rahman *et al*., 2021; Zair *et al*., 2021; Nduche *et al*., 2023), medicinal plant groups (Chi *et al*., 2017; Cahyaningsih, Magos Brehm and Maxted, 2021), and individual wild genera (Maxted *et al*., 2008b; Vincent *et al*., 2012; Cires *et al*., 2013; Shehadeh, Amri and Maxted, 2013; Shankar *et al*., 2023).

We conducted gap analyses of *Verbascum* taxa in the Arabian Peninsula and provide recommendations for their *in situ* and *ex situ* conservation by determining where these taxa are richest, identifying potential sites for *in situ* *Verbascum* taxa conservation within and outside PAs, and identifying potential

areas in which *ex situ* collection is required and the conservation of *Verbascum* taxa can be recommended.

6.3 Materials and methods

6.3.1 The collection and verification of data from observational records

Observation records for the 18 *Verbascum* taxa identified in the Arabian Peninsula (see Chapter 4) were gathered from the following herbarium databases: BM, E, K, KSU, MUZ, OBG, ON, and RIY (Thiers, continuously updated); the JSTOR Global Plants platform (https://plants.jstor.org/); the Global Biodiversity Information Facility (https://www.gbif.org/); Genesys (https://www.genesys-pgr.org/); and the work of Alzahrani *et al*. (see Chapter 4 and Appendix 6.1). Observational data on these species were compiled using the FAO/Bioversity Multi-Crop Passport Descriptor template (Alercia, Diulgheroff and Mackay, 2015). Google Maps (https://www.google.com/maps) was used to georeference specimens that had location data but were missing coordinates. Duplicate records containing identical data obtained from different sources were excluded, and data on introduced populations of *Verbascum* taxa were removed. The TesTable tool of CAPFITOGEN3 was used to validate the observational records, while the GEOQUAL tool was used to evaluate their quality (Parra-Quijano *et al*., 2021). Observational records with TOTALQUAL 100 equal to or greater than 55% were used in this study.

6.3.2 Ecogeographic land characterization map

Ecogeographic land characterisation (ELC) was used to generate a generalist ELC map based on ecogeographic variables using the ELCmapas tool in CAPFITOGEN3 (Parra-Quijano *et al*., 2021), the elbow method, and a cell size

of 10 x 10 km (approximately 5 arc – minutes). To generate the generalist ELC map, 12 environmental variables (4 bioclimatic, 4 edaphic, and 4 geophysic; Appendix 6.6) were chosen using the SelecVar tool in CAPFITOGEN3 (Parra-Quijano *et al*., 2021).

6.3.3 Diversity and conservation gap analyses

The Biological Records Tool in QGIS 3.22 (2022) was used to examine the number of observational records and species richness, with a grid cell size of 0.50 degrees (approximately 55 km x 55 km). Additionally, the 'join' attribute via the location tool in QGIS 3.22 (2022) was used to identify observational records within and outside PAs. For *in situ* conservation, the Complementa tool was used at a resolution of 10 x 10 km (approximately 5 arc – minutes) in CAPFITOGEN3 (Parra-Quijano *et al*., 2021) to conduct a complementarity analysis based on the Rebelo algorithm (Rebelo, 1994) to identify the minimal number of existing PAs or grid cells in the Arabian Peninsula (UNEP-WCMC and IUCN, 2023) needed to conserve all *Verbascum* taxa, as well as the grid cells in which potential conservation sites for taxa that occur exclusively outside of PAs could be established. Supplementary methods were used to carry out a gap analysis for *in situ* and *ex situ* conservation using DIVA-GIS 7.5 software (Hijmans *et al*., 2005). These methods included prediction distributions derived from past climate data (Hijmans *et al*., 2005) and complementarity analysis based on the Rebelo algorithm (Rebelo, 1994; see Methods 6.3a in Appendix 6a). All maps originated from DIVA-GIS 7.5 and were generated using QGIS, version 3.22 (2022).

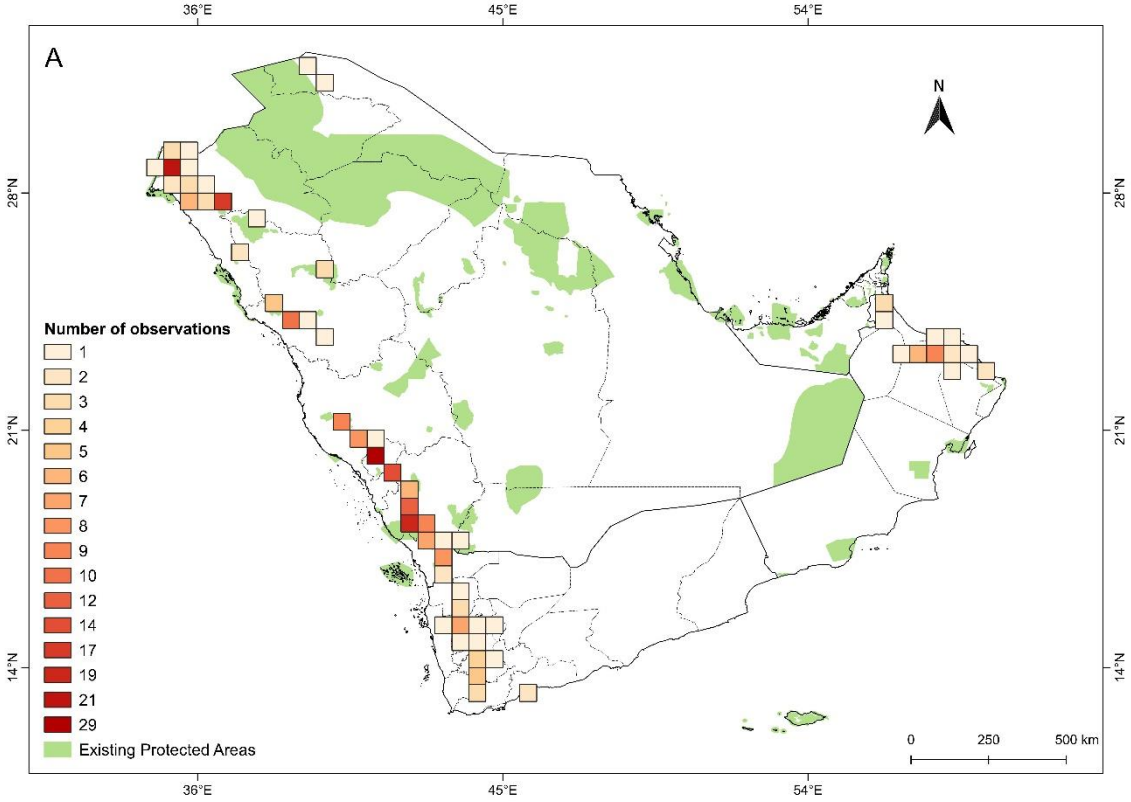
6.4 Results

6.4.1 Observations and the richness of the *Verbascum* taxa

A total of 269 observational records of the 18 *Verbascum* taxa found in the Arabian Peninsula were analysed (Figure 6.1A; Appendix 6.2). Saudi Arabia accounted for the most observational records, at 208 (77%) for 14 taxa, followed by Yemen, with 33 (12%) for 4 taxa, and Oman, with 27 (10%) for 2 taxa (Appendix 6.3). These observational records showed that 30% (82) of all observational data were recorded within PAs. The highest numbers of taxa within PAs were found in Asir National Park (4), Jabal Qaraqir (3), Jabal al-Lawz (2), Wadi Lajb/Jabal al-Qahar (2), and Jabal Uthrub/Al-Balas (2), whereas the largest populations of taxa within PAs were in Jabal al-Lawz (20), Jabal Qaraqir (17), Asir National Park (15), and Raydah (6; Appendix 6.4). Nevertheless, some taxa had fewer than five populations, including *V. schimperianum*, *V. transjordanicum*, *V. decaisneanum*, and *V. saudiarabicum*, the last two of which were found in PAs (Appendix 6.5). Additionally, some *Verbascum* taxa were not found within any PAs, including *V. bottae*, *V. omanense*, *V. sarawaticum*, *V. transjordanicum*, *V. schimperianum*, and *V. yemense var. asiricum* (Appendix 6.4). Thus, 70% of the *Verbascum* taxa population was located outside the countries' PAs.

Two areas were identified as hotspots for *Verbascum* taxa in Saudi Arabia: (i) the northwest region of Tabuk Province (four taxa), with at least some diversity occurring near and within Jabal ad-Dubbagh Reserve, and (ii) the southwest region of Asir Province (four taxa), with the most diversity occurring within Asir National Park, Wadi Tayyab, and Raydah (Figure 6.1B). Within the first hotspot region were four unique *Verbascum* taxa, namely *V. decaisneanum*, *V.*

eremobium, *V. schimperianum*, and *V. deserticola* var. *deserticola*, which are endemic to Saudi Arabia and the surrounding areas. Moreover, four endemic *Verbascum* taxa were present in the second hotspot region: *V. saudiarabicum*, *V. melhanense*, *V. longibracteatum*, and *V. yemense* var. *yemense.*



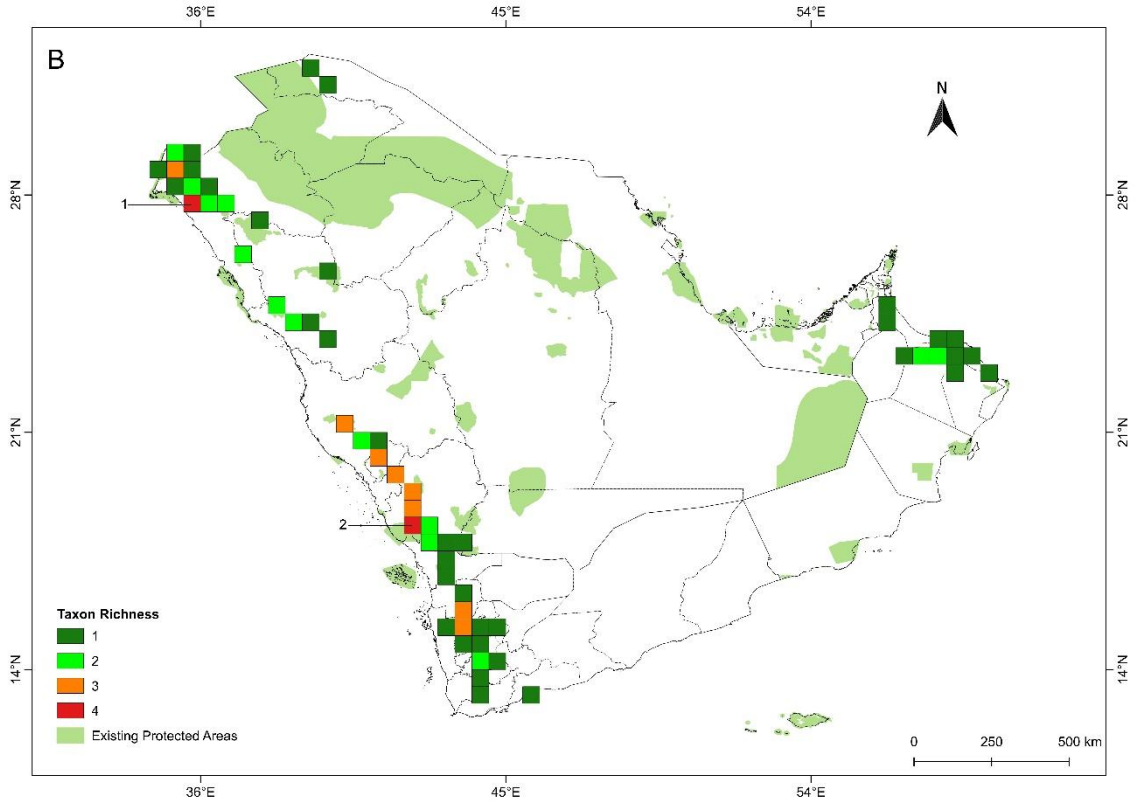


Figure 6.1. Observations and richness of *Verbascum* taxa in the Arabian Peninsula: (A) number of observational records; (B) hotspot areas with the highest number of taxa: (1) the northwest region (Tabuk Province) and (2) the southwest region (Asir Province).

6.4.2 Ecogeographic land characterization map

Using 12 environmental variables (4 bioclimatic, 4 edaphic, and 4 geophysical), 26 ELC zones were generated that showed possible adaptation scenarios for the 18 *Verbascum* taxa (Figure 6.2). In 8 ELC zones, ecogeographic diversity is present both in complementary PAs and at complementary sites (Table 6.1, 6.2). The greatest diversity of *Verbascum* taxa was observed in PAs located in ELC Zones 19 and 25, whereas the highest numbers found outside of PAs were in ELC Zones 22 and 25 (Figures 6.2, 6.3; Appendix 6.7). Additionally, *V. longibracteatum* and *V. melhanense* are the most frequent taxa of *Verbascum* throughout six ELC zones; in contrast, *V*. *decaisneanum*, *V*. *deserticola* var.

sheilae, *V*. *sarawaticum*, *V*. *saudiarabicum*, *V*. *schimperianum*, *V*. *sinaiticum*, *V*. *transjordanicum*, and *V*. *yemense* var. *asiricum* are each confined to a single ELC zone (Appendix 6.8).

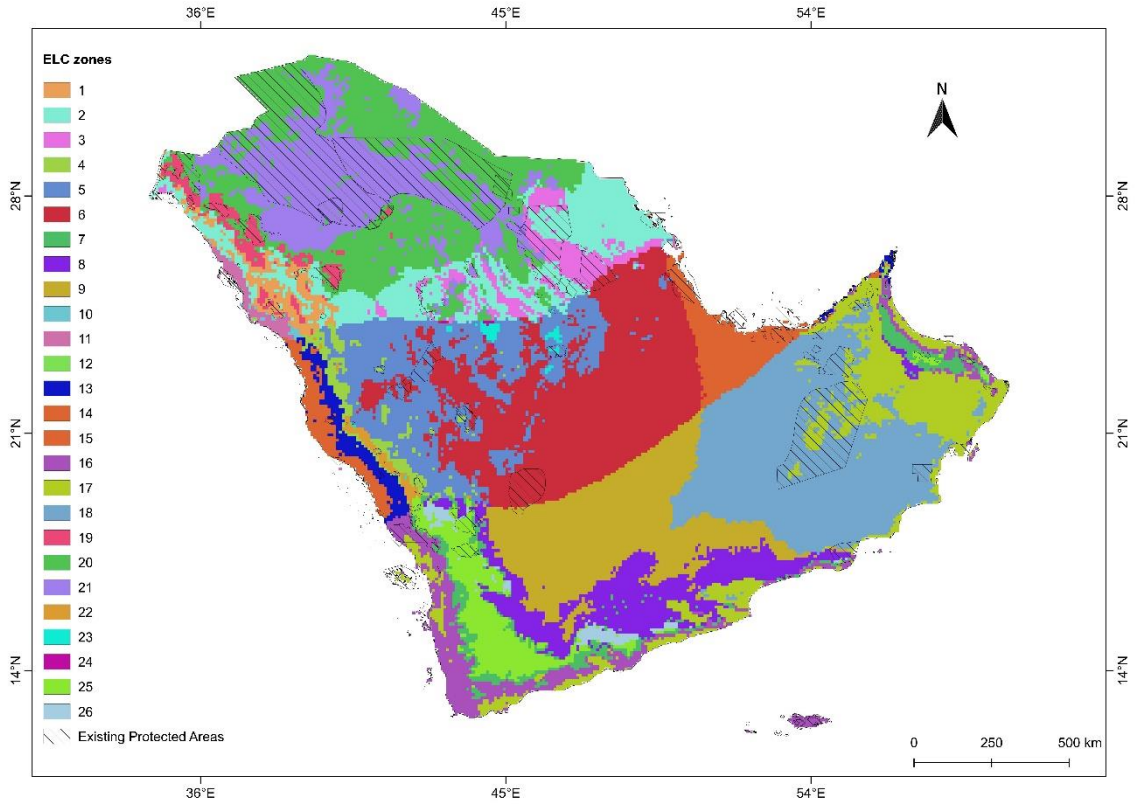


Figure 6.2. The ELC map of the Arabian Peninsula is divided into 26 ELC zones, each representing a distinct combination of environmental variables.

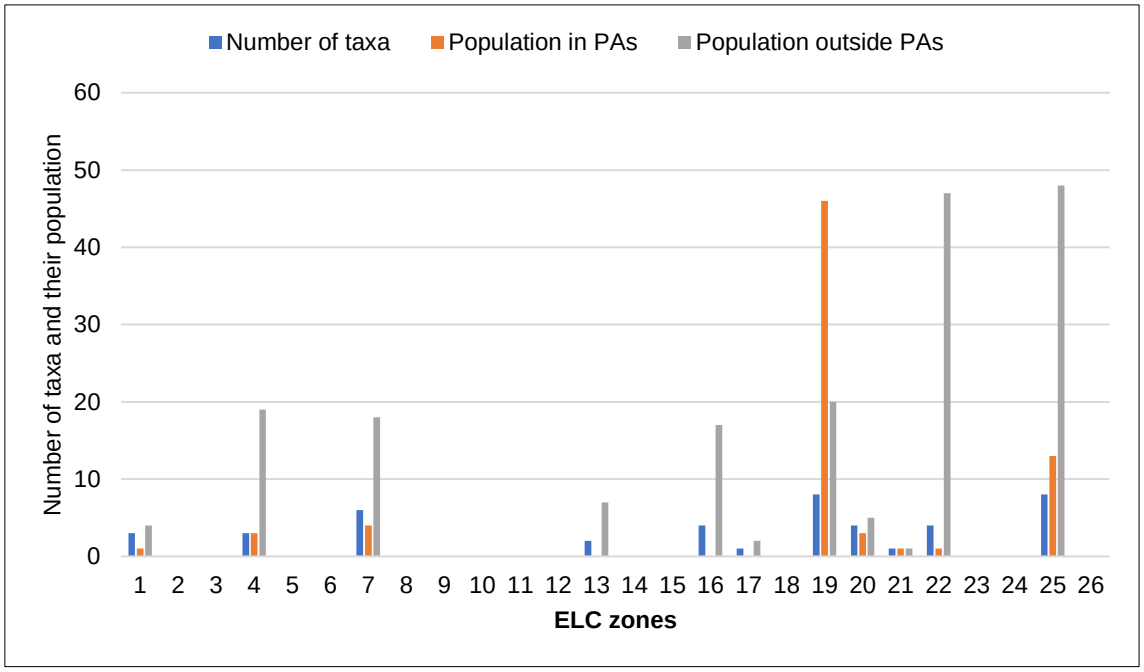


Figure 6.3. Number of *Verbascum* taxa and their population of ELC zones in and outside PAs in the Arabian Peninsula.

6.4.3 *In situ* and *ex situ* conservation gap analyses

Through a complementarity analysis based on the existing network of PAs, six complementary PAs were selected as locations at which *Verbascum* taxa could be conserved in the Arabian Peninsula (Figure 6.4), with the most complementary PAs in Saudi Arabia (five), followed by Oman (one). These six complementary PAs are Asir National Park, Jabal Qaraqir, Jabal Radwa, Jabal al-Lawz, and Ra's Suwayhil/Ra's al-Qasbah in Saudi Arabia, as well as Al Jabal Al Akhdar Scenic Reserve in Oman (Table 6.1; Appendix 6.9). A total of 12 *Verbascum* taxa, representative of 58 populations (21.5%), were found in these PAs (Table 6.1; Appendix 6.10). *V. sinaiticum*, *V. deserticola* var. *sheilae*, and *V. melhanense* had the most taxa populations in these complementary PAs, with 20, 14, and 7, respectively (Appendix 6.10).

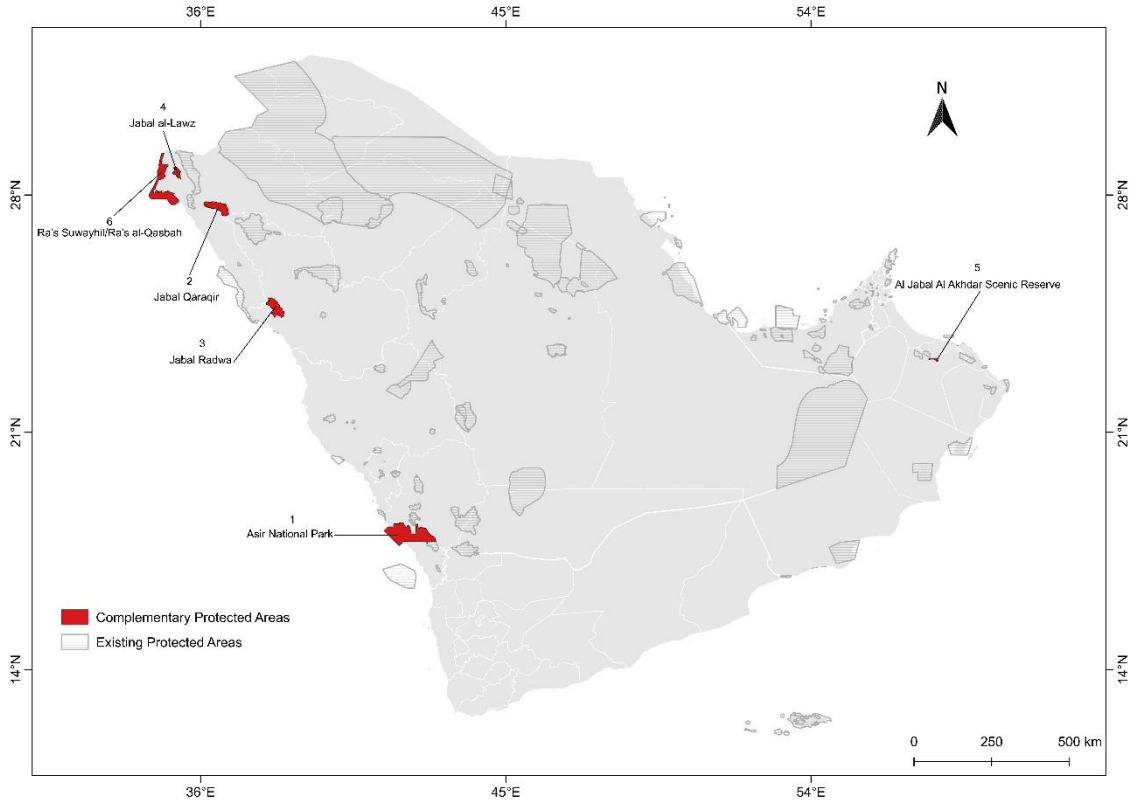


Figure 6.4. Six complementary PAs for *Verbascum* taxa found within the Arabian Peninsula. The numbers indicate the ranks of complementary PAs (the first area contains the highest number of taxa, the second the next-highest number of taxa, and so on).

In addition, 12 sites determined as complementary based on grid cells were selected as locations in which *Verbascum* taxa could be conserved in the Arabian Peninsula (Figure 6.5). Most of these sites were in Saudi Arabia (10), followed by Yemen and Oman (1 each). Eight potential complementary sites were located within existing PAs, and 14 *Verbascum* taxa were found at these sites, representing 47 populations (14.4%; Table 6.2; Appendix 6.10). These sites included PAs, such as Asir National Park, Wadi Tayyah, Jabal al-Lawz, Jabal Radwa, Jabal ad-Dubbagh, Jabal Qaraqir, and Hisma in Saudi Arabia, as well as Western Hajer Stars Lights Reserve and Al Rustaq Wildlife Reserve in Oman (Table 6.2; Appendix 6.11). *V. sinaiticum* and *V. deserticola* var. *sheilae* had the

most taxa populations in these complementary sites, with 16 and 12, respectively (Appendix 6.10). Furthermore, four complementary sites were identified outside PAs, and these sites could be implemented as other effective conservation measures (OECMs) for *Verbascum* taxa not currently found in PAs (Figure 6.5; Appendix 6.10).

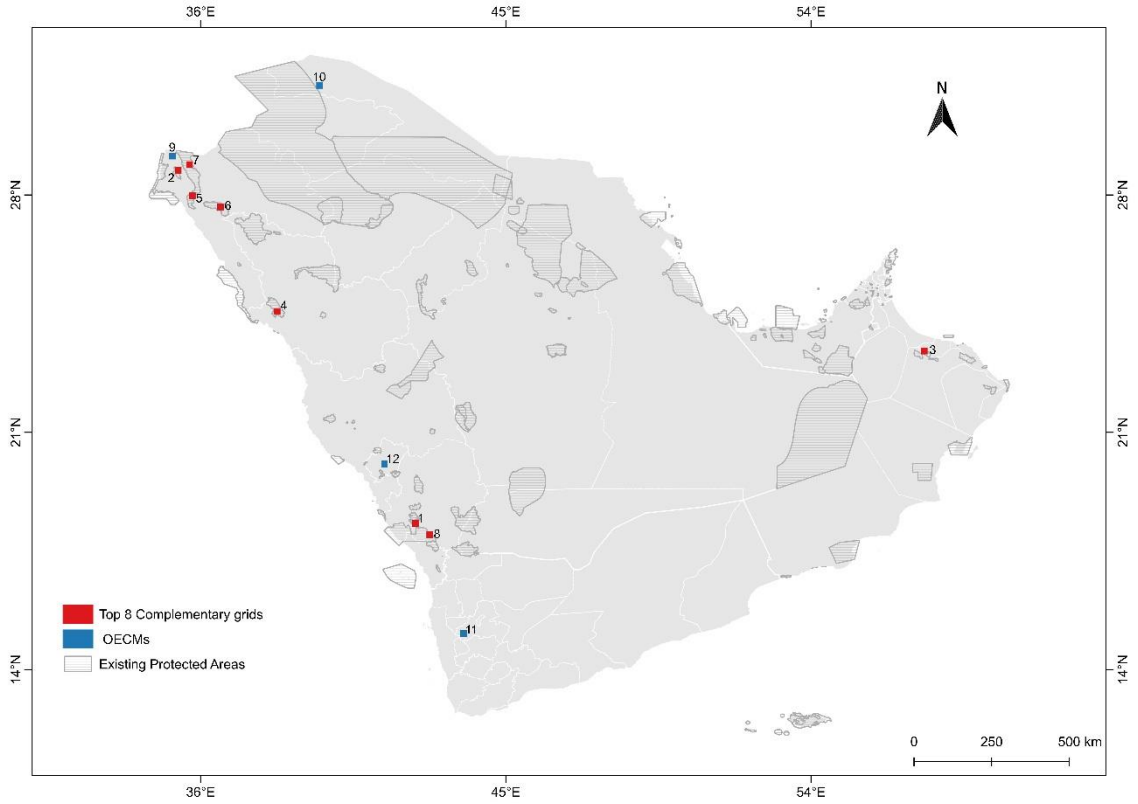


Figure 6.5. Sites in the Arabian Peninsula that host *Verbascum* taxa and are identified as complementary based on grid cells (10 x 10 km). The numbers indicate the rank of each complementary grid (the first site contains the highest number of taxa, the second the next-highest number of taxa, and so on). The four squares are outside PAs, where other effective conservation measures (OECMs) could be implemented.

Table 6.1. Six complementary PAs for *in situ* conservation of *Verbascum* taxa in the Arabian Peninsula.

Rank	Complementary PAs	Number of observational records	Number of *Verbascum* taxa	ELC zones	Province	Country
1	Asir National Park	15	4	1, 4, 13, 19, 22, 25	Asir	Saudi Arabia
2	Jabal Qaraqir	17	3	1, 4, 19, 25	Tabuk	Saudi Arabia
3	Jabal Radwa	4	2	7, 19, 22, 25	Medina	Saudi Arabia
4	Jabal al-Lawz	20	1	7, 19	Tabuk	Saudi Arabia
5	Al Jabal Al Akhdar Scenic Reserve	1	1	7	Al Batinah South	Oman
6	Ra’s Suwayhil/Ra’s al-Qasbah	1	1	19	Tabuk	Saudi Arabia

Table 6.2. Eight complementary sites for *in situ* conservation of *Verbascum* taxa within PAs in the Arabian Peninsula.

Rank	Complementary grid	Number of observational records	Number of *Verbascum* taxa	ELC zones	Province	Country
1	Asir National Park, Wadi Tayyah	5	4	4, 19, 25	Asir	Saudi Arabia
2	Jabal al-Lawz	16	2	19	Tabuk	Saudi Arabia
3	Al Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve	2	2	22, 25	Al Batinah South	Oman
4	Jabal Radwa	4	2	7, 19, 22, 25	Medina	Saudi Arabia
5	Jabal ad-Dubbagh	1	1	19	Tabuk	Saudi Arabia
6	Jabal Qaraqir	14	1	1, 19, 25	Tabuk	Saudi Arabia
7	Hisma	1	1	20	Tabuk	Saudi Arabia
8	Asir National Park	4	1	25	Asir	Saudi Arabia

Unfortunately, the *ex situ* conservation gap analysis in this study revealed that none of the Arabian *Verbascum* taxa are adequately represented in international and national genebanks. In fact, only one sample each of *V. akdarense* and *V. omanense* are stored in the Oman Botanic Garden and Millennium Seed Bank, respectively (Appendix 6.12).

6.5 Discussion

In the Arabian Peninsula, *Verbascum* taxa are widely distributed from the northern plateau to the northwest Hisma Plateau of Saudi Arabia and the western escarpment mountains (the Midian, Hijaz, and Asir Mountains and the Yemen Highlands) and then to the Hajar Mountains in Oman and the UAE (see Chapters 4 and 5). Saudi Arabia had the greatest *Verbascum* diversity, with 13 species, followed by Yemen, with 5, and Oman, with 2 (see Chapter 4). The most observations were recorded in Saudi Arabia. Despite the diversity and wide distribution of *Verbascum* taxa, to the best of our knowledge, no *Verbascum* populations are actively conserved in existing PAs, and only two populations of two taxa have been collected and conserved *ex situ* in genebanks. However, 30% of taxon populations are passively conserved in 14 PAs, while the remaining 70% found outside of PAs are not conserved.

Hotspots were observed in grid cells located in the northwest region of Tabuk Province (Jabal ad-Dubbagh) and the southwest region of Asir Province (the Asir Mountains), both of which areas are well-known in the Arabian Peninsula for their endemism (Miller and Nyberg, 1991). These two hotspots are associated with some observational bias, which is to be expected, given that *Verbascum* taxa were found in areas of endemism or diversity in the region, which may lead

botanists to focus on these areas (Mponya *et al*., 2021). Additionally, given the topography of the Arabian Peninsula and the difficulty of accessing certain rugged regions, this bias could have resulted in less collection from certain regions (Raes, 2009).

The ELC map was developed by Parra-Quijano, Iriondo and Torres (2012a, 2012b) to represent possible adaptation scenarios based on the ecogeographic diversity of taxa. According to the findings of this study, only 8 out of 26 ELC zones are represented in existing PAs, and they are found in both complementary PAs and sites. Furthermore, an ecogeographic diversity of *Verbascum* taxa was noted in PAs located in ELC Zones 19 and 25. Further research could be conducted in these zones, as these environments may represent habitats to which *Verbascum* taxa have adapted and could thus be subjected to additional field surveys.

Nevertheless, determining priority sites for *in situ* conservation of biodiversity based simply on taxa richness is an ineffective approach, as it disregards taxa that require immediate conservation action (Brooks *et al*., 2006). Complementarity analysis is often used as a method of addressing such an issue (Fielder *et al*., 2015; Phillips *et al*., 2016; Contreras-Toledo *et al*., 2019; Mponya *et al*., 2021; Rahman *et al*., 2021; Magos Brehm *et al*., 2022). This study's complementary analysis revealed that the locations of some proposed complementary PAs or complementary sites overlap with *Verbascum* taxa hotspots in the Arabian Peninsula. These areas are the northwest region of Tabuk Province and the southwest region of Asir Province.

The complementary analysis also identified six complementary PAs, eight complementary sites within PAs, and four sites outside of PAs. These complementary PAs and complementary sites are within existing PAs, so managing the sites in such a way as to sustain or enhance *Verbascum* taxa will be relatively easy and economically viable; at the same time, it will also enhance and supplement the existing conservation value of the existing PAs (Maxted and Kell, 2009). OECMs are characterised as locations that are not PAs but are specifically designated as long-term *in situ* sites for conserving biodiversity and its associated ecosystems (CBD, 2018; IUCN-WCPA, 2019). Thus, the presence of *Verbascum* taxa at the four remaining complementary sites not located in PAs provides an opportunity to expand or establish new OECMs.

The Arabian Peninsula contains 228 PAs (UNEP-WCMC and IUCN, 2023). Only 14 of these PAs have records of 15 *Verbascum* taxa; 6 are identified as complementary PAs, and 8 as complementary sites. Additionally, 3 *Verbascum* taxa were found within Jabal Qaraqir, which was established as an important plant area (Llewellyn *et al*., 2010). However, the current conservation site management processes within these PAs are inefficient and require revision and enhancement.

In addition to active *in situ* conservation, *ex situ* conservation is essential to preventing the loss of species (Ford-Lloyd and Maxted 1993). The range of *ex situ* techniques should thus be expanded to ensure the safety of long-term conservation efforts, integrating seed, *in vitro*, pollen, and DNA collection; botanical gardens; and field genebanks (Maxted, Hunter and Ríos, 2020). However, the *ex situ* conservation gap analysis conducted for this study indicates

that both national and international genebanks lack sufficient representation of *Verbascum* taxa from the Arabian Peninsula. Based on this study's findings, the following recommendations are offered for the *in situ* and *ex situ* conservation of *Verbascum* taxa in the Arabian Peninsula:

- Gather more *Verbascum* taxa survey data.
- Conduct field surveys of *Verbascum* taxa within PAs with low recorded populations in Yemen, Oman, and particularly the UAE.
- Conduct field surveys of the four *Verbascum* taxa with fewer than five populations, prioritising surveys within PAs. These four taxa are *V. schimperianum*, *V. transjordanicum*, *V. decaisneanum*, and *V. saudiarabicum* (Appendix 6.5).
- Conduct field surveys of the six taxa that do not exist within any PAs to verify their existence in five PAs in order to reach the minimal number needed for active *in situ* conservation (Dulloo *et al*., 2008). These taxa are *V. bottae*, *V. omanense*, *V. sarawaticum*, *V. transjordanicum*, *V. schimperianum*, and *V. yemense* var. *asiricum* (Appendix 6.4).
- Increase the effectiveness of six complementary PAs and eight complementary sites existing in PAs for active *in situ* conservation by revising the management plans and making the management and monitoring of *Verbascum* taxa more effective to ensure their long-term survival. Additionally, expand or establish new PAs – or, alternatively, OECMs – where taxon populations have been found and are thriving.
- Launch urgent *ex situ* collection fieldwork for all *Verbascum* taxa, focusing on hotspot areas outside PAs (Figure 6.1).

CHAPTER 7. GENERAL DISCUSSION AND CONCLUSION

7.1 General discussion

In general, the purpose of this thesis was to develop a conservation plan for *Verbascum* species in the Arabian Peninsula. However, an understanding of the taxonomy of this genus was a prerequisite, and Mace (2004) explained the relationship between taxonomy and species conservation, as taxonomy and conservation are inseparable. It is not always possible to conserve unidentified organisms. The taxonomic history of the genus *Verbascum* is long and complicated due to the extreme similarity and hybridization among its species (Huber-Morath, 1978; Sotoodeh *et al*., 2014). Therefore, the current thesis investigates the classification of *Verbascum* species in the Arabian Peninsula to identify the most useful characteristics that aid in identifying these species in the regions under investigation. This investigation was conducted with morphological examinations and phylogenetic analyses, providing additional evidence. The main results of these examinations show that inflorescence types with the number of flowers, types of indumentum, number of stamens, filament hairs, anthers, and seed morphology seem to be the most useful characteristics for *Verbascum* species identification (see Chapter 4). However, one of these characteristics is the number of stamens, which shows instability in certain *Verbascum* taxa; this may lead to confusion due to the presence of four to seven stamens. This finding is consistent with the research conducted by Karavelioğulları and Aytaç (2008) in *Verbascum* in Turkey, which is somewhat valid if it is counted carefully within the taxa population (see Chapter 4). In the Arabian Peninsula, the taxonomic revision recognises 16 *Verbascum* species that are widely distributed from the northern plateau to the northwest Hisma

Plateau of Saudi Arabia, the western escarpment mountains (the Midian, Hijaz, and Asir mountains and the Yemen highlands), and the Hajar Mountains in Oman and the UAE (see Chapters 4 and 5). The unexpected results of the study indicate that *Rhabdotosperma* should be reinstated in *Verbascum* (see Chapter 3), which is consistent with the recommendation of Dong *et al*. (2022).

Hence, in light of the recent progress in taxonomic comprehension of Arabian *Verbascum* species, improving the knowledge concerning their threat status and conservation plans is essential. Therefore, the International Union for Conservation of Nature (IUCN) Red List categories and criteria at national, regional, and global levels (2012) were applied to assess and fill the current gap in information on the IUCN Red List of Threatened Species databases of *Verbascum* taxa from the Arabian Peninsula (see Chapter 5). In addition, gap analyses were conducted on *Verbascum* taxa in the investigated regions to identify potential sites for *in situ* and *ex situ* conservation of these taxa, both within and outside of PAs, and to identify probable areas where *ex situ* collection is urgently required (see Chapter 6).

7.2 Conclusion

In this thesis, comprehensive information has been provided and strengthened by taxonomic revision with morphological examinations, DNA barcoding, Red List assessment, gap analysis, and conservation planning of the genus *Verbascum* in the Arabian Peninsula. In addition, this chapter provides a summary of the main findings and recommendations for future research.

- The phylogenetic approach of the genus *Verbascum* in the Arabian Peninsula has not been attempted before. Thus, DNA barcoding based on

four regions (ITS, *rbcL*, *matK*, and *trnL*) was used to review the intraspecific separation between the *Verbascum* and *Rhabdotosperma* species and to evaluate the relationships among Arabian *Verbascum* species. The findings confirmed the monophyly of the genus *Verbascum* and provided new DNA sequences for this genus. The phylogenetic analysis also strongly supports the reinstatement of the genus *Rhabdotosperma* into Verbascum. In addition, the status of the Arabian *Verbascum* taxa was updated, including 16 taxa with four varieties (see Chapter 3).

- The findings from Chapters 2 and 3 were used to review the taxonomy of the genus *Verbascum* in the Arabian Peninsula and investigate the most useful characteristics that aid in identifying this genus in the study areas. The findings provided valuable characteristics for identifying and delimiting Arabian *Verbascum* species, including the stable characteristics of indumentum, filament hairs, types of Anther, and the morphology of seeds. In addition, they confirmed the newly updated list of Arabian *Verbascum* taxa and their taxonomical status: 16 species and four varieties, including new species, new records, and new combinations for the genus *Rhabdotosperma* (see Chapter 4).
- The newly updated list of *Verbascum* taxa from the Arabian Peninsula in Chapter 4 was used to assess their threat status at national, regional, and global levels based on the IUCN Red List Categories and Criteria. The findings revealed that most of the Arabian *Verbascum* taxa are at risk of extinction, with 22% of species being critically endangered (4 taxa), 22%

being endangered (4 taxa), 28% being near threatened (5 taxa), and 28% being least concerned (5 taxa). In addition, the main threats to these taxa are habitat disturbance and loss resulting from overgrazing, suburban and agricultural expansion, climate changes, invasive species, recreational activities, tourism and recreation areas, and war and civil unrest caused by human intrusions and disturbances (see Chapter 5).

- The newly updated list of *Verbascum* taxa in the Arabian Peninsula in Chapter 4 was also used to analyse their *in situ* and *ex situ* conservation gaps. The findings showed that 30% of the *Verbascum* taxa population was found within PAs, while 70% was found outside of PAs. The richest hotspots of *Verbascum* diversity within the Arabian Peninsula are in the northwest region of Tabuk Province and the southwest region of Asir Province in Saudi Arabia. In addition, the *in situ* gap analysis identified six complementary PAs and eight complementary sites within PAs for more active *in situ* conservation, four of which were located outside of PAs where OECMs could be implemented. The ex situ gap analysis revealed that relatively low number of Arabian *Verbascum* taxa are conserved in international or national gene banks; thus, urgent *ex situ* collection for all *Verbascum* taxa focuses on hotspot areas outside of PAs is prudent (see Chapter 6).

7.3 Research limitations

Data collection in botanical field surveys was initially scheduled for March 2020. However, COVID-19 restrictions, accessibility, and time limitations

necessitated a rescheduling, which made fieldwork more challenging in the Arabian Peninsula, as illustrated below:

1. DNA barcoding of Arabian *Verbascum* species

   Due to the COVID-19 pandemic, it was not possible to collect all Arabian *Verbascum* species; therefore, available species from herbaria that were not found during fieldwork were collected instead. In addition, requesting samples from herbaria required time-consuming paperwork, decisions, and material sampling. The results were obtained three months after the completed samples were delivered to the laboratory.

2. Taxonomic revision of Arabian *Verbascum* species

   In Oman, it took time for COVID-19 entry restrictions to ease. As an alternative due to time limitations, Oman Botanic Garden teams were able to assist during the pandemic by providing data and some specimens, but not for all species; however, it took time to do so and to export the specimens. In the UAE, obtaining an official permit to conduct fieldwork and collect samples was extremely difficult due to COVID-19 restrictions. Thus, relying on the available information from herbaria, experts, and published literature was necessary. Yemen was unstable due to political crises, security matters, and wars; thus, permission was difficult to gain, but conducting fieldwork and collecting fresh specimens was extremely difficult and risky. Despite efforts to obtain at least some fresh samples via botanist experts in Yemen, these samples could not be transported outside of Yemen due to the country's ongoing wars. As a result, it was necessary to rely on the information available from herbaria, experts, and literature.

In Saudi Arabia, it was less complicated to continue fieldwork; however, in certain regions, an official permit was required, and obtaining one was time-consuming.

3. Red List assessment of Arabian *Verbascum* taxa

   Only four species from Yemen were examined due to the inability to conduct fieldwork because of political crises, security matters, and conflicts. Thus, the assessment was conducted with limited data from herbaria, experts, and published literature.

4. Gap analysis and conservation planning of Arabian *Verbascum* taxa

   Four species had fewer than five records of observation. In addition, the preliminary data analysis results for this section were invalid, necessitating a substantial amount of time and effort to rectify the situation. This led to the realisation that there were some problems with the methodology; according to the person who developed these methods, more time was required to rectify these problems. Thus, this analysis was carried out using these methods, even with limited data, in addition to different approaches.

7.4 Recommendations and further work

- Further botanical field surveys are required to ascertain the current status of Arabian *Verbascum* species, particularly in Yemen and the UAE.
- Additional DNA samples of the genus *Verbascum* from beyond the Arabian Peninsula, as well as the investigation of additional informative gene regions, are necessary for a complete understanding of this genus's evolutionary history.

- Increased public and educational awareness is necessary to protect the Arabian *Verbascum's* endangered taxa.
- More urgent action must be taken to determine and address the main threats to *Verbascum* taxa within the Arabian Peninsula, including habitat degradation and overgrazing, especially for those outside protected areas.
- *Verbascum* taxa within protected areas must be managed and monitored to guarantee that their populations are effectively conserved for *in situ* conservation and ensure their long-term survival.
- Additional data on Arabian *Verbascum* species from herbaria and genebanks that are not included in this study and have not been published in online databases should be gathered to help more effectively understand the *in situ* and *ex situ* conservation gap.
- Finally, it is hoped that authorities concerned with wildlife conservation on the Arabian Peninsula will use these findings and recommendations to further biodiversity conservation.

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APPENDICES

Appendix 3.1. Species names and GenBank/NCBI accession numbers used in this study are listed below. For each accession, the following voucher information is provided: species name, locality, country, collector, collection number, herbarium code, ITS, *matK*, *rbcL*, t*rnL*, and GenBank accession numbers. **!** and ***** indicate unsuccessful data and newly generated DNA sequences, respectively.

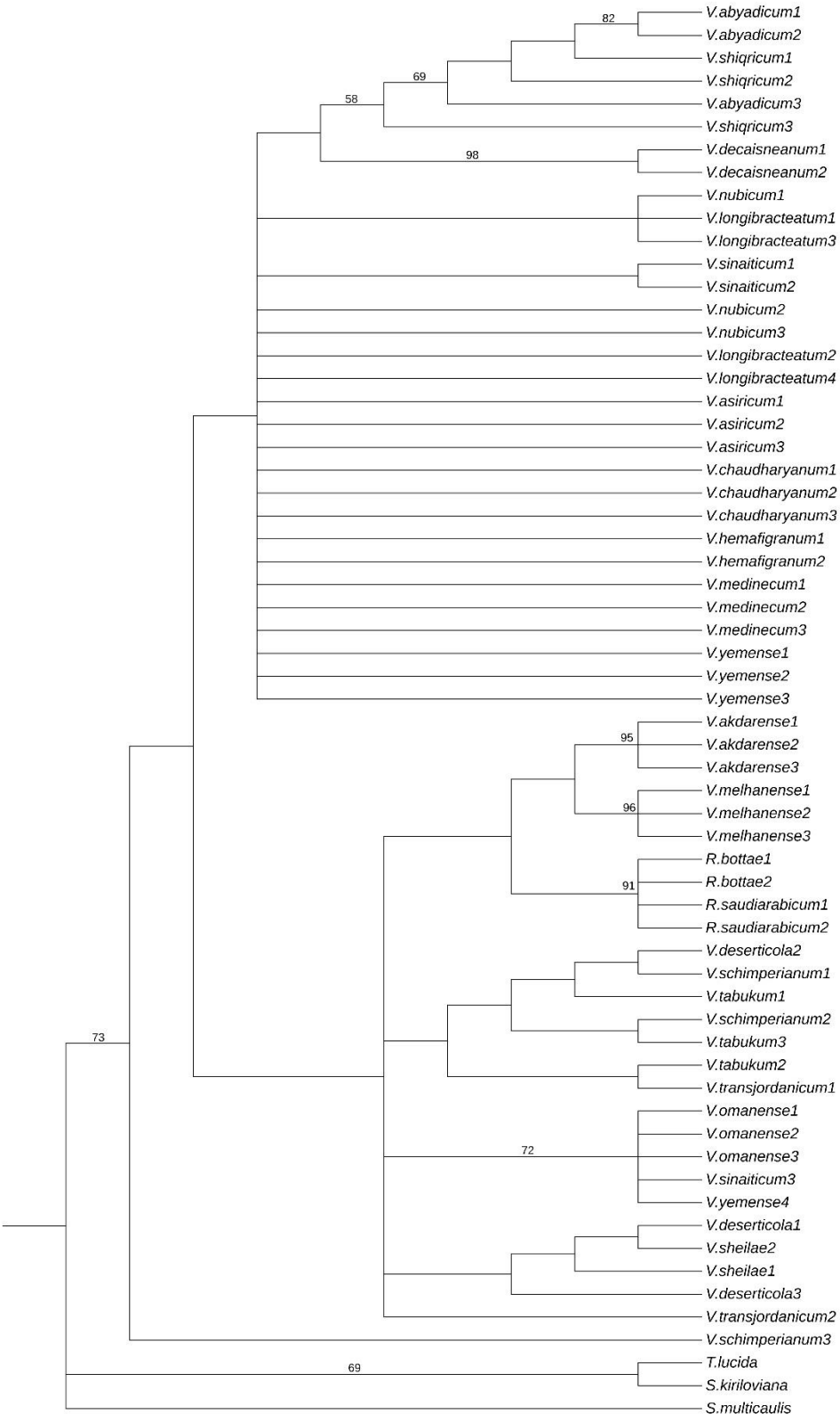
Rhabdotosperma bottae (Deflers) Hartl **1***, Bait Albeshari, Al Mahwit, Yemen, *J.R.I Wood 3108* (K), OR196975, OR232416, OR232475, OR232354; ***Rhabdotosperma bottae*** (Deflers) Hartl **2***, Jabal Taqar, Ibb, Yemen, *J.R.I Wood 1707* (K), OR196976, OR232417, OR232476, OR232355; ***Rhabdotosperma bottae*** (Deflers) Hartl **3!**, Jabal Sabir, Taizz, Yemen, *K.J. Gordon 1* (E [E00066923]); ***Rhabdotosperma saudiarabicum*** A.Alzahrani **1***, Al-Soudah, Abha, Saudi Arabia, *L. Boulos & A.S. Ads 14165* (K), OR196977, OR232418, OR232477, OR232356; ***Rhabdotosperma saudiarabicum*** A.Alzahrani **2***, Jabal Al-Soudah, Abha, Saudi Arabia, *I.S. Collenette 3316* (K), OR196978, OR232419, OR232478, OR232357; ***Rhabdotosperma saudiarabicum*** A.Alzahrani **3!**, Jabal Al-Soudah, Abha, Saudi Arabia, *I.S. Collenette 5368* (E [E00066943]); ***Verbascum abyadicum*** Hemaid **1***, Harrat Khaybar, Khaybar, Saudi Arabia, *A. Alzahrani 151* (MUZ), OR196979, OR232420, OR232479, OR232358; ***Verbascum abyadicum*** Hemaid **2***, Harrat Khaybar, Khaybar, Saudi Arabia, *I.S. Collenette 3757* (E [E00066949]), OR196980, OR232421, OR232480, OR232359; ***Verbascum abyadicum*** Hemaid **3***, Harrat Khaybar, Khaybar, Saudi Arabia, *A. Alzahrani 150* (MUZ), OR196981, OR232422, OR232481, OR232360; ***Verbascum akdarense*** (Murb.) Hub.-Mor. **1***, Jabal Akhdar, Ad Dakhiliyah, Oman, *A. Radcliffe-Smith 3980* (E [E00066951]), OR196989, OR232430, OR232489, OR232361; ***Verbascum akdarense*** (Murb.) Hub.-Mor. **2***, Ar Ruhbah, Ad Dakhiliyah, Oman, *A. Alzahrani 189* (MUZ), OR196990, OR232431, OR232490, OR232362; ***Verbascum akdarense*** (Murb.) Hub.-Mor. **3***, Wadi Asahban, Al Batinah North, Oman, *A. Alzahrani 192* (MUZ), OR196991, OR232432, OR232491, OR232363; ***Verbascum asiricum*** Hemaid **1***, Tamniah village, Abha, Saudi Arabia, *A. Alzahrani 175* (MUZ), OR196992, OR232433, OR232492, OR232364; ***Verbascum asiricum*** Hemaid **2***, Dalagan, Abha, Saudi Arabia, *I.S. Collenette 9347* (E [E00095077]), OR196993, OR232434, OR232493, OR232365; ***Verbascum asiricum*** Hemaid **3***, Abha, Saudi Arabia,

I.S. Collenette 2091 (K), OR196994, OR232435, OR232494, OR232366; ***Verbascum chaudharyanum*** Hemaid **1***, Bilhamr, Abha, Saudi Arabia, *A. Alzahrani 178* (MUZ), OR196995, OR232436, OR232495, OR232367; ***Verbascum chaudharyanum*** Hemaid **2***, Jabal Mna'a, Abha, Saudi Arabia, *A. Alzahrani 179* (MUZ), OR196996, OR232437, OR232496, OR232368; ***Verbascum chaudharyanum*** Hemaid **3***, Bilasmar and Bilhamr road, Abha, Saudi Arabia, *A. Alzahrani 108* (MUZ), OR196997, OR232438, OR232497, OR232369; ***Verbascum decaisneanum*** Kuntze **1***, Jabal Dabbagh, Tabuk, Saudi Arabia, *I.S. Collenette 5260* (E [E00066909]), OR196998, OR232439, OR232498, OR232370; ***Verbascum decaisneanum*** Kuntze **2***, Jabal Dabbagh, Tabuk, Saudi Arabia, *I.S. Collenette 717* (K), OR196999, OR232440, OR232499, OR232371; ***Verbascum deserticola*** (Vatke ex Murb.) Hub.-Mor. **1***, Duba and Shigry road, Tabuk, Saudi Arabia, *A. Alzahrani 147* (MUZ), OR197000, OR232441, OR232500, OR232372; ***Verbascum deserticola*** (Vatke ex Murb.) Hub.-Mor. **2***, Jabal Al-Figrah road, Medina, Saudi Arabia, *A. Alzahrani 152* (MUZ), OR197001, OR232442, OR232501, OR232373; ***Verbascum deserticola*** (Vatke ex Murb.) Hub.-Mor. **3***, Wadi Buwat, Medina, Saudi Arabia, *I.S. Collenette 8215* (K), OR197002, OR232443, OR232502, OR232374; ***Verbascum hema-figranum*** Hemaid **1***, Jabal Al-Figrah, Medina, Saudi Arabia, *A. Alzahrani 103* (MUZ), OR197003, OR232444, OR232503, OR232375; ***Verbascum hema-figranum*** Hemaid **2***, Jabal Al-Figrah, Medina, Saudi Arabia, *I.S. Collenette 6977* (E [E00066970]), OR197004, OR232445, OR232504, OR232376; ***Verbascum hema-figranum*** Hemaid **3!**, Jabal Radwa, Medina, Saudi Arabia, *I.S. Collenette 5889* (E [E00066948]); ***Verbascum longibracteatum*** Defl. **1***, Baljurashi, Al-Baha, Saudi Arabia, *I.S. Collenette 4330* (K), OR196985, OR232426, OR232485, OR232377; ***Verbascum longibracteatum*** Defl. **2***, Heznah road, Al-Baha, Saudi Arabia, *A. Alzahrani 170* (MUZ), OR196986, OR232427, OR232486, OR232378; ***Verbascum longibracteatum*** Defl. **3***, Baljurashi, Al-Baha, Saudi Arabia, *A. Alzahrani 167* (MUZ), OR196987, OR232428, OR232487, OR232379; ***Verbascum longibracteatum*** Defl. **4***, Al-Abna Road, Al-Baha, Saudi Arabia, *A. Alzahrani 171* (MUZ), OR196988, OR232429, OR232488, OR232380; ***Verbascum longibracteatum*** Defl. **5!**, Jabal Al-Qahar, Jazan, Saudi Arabia, *A. Alzahrani 144* (MUZ); ***Verbascum medinecum*** Hemaid **1***, Jabal Al-Figrah, Medina, Saudi Arabia, *I.S. Collenette 7116* (E [E00066952]), OR197005,

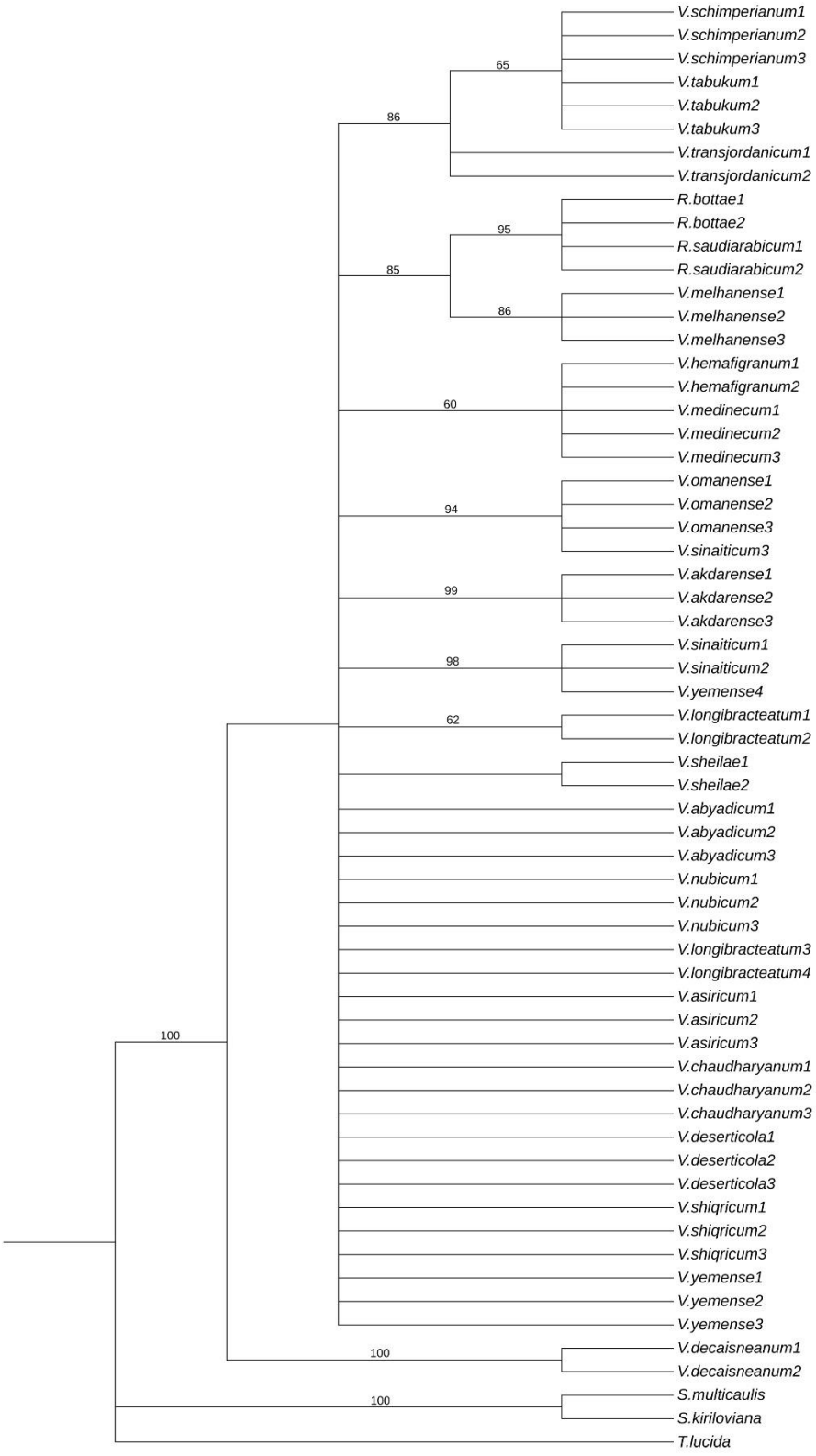
OR232446, OR232505, OR232381; ***Verbascum medinecum*** Hemaid **2***, Jabal Al-Figrah, Medina, Saudi Arabia, *A. Alzahrani 153* (MUZ), OR197006, OR232447, OR232506, OR232382; ***Verbascum medinecum*** Hemaid **3***, Jabal Odks, Medina, Saudi Arabia, *A. Alzahrani 182* (MUZ), OR197007, OR232448, OR232507, OR232383; ***Verbascum melhanense*** (Murb.) Hub.-Mor. **1***, King Khalid road, Al-Baha, Saudi Arabia, *A. Alzahrani 164* (MUZ), OR197008, OR232449, OR232508, OR232384; ***Verbascum melhanense*** (Murb.) Hub.-Mor. **2***, Jabal Melhan, Al-Mahwit, Yemen, *J.R.I. Wood 2864* (K), OR197009, OR232450, OR232509, OR232385; ***Verbascum melhanense*** (Murb.) Hub.-Mor. **3***, Jabal Mna'a, Abha, Saudi Arabia, *A. Alzahrani 109* (MUZ), OR197010, OR232451, OR232510, OR232386; ***Verbascum nubicum*** Murb. **1***, Tanomah, Abha, Saudi Arabia, *I.S. Collenette 7170* (K), OR196982, OR232423, OR232482, OR232387; ***Verbascum nubicum*** Murb. **2***, Baidhan, Al-Baha, Saudi Arabia, *A. Alzahrani 165* (MUZ), OR196983, OR232424, OR232483, OR232388; ***Verbascum nubicum*** Murb. **3***, King Abdulaziz Road, Al-Mandaq, Al-Baha, Saudi Arabia, *A. Alzahrani 168* (MUZ), OR196984, OR232425, OR232484, OR232389; ***Verbascum nubicum*** Murb. **4!**, Al-Hada, Taif, Saudi Arabia, *I.S. Collenette 1090* (K); ***Verbascum nubicum*** Murb. **5!**, Wadi Masal, Ash Shafa, Taif, Saudi Arabia, *A. Alzahrani 157* (MUZ); ***Verbascum omanense*** Hub.-Mor. **1***, Hibra, Al Batinah South, Oman, *R.P. Whitcombe 472* (E [E00219515]), OR197011, OR232452, OR232511, OR232390; ***Verbascum omanense*** Hub.-Mor. **2***, Wadi Jeema, Hatta Town, UAE, *J.N.B. Brown 905* (E [E00066936]), OR197012, OR232453, OR232512, OR232391; ***Verbascum omanense*** Hub.-Mor. **3***, Jabal Al Halla, Ad Dakhiliyah, Oman, *J.R. Edmondson 3399* (E [E00066931]), OR197013, OR232454, OR232513, OR232392; ***Verbascum schimperianum*** Boiss. **1***, Jabal Al-Lawz, Tabuk, Saudi Arabia, *I.S. Collenette 7048* (E [E00066928]), OR197014, OR232455, OR232514, OR232393; ***Verbascum schimperianum*** Boiss. **2***, Jabal Al-Lawz, Tabuk, Saudi Arabia, *I.S. Collenette 7227* (E [E00066930]), OR197015, OR232456, OR232515, OR232394; ***Verbascum schimperianum*** Boiss. **3***, Wadi Sawawin, Tabuk, Saudi Arabia, *I.S. Collenette 527* (K), OR197016, OR232457, OR232516, OR232395; ***Verbascum sheilae*** Hemaid **1***, Wadi Al-Disah, Tabuk, Saudi Arabia, *A. Alzahrani 85* (MUZ), OR197017, OR232458, OR232517, OR232396; ***Verbascum sheilae*** Hemaid **2***, Wadi Al-Disah, Tabuk, Saudi

Arabia, *I.S. Collenette 9072* (K), OR197018, OR232459, OR232518, OR232397; ***Verbascum shiqricum*** Hemaid **1***, Bir Al-Qurr, Al-Ula, Medina, Saudi Arabia, *A. Alzahrani 149* (MUZ), OR197019, OR232460, OR232519, OR232398; ***Verbascum shiqricum*** Hemaid **2***, Shigry, Tabuk, Saudi Arabia, *A. Alzahrani 180* (MUZ), OR197020, OR232461, OR232520, OR232399; ***Verbascum shiqricum*** Hemaid **3***, Alaqan, Tabuk, Saudi Arabia, *A. Alzahrani 146* (MUZ), OR197021, OR232462, OR232521, OR232400; ***Verbascum sinaiticum*** Benth. **1***, Jabal Raymah, Raymah, Yemen, *A. G. Miller & R. A. King 5327* (E [E00066966]), OR197022, OR232463, OR232522, OR232401; ***Verbascum sinaiticum*** Benth. **2***, Ad Delil, Ibb, Yemen, *J.R.I. Wood 75/108* (E [E00066959]), OR197023, OR232464, OR232523, OR232402; ***Verbascum sinaiticum*** Benth. **3***, Wadi Mahil, Ad Dakhiliyah, Oman, *A. Radcliffe-Smith 3766* (K), OR197024, OR232465, OR232524, OR232403; ***Verbascum sinaiticum*** Benth. **4!**, Jabal Al-Lawz, Tabuk, Saudi Arabia, *A. Alzahrani 181* (MUZ); ***Verbascum* sp 1!**, Al-Safiha road, Taif, Saudi Arabia, *A. Alzahrani 163* (MUZ); ***Verbascum* sp 2!**, Al-Abna Road, Al-Baha, Saudi Arabia, *I.S. Collenette 9015* (E [E00092215]); ***Verbascum tabukum*** Hemaid **1***, Duba road, Tabuk, Saudi Arabia, *I.S. Collenette 9115* (E [E00092230]), OR197025, OR232466, OR232525, OR232404; ***Verbascum tabukum*** Hemaid **2***, Shigry, Tabuk, Saudi Arabia, *I.S. Collenette 4347* (E [E00066929]), OR197026, OR232467, OR232526, OR232405; ***Verbascum tabukum*** Hemaid **3***, Duba road, Tabuk, Saudi Arabia, *I.S. Collenette 9115* (K), OR197027, OR232468, OR232527, OR232406; ***Verbascum transjordanicum*** Murb. **1***, Harrat Al-Harrat, Turaif, Saudi Arabia, *A. Alzahrani 148* (MUZ), OR197028, OR232469, OR232528, OR232407; ***Verbascum transjordanicum*** Murb. **2***, Turaif, Saudi Arabia, *I.S. Collenette 9092* (E [E00092227]), OR197029, OR232470, OR232529, OR232408; ***Verbascum yemense*** Defl. **1***, Jabal An Nabi Shu'ayb, Sana'a, Yemen, *A. Miller 143* (E [E00066954]), OR197030, OR232471, OR232530, OR232409; ***Verbascum yemense*** Defl. **2***, Jabal An Nabi Shu'ayb, Sana'a, Yemen, *J.R.I. Wood 3097* (E [E00066956]), OR197031, OR232472, OR232531, OR232410; ***Verbascum yemense*** Defl. **3***, Jabal Al-Aswad, Jazan, Saudi Arabia, *A. Alzahrani 145* (MUZ), OR197032, OR232473, OR232532, OR232411; ***Verbascum yemense*** Defl. **4***, Al-Hada palm, Al-Hada, Taif, Saudi Arabia, *A. Alzahrani 155* (MUZ), OR197033, OR232474, OR232533, OR232412; ***Verbascum yemense*** Defl. **5!**, Al-Sahab park, Al-

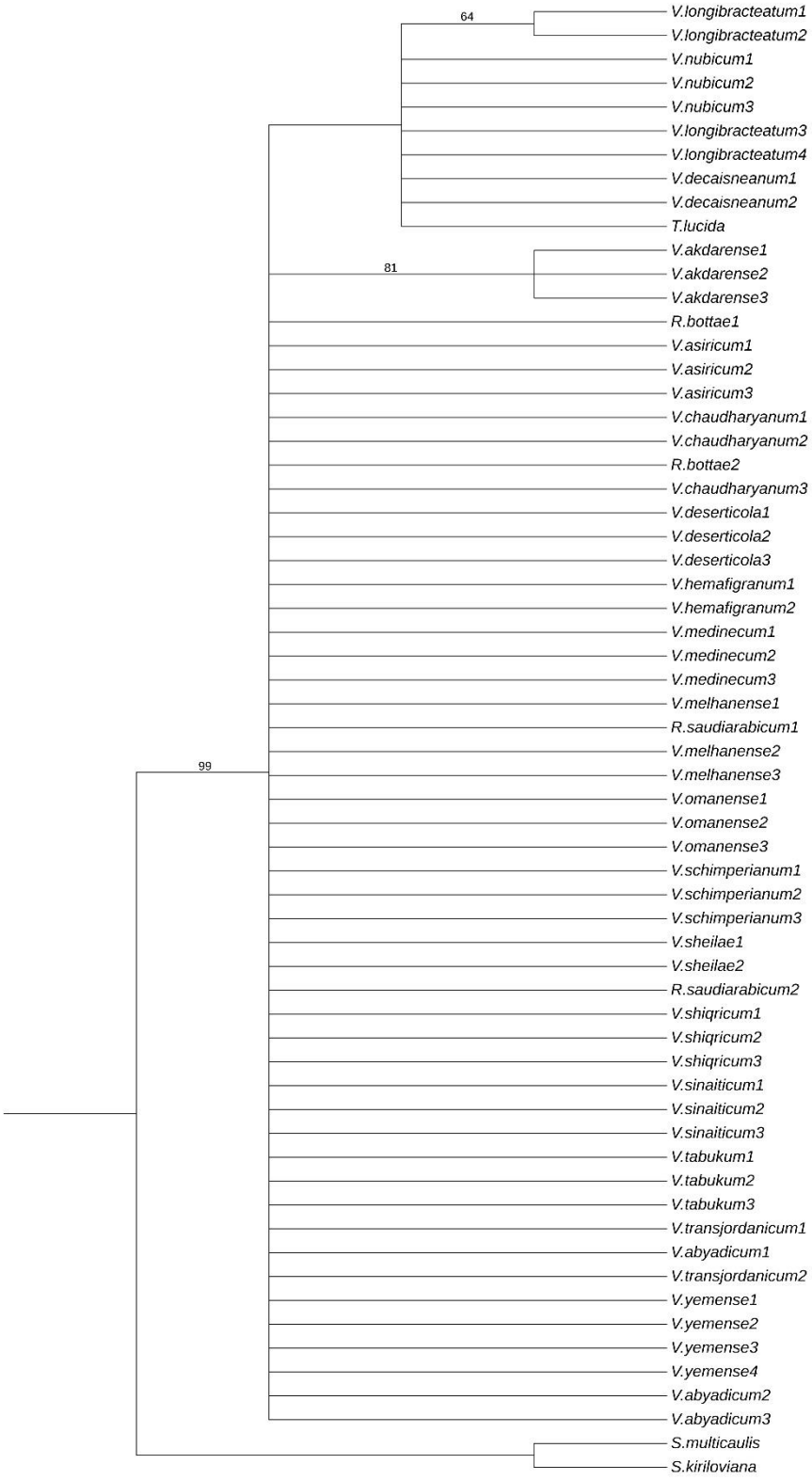
Soudah, Abha, Saudi Arabia, *A. Alzahrani 177* (MUZ); ***Scrophularia kiriloviana*** Schischk., DPC202-21; DPC202-21; DPC202-21; MW657274; ***Scrophularia multicaulis*** Turcz., ENDEM031-16, ENDEM031-16, ENDEM031-16, KY067910; ***Teedia lucida*** (Aiton) Rudolphi, AF375148, AF375187, AM235150, AJ608561.



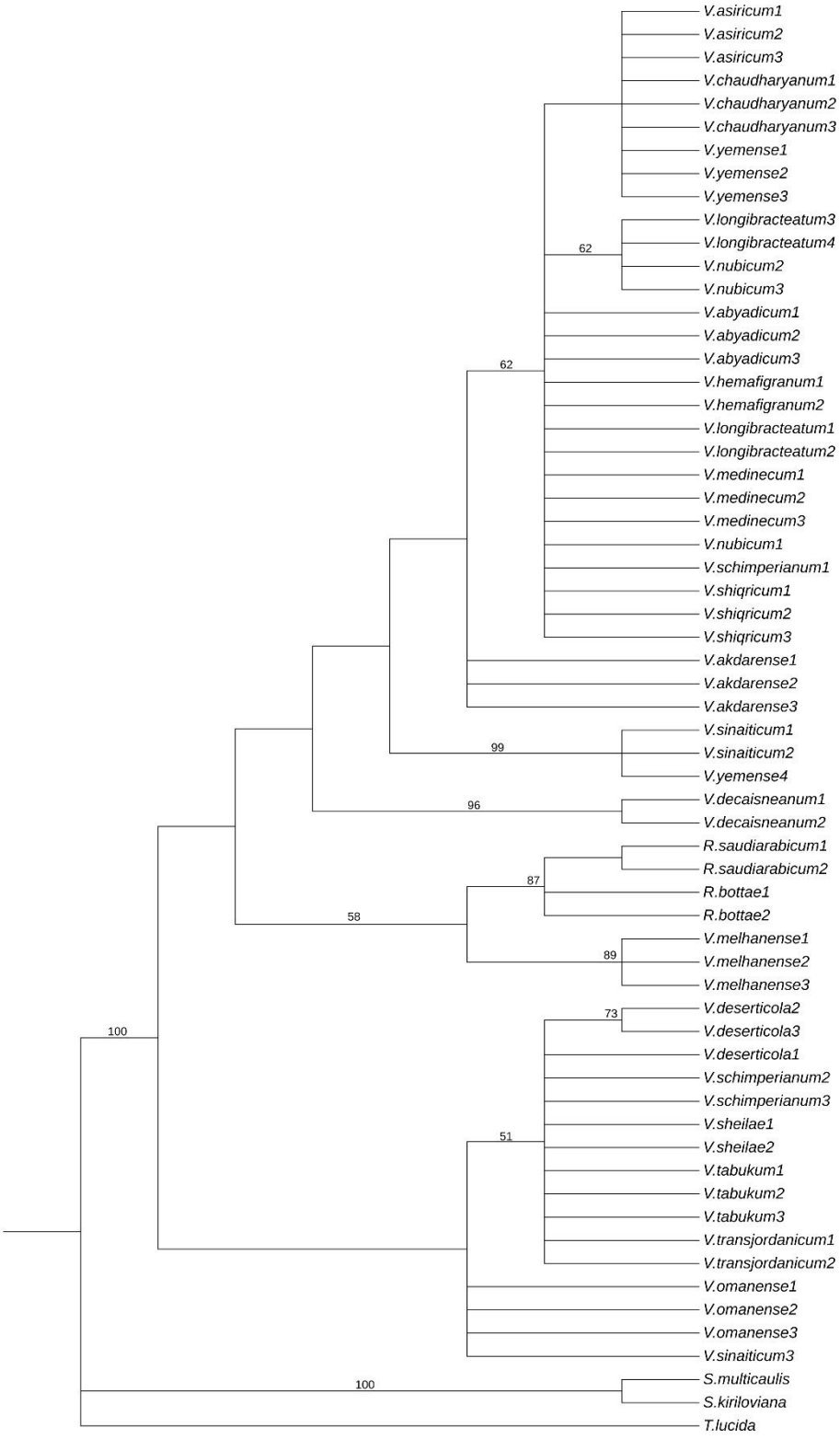
Appendix 3.2. Consensus tree of Maximum Parsimony analysis based on nuclear ITS region with bootstrap values on branches.



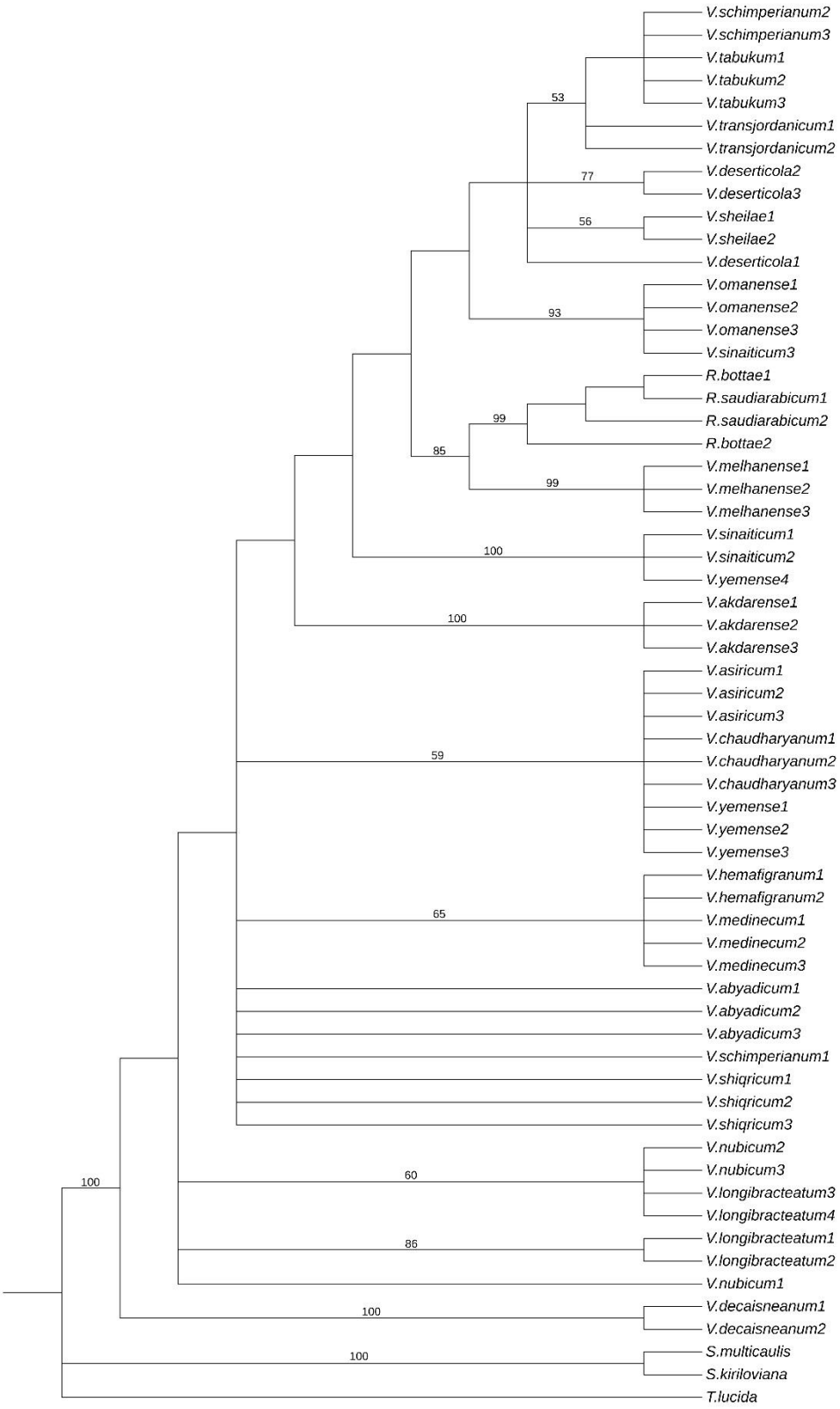
Appendix 3.3. Consensus tree of Maximum Parsimony analysis based on chloroplastic *matK* region with bootstrap values on branches.



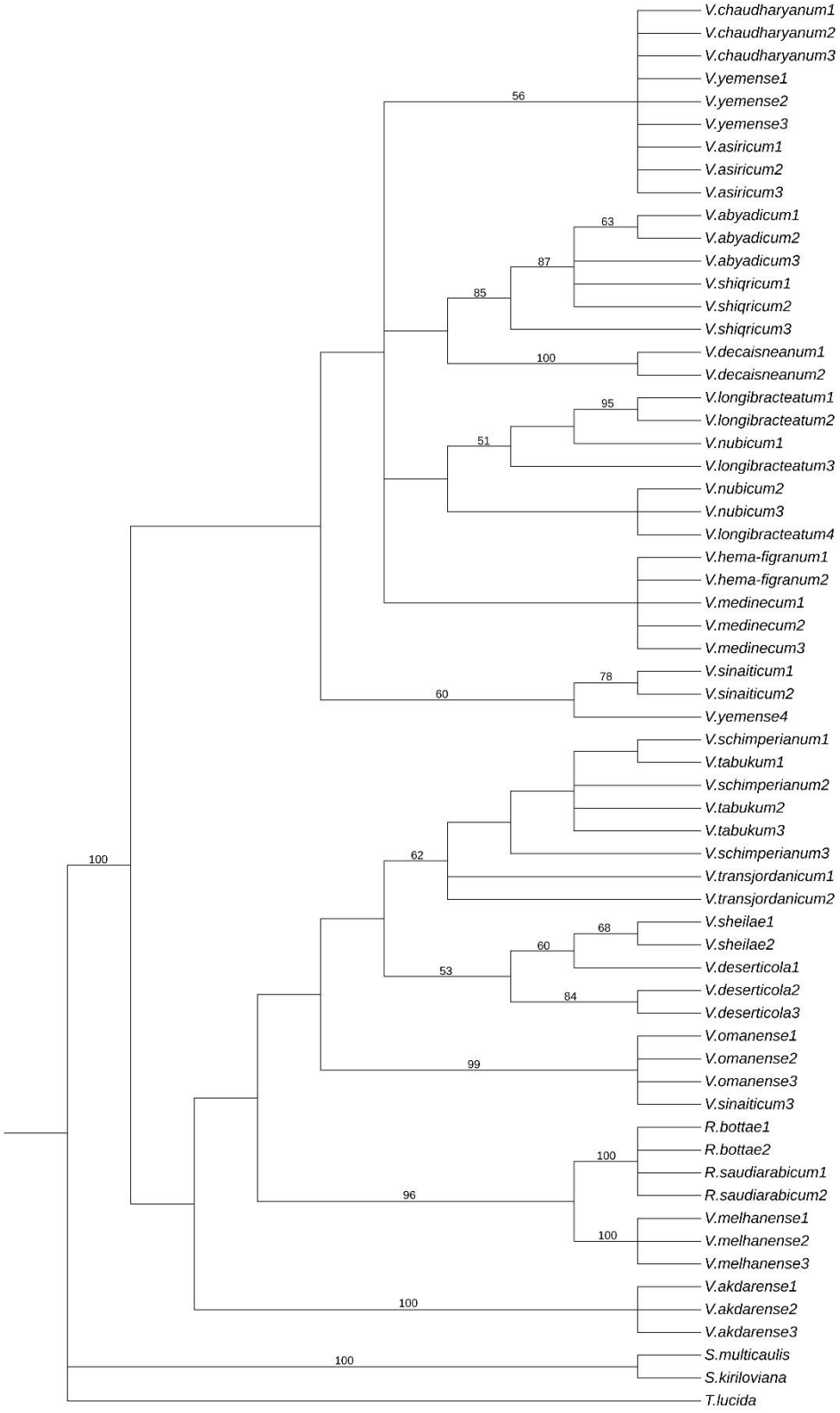
Appendix 3.4. Consensus tree of Maximum Parsimony analysis based on chloroplastic *rbcL* region with bootstrap values on branches.



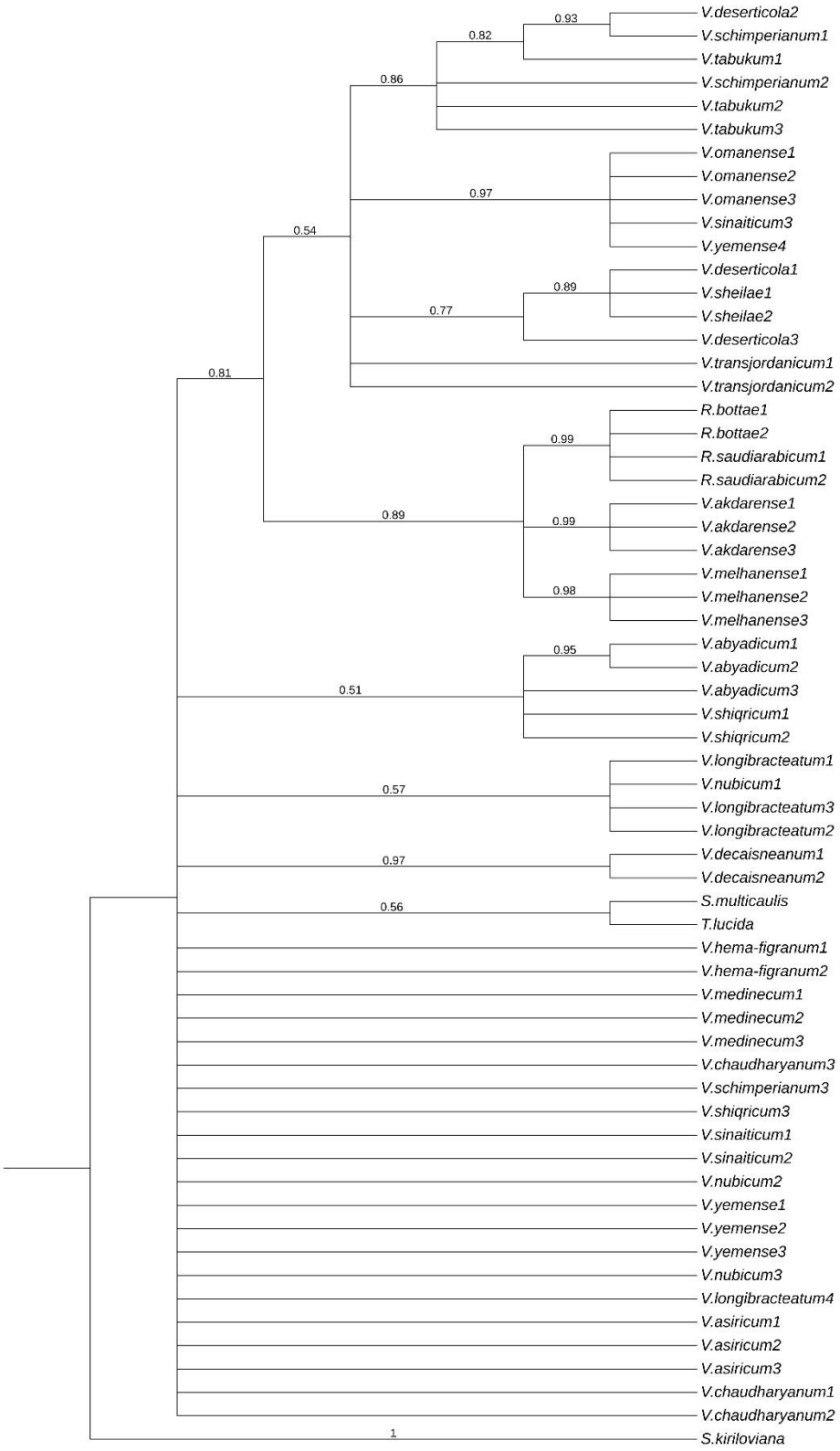
Appendix 3.5. Consensus tree of Maximum Parsimony analysis based on chloroplastic *trnL* region with bootstrap values on branches.



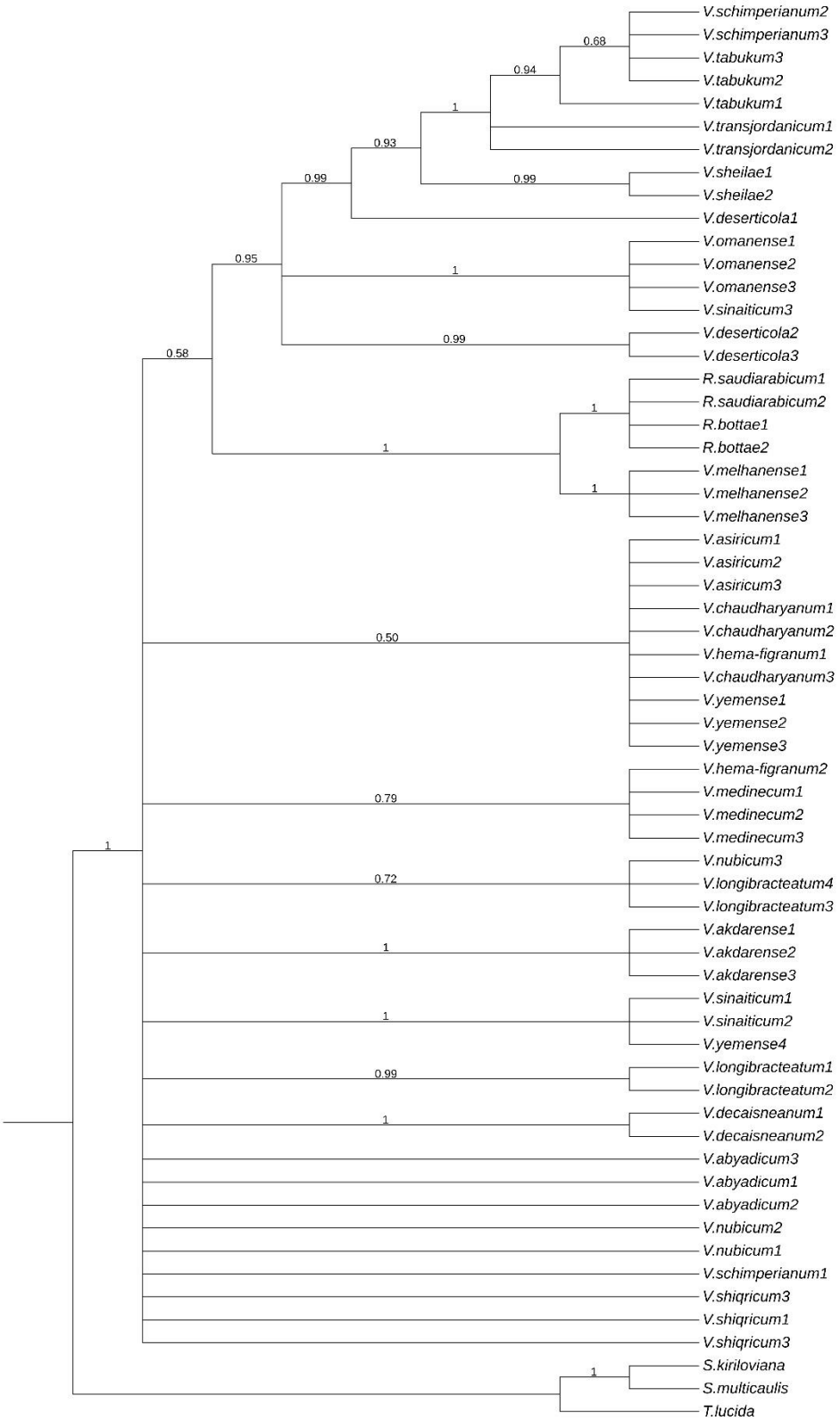
Appendix 3.6. Consensus tree of Maximum Parsimony analysis based on three combined chloroplastic (*rbcL*, *matK*, and *trnL*) regions with bootstrap values on branches.



Appendix 3.7. Consensus tree of Maximum Parsimony analysis based on combined nuclear ITS and three chloroplastic (*rbcL*, *matK*, and *trnL*) regions with bootstrap values on branches.



Appendix 3.8. Bayesian majority-rule (50%) consensus tree of nuclear ITS region with posterior probability values on branches.



Appendix 3.9. Bayesian majority-rule (50%) consensus tree of three combined chloroplastic (*rbcL*, *matK*, and *trnL*) regions with posterior probability values on branches.

Appendix 5.1. Global draft assessment

Verbascum akdarense (Murb.) Huber-Morath, Bauhinia 5(1): 10 (1973).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Photograph: Yes.

General information

Synonyms: *Celsia akdarensis* Murb., in Lunds Univ. Arsskrift, n. f. xxii. No. 1, 123 (1925).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Common Names: None.

Taxonomic notes: *Verbascum akdarense* can be easily distinguished from other species in the Arabian Peninsula. In addition, the species name is sometimes miss-spelt as '*akhdarense*' (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum akdarense* is an endemic species widespread in the Hajar foothills and mountains to the northeast of Oman with an extent of occurrence (EOO) of 14,265 km^2 and an area of occupancy (AOO) of 84 km^2.

Area of Occupancy (AOO): 84 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman.

Extent of Occurrence (EOO): 14,265 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman.

Elevation: 200 – 2000 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: No.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Oman.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Estimated.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in rocky slopes, rocks and fine soil, edge of wadis and gardens, and gravelly wadi beds (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Artificial/Terrestrial -> Artificial/Terrestrial - Rural Gardens/ Resident/ Suitable/ Yes.

Decline in Habitat: No.

Qualification: Estimated.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Oman.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the species in Oman.

Selections for Threats: No past, ongoing, or future threats exist to this species.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds were collected and conserved in Oman Botanic Garden (OBG) in Muscat, Oman (Patzelt, 2015). In addition, *V. akdarense* occurs near or within protected areas, namely in Al Sareen Nature Reserve, Al Rustaq Wildlife Reserve, Al Jabal Al Akhdar Scenic Reserve, and Western Hajer Stars and Lights Reserve (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within protected areas, namely in Al Sareen Nature Reserve, Al Rustaq Wildlife Reserve, Al Jabal Al Akhdar Scenic Reserve, and Western Hajer Stars and Lights Reserve.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds were collected and conserved in Oman Botanic Garden (OBG) in Muscat, Oman (Patzelt, 2015).

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: LC

Rationale for the Red List Assessment: *Verbascum akdarense* is an endemic species widespread throughout its distribution range in Oman, it is not currently experiencing any major threats and no significant future threats have been identified. This species is therefore assessed as Least Concern.

Reason(s) for Change: The species was assessed as Near Threatened (Patzelt, 2015) due to its widespread distribution and neither a continuing decline nor threats. With new information on its geographic distribution and neither a continuing decline nor threats, its threat status is assessed as Least Concern.

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Appendix 5.2. Global draft assessment

Verbascum bottae (Defl.) Huber-Morath, Bauhinia 5(1): 11 (1973).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Photograph: Yes.

General information

Synonyms: *Rhabdotosperma bottae* (Defl.) D.Hartl, Beitr. Biol. Pflanzen 53(1): 58 (1977). *Celsia melhanensis* Murb. in Lunds Univ. Arsskrift, n. f. xxii. No.1, 155 (1925).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Common Names: None.

Taxonomic notes: *Verbascum bottae* is easily confused with the closely related species *V. melhanense* (Murb.) Huber-Morath due to their similar morphology and habitats, but it can be distinguished by its two anterior glabrous near the apex and aulacospermous seeds (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum bottae* is an endemic species widespread from the southwestern to southern regions of Yemen with an extent of occurrence (EOO) of 20,406 km^2 and an area of occupancy (AOO) of 72 km^2.

Area of Occupancy (AOO): 72 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the highlands in Yemen.

Extent of Occurrence (EOO): 20,406 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the highlands in Yemen.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in the highlands in Yemen.

Elevation: 1800 – 3100 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Yemen.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Suspected

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on rocky slopes, limestone cliffs, terrace walls, granite crevices, and wadi banks (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Estimated.

Justification: The species' habitat seems to be declining due to human intrusions and disturbances caused by war and civil unrest.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Yemen.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: It is estimated that the quality and area of the habitat of this species is declining due to human intrusions and disturbances caused by war and civil unrest.

Selections for Threats: Yes.

- Human intrusions & disturbance -> War, civil unrest & military exercises/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no *in situ* nor *ex situ* conservation actions currently targeting this species. However, *V. bottae* occurs near or within Haraz Wildlife Sanctuary (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurred near or within Haraz Wildlife Sanctuary.

Percentage of population protected by PAs (0-100): 1 – 10%.

Subject to ex-situ conservation: No.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications
- Land/water management -> Site/area management.
- Species management -> Species recovery

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: NT B1b(iii)+2b(iii)

Rationale for the Red List Assessment: *Verbascum bottae* is endemic to Yemen, occurring in an extent of occurrence of 20,406 km^2 and an area of occupancy of 72 km^2, which would qualify the species as Endangered under criterion B2. Precise information about population size is unavailable, but it is estimated that the quality and area of its habitat is declining due to human intrusions and disturbances caused by war and civil unrest. More specific information about the threats affecting *V. bottae* is currently unavailable. Based on the available data and to some degree of uncertainty, the most plausible threat is Near Threatened.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.
- Murbeck S. 1925. Monographie der Gattung *Celsia*. Acta Univ. Lund. 22: 1 – 20.
- Wood J R I. 1997. A Handbook of the Yemen Flora. Royal Botanic Gardens, Kew.

Appendix 5.3. Regional Saudi Arabia draft assessment

Verbascum decaisneanum O. Kuntze, Revis. Gen. Pl. 2: 468 (1891).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Photograph: Yes.

General information

Synonyms: *Celsia parviflora* Decne., Ann. Sci. Nat., Bot. sér. 2, 2: 254 (1834).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Common Names: None.

Taxonomic notes: *Verbascum decaisneanum* is considered a distinct species by its indumentum dense glandular hairs above and forked hairs below, basal leaves oblong-lanceolate, four stamens, and filaments yellow with yellow hairs (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum decaisneanum* is found in Saudi Arabia, Lebanon, Jordan, Syria, Palestine, and Egypt (Sinai). In Saudi Arabia, the species is known from two locations in the northwest, with an extent of occurrence (EOO) of 93 km^2 and an area of occupancy (AOO) of 12 km^2.

Area of Occupancy (AOO): 12 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: This species is known from two locations in Tabuk province (Jabal Al-Lawz and Jabal Dabbagh).

Extent of Occurrence (EOO): 93 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: This species is known from two locations in Tabuk province (Jabal Al-Lawz and Jabal Dabbagh).

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 2.

Continuing decline in number of locations: Yes

Qualification: Estimated.

Justification: The species is found in two locations in Tabuk province, with continuing decline, and its habitat in Jabal Al-Lawz is under threat caused by suburban expansion and by tourism and recreation, also its other location in Jabal Dabbagh is by tourism and recreation.

Very restricted: Yes.

Justification: This species is known from two locations in Tabuk province (Jabal Al-Lawz and Jabal Dabbagh).

Elevation: 1500 – 1900 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of species seems to be declining.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Estimated.

Number of mature individuals: Less than 250.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in granite crevices of cliffs and rocky slopes (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The species' habitat seems to be declining due to habitat disturbance caused by suburban expansion and by tourism and recreation.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats are continuing affecting this species leading to a continuing decline; habitats of both Jabal Al-Lawz are threatened by suburban expansion and by tourism and recreation.

Selections for Threats: Yes.

- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

- Residential & commercial development -> Housing & urban areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no *in situ* nor *ex situ* conservation actions currently targeting this species. However, *V. decaisneanum* occurs within Jabal Al-Lawz Reserve and Jabal Dabbagh Nature Reserve (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs within Jabal Al-Lawz Reserve and Jabal Dabbagh Nature Reserve.

Percentage of population protected by PAs (0-100): 100%.

Subject to ex-situ conservation: None.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: EN B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum decaisneanum* is known from two locations in northwest Saudi Arabia, with an extent of occurrence (EOO) of 93 km^2 and an area of occupancy (AOO) of 12 km^2. The population of species seems to be declining, and its habitat is declining due to habitat disturbance caused by suburban expansion and as a tourism destination and recreation area, and it is therefore assessed as Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Appendix 5.4. Global draft assessment

Verbascum deserticola var. ***deserticola***

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: None.

Common Names: None.

Taxonomic notes: *Verbascum deserticola* var. *deserticola* can be distinguished from var. *sheilae* (Hemaid) A.Alzahrani by its ovate-obovate to lanceolate leaves, serrate to sinuate margins, yellowish or grey green lamina with rough tomentose with stellate hairs, and 1 – 6.5 cm petiole (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum deserticola* var. *deserticola* is an endemic variety widespread from northwest to western Saudi Arabia, with an extent of occurrence (EOO) of 21,906 km^2 and an area of occupancy (AOO) of 36 km^2.

Area of Occupancy (AOO): 36 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common variety from northwest to western Saudi Arabia.

Extent of Occurrence (EOO): 21,906 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common variety from northwest to western Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Elevation: 400 – 1300 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population is stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The variety grows on rocky black hillsides, rocky slopes, roadsides, and among fallen rocks in wadis (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: No.

Qualification: Observed.

Justification: It is a common variety from northwest to western Saudi Arabia, with no continuing decline or threats.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The variety is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no threats to the variety in Saudi Arabia.

Selections for Threats: No past, ongoing, or future threats exist to this species.

Conservation

Conservation Actions Information: There are no current conservation actions for this taxon, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, it occurs near or within the protected areas of Hisma, Harrat ‘Uwayrid, and Jabal Radwa (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The variety occurs near or within the protected areas of (Hisma, Harrat ‘Uwayrid, and Jabal Radwa).

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: LC

Rationale for the Red List Assessment: *Verbascum deserticola* var. *deserticola* is an endemic taxon widespread from northwest to western Saudi Arabia, with an extent of occurrence (EOO) of 21,906 km^2 and an area of occupancy (AOO) of 36 km^2. It is not currently experiencing any major threats and no significant future threats have been identified. This species is therefore assessed as Least Concern.

Reason(s) for Change: None.

Bibliography and Sources:

- Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.
- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.

Appendix 5.5. Global draft assessment

Verbascum deserticola var. ***sheilae***

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: *Verbascum sheilae* Hemaid, Pakistan J. Bot. 33(4): 324 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum deserticola* var. *sheilae* can be distinguished from var. *deserticola* by its oblong-lanceolate leaves, deeply crenate to sinuate margins, yellowish-green lamina with dense stellate hairs, and 0.5 – 1.5 cm petiole (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum deserticola* var. *sheilae* is an endemic variety to northwest Saudi Arabia, known only from the type locality in Tabuk province. Both extent of occurrence (EOO) and area of occupancy (AOO) are 24 km^2.

Area of Occupancy (AOO): 24 km^2.

Decline: Yes.

Qualification: Observed.

Justification: It is known only from the type locality in Wadi Al-Disah in Tabuk province, northwest Saudi Arabia.

Extent of Occurrence (EOO): 24 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from the type locality in Wadi Al-Disah in Tabuk province, northwest Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 1.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: It is known only from the type locality in Wadi Al-Disah in Tabuk province, northwest Saudi Arabia, with continuing decline, and its locality is threatened by agricultural expansion, vehicle tracks, and by tourism destination and recreation.

Very restricted: Yes.

Justification: It is known only from the type locality in Wadi Al-Disah in Tabuk province, northwest Saudi Arabia.

Elevation: 400 – 1300 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population seems to be declining and it includes less than 50 mature individuals.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Observed.

Number of mature individuals: less than 50.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: It grows on rocky black hillsides, rocky slopes, roadsides, and among fallen rocks in wadis (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: Its habitat seems to be declining due to agricultural expansion, vehicle tracks, tourism and recreation.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The variety is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats are continuing affecting this taxon; and its locality is threatened by agricultural expansion, vehicle tracks, tourism and recreation.

Selections for Threats: Yes.

- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this taxon, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, it occurs within the Jabal Qaraqir protected area (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. It occurs within the Jabal Qaraqir protected area.

Percentage of population protected by PAs (0-100): 100%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications.
- Land/water management -> Site/area management.

Research Needed:

- Monitoring -> Population trends.
- Conservation Planning -> Species Action/Recovery Plan.

Red List Assessment

Red List Criteria: CR B1ab(i,ii,iii,iv); C2a(i); D

Rationale for the Red List Assessment: *Verbascum deserticola* var. *sheilae* is an endemic variety to northwest Saudi Arabia, known only from the type locality in Tabuk province, with an extent of occurrence (EOO) and area of occupancy (AOO) of 24 km^2. It is assessed as Critically Endangered due to its continuing decline in EOO, AOO, habitat quality and area, and the number of locations. The population of taxon seems to be declining and it includes less than 50 mature individuals, as well as its locality is threatened by agricultural expansion, vehicle tracks, and by tourism and recreation.

Reason(s) for Change: None.

Bibliography and Sources:

- Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.
- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.

Appendix 5.6. Regional Saudi Arabia draft assessment

Verbascum eremobium Murb. in Lunds Univ. Arsskrift, N. F. xxix. No. 2 p. 458 (1933).

Ref: Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Photograph: Yes.

General information

Synonyms: *Verbascum tabukum* Hemaid, Pakistan J. Bot. 33(4): 327 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: *Desert mullein* (English) (Alzahrani *et al*., see Chapter 4).

Taxonomic notes: *Verbascum eremobium* is closely related to *V. schimperianum* Boiss. by its dense rough tomentose with stellate hairs, branched from the base, woody base, five stamens, and all anthers reniform, but differs in having dichasium inflorescence with bracteoles, calyx lobes lanceolate, filaments red with red-purple hairs, and globose-subglobose capsule (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum eremobium* is found in Saudi Arabia, Lebanon, Jordan, Syria, Palestine, and Egypt (Sinai). The species is widespread in Tabuk province in northwest Saudi Arabia, with an extent of occurrence (EOO) of 5,294 km^2 and an area of occupancy (AOO) of 32 km^2.

Area of Occupancy (AOO): 32 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common species in Tabuk province in northwest Saudi Arabia.

Extent of Occurrence (EOO): 5,294 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in Tabuk province in northwest Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in Tabuk province in northwest Saudi Arabia.

Elevation: 915 – 1420 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: Most population of this species is stable, except for one subpopulation that is declining.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on rocky black hillsides, barren rocky wadis, and roadsides (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Desert -> Desert - Hot/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The quality and area of its habitat is declining due to suburban expansion and as a tourism destination and recreation area.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no major threats to the species, except for one subpopulation that is threatened by suburban expansion and tourism and recreation.

Selections for Threats: Yes.

- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.
- Residential & commercial development -> Housing & urban areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no *in situ* nor *ex situ* conservation actions currently targeting this species. However, the *V. eremobium* occurs near or within protected areas, namely in Hisma and Jabal Al-Lawz Reserve (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within protected areas, namely in Hisma and Jabal Al-Lawz Reserve.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: None.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Monitoring -> Population trends.
- Monitoring -> Habitat trends.

Red List Assessment

Red List Criteria: NT B1b(iii)+2b(iii)

Rationale for the Red List Assessment: *Verbascum eremobium* is widespread in northwest Saudi Arabia, with an extent of occurrence (EOO) of 5,294 km^2 and an area of occupancy (AOO) of 32 km^2. Most population of this species is stable, except for one subpopulation that is declining. However, it is observed that the quality and area of its habitat is declining due to suburban expansion and tourism and recreation, and it is therefore assessed as Near Threatened.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Appendix 5.7. Global draft assessment

Verbascum longibracteatum Defl., Bull. Soc. Bot. France 43: 218 (1896).

Ref: Deflers A. 1896. Descriptions De Quelques Plantes Nouvelles Ou Peu Connues De L'ARABIE Meridionale. In: *Bulletin de la Société botanique de France*, 3rd ed. Paris: Au Sieoe De La Societe, pp.218-219.

Photograph: Yes.

General information

Synonyms: *Verbascum luntii* Baker, Bull. Misc. Inform. Kew (93): 337 (1894).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: *Zohara* (Arabic) (Alzahrani *et al*., see Chapter 4).

Taxonomic notes: *Verbascum longibracteatum* is a very distinctive and variable species in Saudi Arabia and Yemen (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum longibracteatum* is an endemic species widespread in the southwestern Arabian Peninsula (Saudi Arabia and Yemen), with an extent of occurrence (EOO) of 211,736 km^2 and an area of occupancy (AOO) of 128 km^2.

Area of Occupancy (AOO): 128 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common species in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

Extent of Occurrence (EOO): 211,736 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

Elevation: 300 – 2750 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia and Yemen.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in roadsides, rocky slopes, and edge of wadis (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Estimated.

Justification: The species' habitat seems to be declining due to human intrusions and disturbances caused by war and civil unrest.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia and Yemen.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the species in Saudi Arabia; however, it is estimated that the quality and area of the habitat of this species in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest.

Selections for Threats: Yes.

- Human intrusions & disturbance -> War, civil unrest & military exercises/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. longibracteatum* occurs near or within the Asir National Park and Jabal al-Qahar in protected areas Saudi Arabia (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within the Asir National Park and Jabal al-Qahar protected areas in Saudi Arabia.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.

Red List Assessment

Red List Criteria: NT B1b(iii)+2b(iii)

Rationale for the Red List Assessment: *Verbascum longibracteatum* is widespread throughout its distribution range distribution in Saudi Arabia and Yemen, with an extent of occurrence (EOO) of 211,736 km^2 and an area of occupancy (AOO) of 128 km^2. It is not currently experiencing any major threats and no significant future threats have been identified in Saudi Arabia, but it is estimated that the quality and area of its habitat in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest. More specific information about the threats affecting *V. longibracteatum* in Yemen is currently unavailable. This species is therefore assessed as Near Threatened.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.

- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.
- Wood J R I. 1997. A Handbook of the Yemen Flora. Royal Botanic Gardens, Kew.

Appendix 5.8. Global draft assessment

Verbascum medinecum Hemaid, Pakistan J. Bot. 33(4): 321 (2001).

Ref: Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.

Photograph: Yes.

General information

Synonyms: *Verbascum hema-figranum* Hemaid, Pakistan J. Bot. 33(4): 321 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum medinecum* is distinctive species in Saudi Arabia. In addition, the species name is sometimes miss-spelt as '*medinicum*' (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum medinecum* is an endemic species that is found in three locations, including the type locality in the province of Medina in western Saudi Arabia, with an extent of occurrence (EOO) of 2,676 km^2 and an area of occupancy (AOO) of 24 km^2.

Area of Occupancy (AOO): 24 km^2.

Decline: Yes.

Qualification: Observed.

Justification: It is known only from three locations, including the type locality in the Hijaz mountains in western Saudi Arabia (Jabal Al-Figrah, Jabal Odks, and Jabal Radwa).

Extent of Occurrence (EOO): 2,676 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from three locations, including the type locality in the Hijaz mountains in western Saudi Arabia (Jabal Al-Figrah, Jabal Odks, and Jabal Radwa).

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 3.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: The species is found in three locations in Medina province, with continuing decline, and the type locality in Jabal Al-Figrah is under threat caused by suburban, agricultural expansion, overgrazing, vehicle tracks, and as a tourism destination and recreation area, also its other location in Jabal Odks is suffering from extreme drought and overgrazing. However, the subpopulation in Jabal Radwa seems to be stable.

Very restricted: No.

Elevation: 1730 – 1981 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of this species seems to be declining. However, the subpopulation in Jabal Radwa seems to be stable.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Observed.

Number of mature individuals: Less than 250.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on rocky slopes, gravelly or sandy wadis, roadsides, and abandoned old gardens (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Artificial/Terrestrial -> Artificial/Terrestrial - Rural Gardens/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The species' habitat seems to be declining due to suburban, agricultural expansion, overgrazing, vehicle tracks, and as a tourism destination and recreation area, also suffering from extreme drought.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats seems to be causing a continuing decline of this species. The type locality in Jabal Al-Figrah is threatened by suburban, agricultural expansion, overgrazing, vehicle tracks, and by tourism and recreation; the other location in Jabal Odks is suffering from extreme drought and overgrazing.

Selections for Threats: Yes.

- Agriculture & aquaculture -> Livestock farming & ranching -> Nomadic grazing/ Ongoing/ Minority (<50%)/ Causing/Could cause fluctuations/ 2.

- Residential & commercial development -> Housing & urban areas/ Ongoing/ Majority (50-90%)/ Slow, Significant Declines/ 1.
- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.
- Climate change & severe weather -> Droughts/ Ongoing/ Majority (50-90%)/ Negligible declines/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. medinecum* occurs within the protected area Jabal Radwa (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs within the protected area Jabal Radwa.

Percentage of population protected by PAs (0-100): 1 - 10%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications
- Land/water management -> Site/area management.
- Species management -> Species recovery

Research Needed:

- Research -> Population size, distribution & trends.
- Monitoring -> Population trends.
- Monitoring -> Habitat trends.

Red List Assessment

Red List Criteria: EN B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum medinecum* is an endemic species that is found in three locations, including the type locality in the province of Medina in western Saudi Arabia, with an extent of occurrence (EOO) of 2,676 km^2 and an area of occupancy (AOO) of 24 km^2. The population of species seems to be declining in Jabal Al-Figrah and Jabal Odks, however, the subpopulation in Jabal Radwa seems to be stable. The type locality in Jabal Al-Figrah is threatened by suburban, agricultural expansion, overgrazing, vehicle tracks, and by tourism and recreation; the other location in Jabal Odks is suffering from extreme drought and overgrazing. This species is therefore assessed as Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.
- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.

Appendix 5.9. Global draft assessment

Verbascum melhanense (Murb.) Huber-Morath, Bauhinia 5(1): 14 (1973).

Ref: Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.

Photograph: Yes.

General information

Synonyms: *Celsia melhanensis* Murb. in Lunds Univ. Arsskrift, n. f. xxii. No.1, 155 (1925).

Ref: Murbeck S. 1925. Monographie der Gattung *Celsia*. Acta Univ. Lund. 22: 1 – 20.

Common Names: None.

Taxonomic notes: *Verbascum melhanense* is easily confused with the closely related species *V. bottae* (Defl.) Huber-Morath due to their similar morphology and habitats, but it can be distinguished by its two anterior glabrous filaments and transversally elongated seeds (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum melhanense* is an endemic species widespread in the southwestern Arabian Peninsula (Saudi Arabia and Yemen), with an extent of occurrence (EOO) of 28,882 km^2 and an area of occupancy (AOO) of 92 km^2.

Area of Occupancy (AOO): 92 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common species in the Asir mountains in Saudi Arabia and highlands in Yemen, in the southwestern Arabian Peninsula.

Extent of Occurrence (EOO): 28,882 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the Asir mountains in Saudi Arabia and highlands in Yemen, in the southwestern Arabian Peninsula.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in the Asir mountains in Saudi Arabia and highlands in Yemen, in the southwestern Arabian Peninsula.

Elevation: 1600 – 2600 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia and Yemen.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on rocky slopes, limestone cliffs, terrace walls, granite crevices, and wadi banks (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Estimated.

Justification: The species' habitat in Yemen seems to be declining due to human intrusions and disturbances caused by war and civil unrest.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia and Yemen.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the species in Saudi Arabia; however, it is estimated that the quality and area of the habitat of this species in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest.

Selections for Threats: Yes.

- Human intrusions & disturbance -> War, civil unrest & military exercises/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. melhanense* occurs near or within Wadi Turbah, Raidah Sanctuary, Asir National Park, and Ballasmar protected areas in Saudi Arabia (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within Wadi Turbah, Raidah Sanctuary, Asir National Park, and Ballasmar protected areas in Saudi Arabia.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.

Red List Assessment

Red List Criteria: NT B1b(iii)+2b(iii)

Rationale for the Red List Assessment: *Verbascum melhanense* is widespread throughout its distribution range distribution in Saudi Arabia and Yemen, with an extent of occurrence (EOO) of 28,882 km^2 and an area of occupancy (AOO) of 92 km^2. It is not currently experiencing any major threats and no significant future threats have been identified in Saudi Arabia, but it is estimated that the quality and area of its habitat in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest. More specific information about the threats affecting *V. melhanense* in Yemen is currently unavailable. This species is therefore assessed as Near Threatened.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.

- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Huber-Morath A. 1973. *Verbascum* L. s. 1. (incl. *Celsia* L. et *Staurophragma* Fisch. & Mey.). Bauhinia.
- Murbeck S. 1925. Monographie der Gattung *Celsia*. Acta Univ. Lund. 22: 1 – 20.
- Wood J R I. 1997. A Handbook of the Yemen Flora. Royal Botanic Gardens, Kew.

Appendix 5.10. Global draft assessment

Verbascum omanense Huber-Morath, Candollea 39(1): 320 (1984).

Ref: Huber-Morath A. 1984. *Verbascum omanense* Hub.-Mor., ein neues Verbascum aus Oman. Candollea, 39(1) 319 - 321.

Photograph: Yes.

General information

Synonyms: None

Common Names: *Metah* (Arabic) (Alzahrani *et al*., see Chapter 4).

Taxonomic notes: *Verbascum omanense* is a distinct species, but its highly variable leaves, bracts, bracteoles, and margin shapes have previously led to confusion with the closely related *V. sinaiticum* Benth. (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum omanense* is an endemic species widespread in the Hajar foothills and mountains to the northeast of Oman and the United Arab Emirates, with an extent of occurrence (EOO) of 19,039 km^2 and an area of occupancy (AOO) of 80 km^2.

Area of Occupancy (AOO): 80 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman and the United Arab Emirates.

Extent of Occurrence (EOO): 19,039 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman and the United Arab Emirates.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in the Hajar foothills and mountains northeast of Oman and the United Arab Emirates.

Elevation: 100 – 800 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: No.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Oman and the United Arab Emirates.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Estimated.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in abandoned or date gardens, roadsides, and rocky wadis beds (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Artificial/Terrestrial -> Artificial/Terrestrial - Rural Gardens/ Resident/ Suitable/ Yes.

Decline in Habitat: No.

Qualification: Estimated.

Justification: The species is found in eight locations throughout the Hajar foothills and mountains northeast of Oman and the United Arab Emirates.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Oman and the United Arab Emirates.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the species in Oman and the United Arab Emirates.

Selections for Threats: No past, ongoing, or future threats exist to this species.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. omanense* occurs near or within Al Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve, Al Jabal Al Akhdar Scenic Reserve in Oman, and Hatta Mountain Reserve in UAE (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within Al Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve, Al Jabal Al Akhdar Scenic Reserve in Oman, and Hatta Mountain Reserve in UAE.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: LC

Rationale for the Red List Assessment: *Verbascum omanense* is an endemic species widespread throughout the Hajar foothills and mountains northeast of Oman and the United Arab Emirates, it is not currently experiencing any major threats and no significant future threats have been identified. This species is therefore assessed as Least Concern.

Reason(s) for Change: The species was assessed as Data Deficient (Patzelt, 2015) due to its taxonomic status and lack of geographic distribution information. Recent taxonomic revision and phylogenetic studies (Alzahrani *et al*., see Chapter 3) confirmed the taxonomic status of this species, which is a distinct species among the Arabian *Verbascum*.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Ghazanfar S A. 1992. An annotated catalogue of the vascular plants of Oman and their vernacular names. Scripta Botanica Belgica.
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- Huber-Morath A. 1984. *Verbascum omanense* Hub.-Mor., ein neues Verbascum aus Oman. Candollea, 39(1) 319 - 321.
- Jongbloed M, Feulner G, Böer B, Western A R. 2003. The Comprehensive Guide to the Wild Flowers of the United Arab Emirates. Abu Dhabi, UAE: Environmental Research and Wildlife Development Agency.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.
- Patzelt A. 2015. Oman Plant Red Data Book. Muscat, Sultanate of Oman: Al Roya Press.

Appendix 5.11. Global draft assessment

Verbascum sarawaticum A.Alzahrani, **sp. nov.**

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: None.

Common Names: None.

Taxonomic notes: *Verbascum sarawaticum* is closely related to *V. yemense* Defl. by its indumentum glabrescent or sparse stellate hairs above, and dense stellate hairs below, but differs in its growth life biennial, many-branched stems from the base, basal leaves elliptic-lanceolate, calyx lobes oblong, corolla with pellucid glands and with sparse ciliated hairs inside, filaments with whitish hairs, and capsule ovoid (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum sarawaticum* is an endemic species that is found in two locations in the Sarawat mountains in southwest Saudi Arabia, with an extent of occurrence (EOO) of 165 km^2 and an area of occupancy (AOO) of 16 km^2.

Area of Occupancy (AOO): 16 km^2.

Decline: Yes.

Qualification: Observed.

Justification: It is known only from two locations, including the type locality in the Sarawat mountains of southwestern Saudi Arabia (Red Mountain Baljurashi in Al-Baha and Near Al-Hada palm in Taif).

Extent of Occurrence (EOO): 165 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from two locations, including the type locality in the Sarawat mountains of southwestern Saudi Arabia (Red Mountain Baljurashi in Al-Baha and Near Al-Hada palm in Taif).

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 2.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: The species is found in two locations the Sarawat mountains in southwestern Saudi Arabia, with continuing decline, and the type locality in near Al-Hada palm is under threat caused by recreational activities, also its other location in Red Mountain is threatened by overgrazing.

Very restricted: Yes.

Justification: It is known only from two locations, including the type locality in the Sarawat mountains of southwestern Saudi Arabia (Red Mountain Baljurashi in Al-Baha and Near Al-Hada palm in Taif).

Elevation: 1600 – 1980 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of this species seems severely fragmented and continues to decline.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Observed.

Number of mature individuals: less than 250.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on granite rubbles and roadsides (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The quality and area of this species' habitat seems to be declining mainly due to overgrazing and recreational activities.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: The type locality in near Al-Hada palm is threatened by recreational activities and the other locality, in the Red Mountain, is suffering from overgrazing. The species seems to be in continuing decline.

Selections for Threats: Yes.

- Human intrusions & disturbance -> Recreational activities/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

- Agriculture & aquaculture -> Livestock farming & ranching -> Nomadic grazing/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations / 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. However, *V. sarawaticum* is known to occur near or within existing protected areas. (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: No. The species is not known to occur near or within existing protected areas.

Percentage of population protected by PAs (0-100): None.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications.
- Land/water management -> Site/area management.

Research Needed:

- Conservation Planning -> Species Action/ Recovery Plan.
- Monitoring -> Population trends.
- Monitoring -> Habitat trends.

Red List Assessment

Red List Criteria: EN B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum sarawaticum* is an endemic species that is found in two locations in the Sarawat mountains in southwest Saudi Arabia, with an

extent of occurrence (EOO) of 165 km^2 and an area of occupancy (AOO) of 16 km^2. The population of this species seems severely fragmented and continues to decline. The type locality near Al-Hada palm is under threat caused by recreational activities; also its other location in Red Mountain is threatened by overgrazing. *Verbascum sarawaticum* is therefore assessed as Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.

Appendix 5.12. Global draft assessment

Verbascum saudiarabicum (A.Alzahrani) A.Alzahrani, **comb. nov.**

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: *Rhabdotosperma saudiarabicum* A.Alzahrani, Kew Bull. 77(4): 987 (2022).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: Alzahrani *et al*. (2022) described *Rhabdotosperma saudiarabicum* as new species from Saudi Arabia; however, recent phylogenetic research (Alzahrani *et al*., see Chapter 3) confirms and supports the inclusion of *Rhabdotosperma* within *Verbascum*. Moreover, *Verbascum saudiarabicum* is morphologically similar to *V. bottae* (Defl.) Huber-Morath and *V. melhanense* (Murb.) Huber-Morath, but differs in its alternate leaves, oblong-ovate leaves, and two anterior anthers inserted obliquely on filaments (Alzahrani *et al*., 2022, see Chapter 4).

Distribution

Geographic Range: *Verbascum saudiarabicum* is an endemic species to Al-Soudah in the Asir Mountains in southwest Saudi Arabia, with an extent of occurrence (EOO) of 12 km^2 and an area of occupancy (AOO) of 11 km^2.

Area of Occupancy (AOO): 11 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from the type locality in Al-Soudah in the Asir Mountains in southwest Saudi Arabia. The species was last recorded in 1985 by Collenette. However, during fieldwork in Al-Soudah in 2019, 2020, and 2021, the first author failed to find it, indicating that it might be either very rare or extinct from the type locality.

Extent of Occurrence (EOO): 12 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from the type locality in Al-Soudah in the Asir Mountains in southwest Saudi Arabia. The species was last recorded in 1985 by Collenette. However, during fieldwork in Al-Soudah in 2019, 2020, and 2021, the first author failed to find it, indicating that it might be either very rare or extinct from the type locality.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 1.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: The species is found only in one location in Al-Soudah in the Asir Mountains in southwest Saudi Arabia, with continuing decline, and its type locality is threatened by suburban and agricultural expansion, colonisation by invasive species, and recently by tourism and recreation.

Very restricted: Yes.

Justification: The species is found only in one location in Al-Soudah in the Asir Mountains in southwest Saudi Arabia.

Elevation: 2500 – 3000 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of species seems to be declining.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Estimated.

Number of mature individuals: Less than 50.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in granite crevices and near streams (Alzahrani *et al*., 2022).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The area and quality of this species' habitat seems to be declining due to suburban and agricultural expansion, colonisation by invasive species, and recently by tourism and recreation.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats are continuing to affect this species; the area and quality of its habitat is declining due to suburban and agricultural expansion, colonisation by invasive species, and recently by tourism and recreation.

Selections for Threats: Yes.

- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.
- Residential & commercial development -> Housing & urban areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.
- Invasive and other problematic species, genes & diseases -> Invasive non-native/alien species/diseases -> Verbesina encelioides/ Ongoing/ Minority (<50%)/ Causing/Could cause fluctuations/ 1.
- Invasive and other problematic species, genes & diseases -> Invasive non-native/alien species/diseases -> Tagetes minuta/ Ongoing/ Minority/ (<50%)/ Causing/Could cause fluctuations / 1.
- Invasive and other problematic species, genes & diseases -> Invasive non-native/alien species/diseases -> Opuntia ficus-indica/ Ongoing/ Majority/ (50-90%)/ Causing/Could cause fluctuations / 1.
- Invasive and other problematic species, genes & diseases -> Invasive non-native/alien species/diseases -> Nicotiana glauca/ Ongoing/ Minority/ (<50%)/ Causing/Could cause fluctuations / 1.
- Invasive and other problematic species, genes & diseases -> Invasive non-native/alien species/diseases -> Argemone ochroleuca/ Ongoing/ Minority (<50%)/ Causing/Could cause fluctuations / 1.

Conservation

Conservation Actions Information: There are no *in situ* nor *ex situ* conservation actions currently targeting this species. However, *V. saudiarabicum* occurs within the Asir National Park (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs within the Asir National Park.

Percentage of population protected by PAs (0-100): 100%.

Subject to ex-situ conservation: No.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery

- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications.
- Land/water management -> Site/area management.

Research Needed:

- Conservation Planning -> Species Action/ Recovery Plan.
- Monitoring -> Population trends.
- Monitoring -> Habitat trends.

Red List Assessment

Red List Criteria: CR B1ab(iii); D

Rationale for the Red List Assessment: *Verbascum saudiarabicum* is an endemic species to Al-Soudah in the Asir Mountains in southwest Saudi Arabia, with an extent of occurrence (EOO) of 12 km^2 and an area of occupancy (AOO) of 11 km^2. The species was last recorded in 1985 by Collenette. However, during fieldwork in Al-Soudah in 2019, 2020, and 2021, the first author failed to find it, indicating that it might be either very rare or extinct from the type locality. The population of species seems to be declining, and its habitat is declining due to suburban and agricultural expansion, colonisation by invasive species, and recently by tourism and recreation. This species is therefore assessed as Critically Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani A M, Brehm J M, Ghazanfar S A, Nigel M. 2022. *Rhabdotosperma saudiarabicum* (Scrophulariaceae), a new species from Saudi Arabia. Kew Bull 77, 987–992 (2022). https://doi.org/10.1007/s12225-022-10063-y
- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.

Appendix 5.13. Regional Saudi Arabia draft assessment

Verbascum schimperianum Boiss. Diagn. Pl. Orient. ser. 1, 12: 11 (1853).

Ref: Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Photograph: Yes.

General information

Synonyms: *Verbascum crispum* Ehrenb. ex Boiss., Fl. Orient. 4(2): 341 (1879).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum schimperianum* is closely related to *V. eremobium* Murb. by its dense rough tomentose with stellate hairs, branched from the base, woody base, five stamens, and all anthers reniform, but differs in having racemose inflorescence without bracteoles, calyx lobes ovate-elliptic, filaments yellow with yellow hairs, and ellipsoid-ovoid capsule (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum schimperianum* is found in Saudi Arabia, Jordan, Palestine, and Egypt (Sinai). In Saudi Arabia, the species is known from one location in the northwest, with an extent of occurrence (EOO) of 51 km^2 and an area of occupancy (AOO) of 12 km^2.

Area of Occupancy (AOO): 12 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: This species was collected from one location Wadi Sawawin in 1978 by Sheila Collenette; otherwise, it has not been collected since that. Recent observations were made by locals in Ain Al-Shayatei and surrounding areas near Wadi Sawawin, but no specimens were collected.

Extent of Occurrence (EOO): 51 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: This species was collected from one location Wadi Sawawin in 1978 by Sheila Collenette; otherwise, it has not been collected since that. Recent observations were made by locals in Ain Al-Shayatei and surrounding areas near Wadi Sawawin, but no specimens were collected.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 1.

Continuing decline in number of locations: Yes

Qualification: Estimated.

Justification: The species is found in one location in Tabuk province, its habitat is declining due to human intrusions and disturbances caused by recreational activities.

Very restricted: Yes.

Justification: This species was collected from one location Wadi Sawawin in 1978 by Sheila Collenette; otherwise, it has not been collected since that. Recent observations were made by locals in Ain Al-Shayatei and surrounding areas near Wadi Sawawin, but no specimens were collected.

Elevation: 600 – 1280 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of species seems to be declining.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Estimated.

Number of mature individuals: Less than 50.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on among rocks in wadis edge and granite sand in lava (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Desert -> Desert - Hot/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The species' habitat seems to be declining due to human intrusions and disturbances caused by recreational activities.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats are continuing affecting this species leading to a continuing decline; habitat of Wadi Sawawin is threatened by human intrusions and disturbances caused by recreational activities.

Selections for Threats: Yes.

- Human intrusions & disturbance -> Recreational activities/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no *in situ* nor *ex situ* conservation actions currently targeting this species. However, *V. schimperianum* occurs near protected areas (Hisma and Jabal Dabbagh Nature Reserve) (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: No. The species occurs near protected areas (Hisma and Jabal Dabbagh Nature Reserve).

Percentage of population protected by PAs (0-100): None.

Subject to ex-situ conservation: None.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.

Red List Assessment

Red List Criteria: CR B1ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum schimperianum* is known from one location in northwest Saudi Arabia, with an extent of occurrence (EOO) of 51 km^2 and an area of occupancy (AOO) of 12 km^2. This species was collected from one location Wadi Sawawin in 1978 by Sheila Collenette; otherwise, it has not been collected since that. Recent observations were made by locals in Ain Al-Shayatei and surrounding areas near Wadi Sawawin, but no specimens were collected. The population of species seems to be

declining, and its habitat is declining due to human intrusions and disturbances caused by recreational activities. This species is therefore assessed as Critically Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Appendix 5.14. Global draft assessment

Verbascum shiqricum Hemaid, Pakistan J. Bot. 33(4): 324 (2001).

Ref: Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.

Photograph: Yes.

General information

Synonyms: *Verbascum abyadicum* Hemaid, Pakistan J. Bot. 33(4): 316 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum shiqricum* is a very distinct and variable species in Saudi Arabia (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum shiqricum* is an endemic species widespread from northwest to western Saudi Arabia, with an extent of occurrence (EOO) of 39,174 km^2 and an area of occupancy (AOO) of 40 km^2.

Area of Occupancy (AOO): 40 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common species from northwest to western Saudi Arabia.

Extent of Occurrence (EOO): 39,174 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species from northwest to western Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species from northwest to western Saudi Arabia.

Elevation: 915 – 1680 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: Most population of this species is stable, except for one subpopulation that is declining.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in crevices of black lava, roadsides, and rocky sandstone (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Desert -> Desert - Hot/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The quality and area of its habitat is declining due to overgrazing.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no major threats to the species, except for one subpopulation that is threatened by overgrazing.

Selections for Threats: Yes.

- Agriculture & aquaculture -> Livestock farming & ranching -> Nomadic grazing/ Ongoing/ Minority (<50%)/ Causing/Could cause fluctuations/ 2.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. shiqricum* occurs near or within Jabal Qaraqir, Harrat ‘Uwayrid, Hisma, and Harrat Khaybar protected areas (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within Jabal Qaraqir, Harrat ‘Uwayrid, Hisma, and Harrat Khaybar protected areas.

Percentage of population protected by PAs (0-100): 11 – 20%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.
- Species management -> Species recovery.
- Education & awareness -> Awareness & communications.

Research Needed:

- Monitoring -> Population trends.

Red List Assessment

Red List Criteria: NT B1b(iii)+2b(iii)

Rationale for the Red List Assessment: *Verbascum shiqricum* is an endemic species widespread throughout its distribution range in Saudi Arabia, with an extent of occurrence (EOO) of 39,174 km^2 and an area of occupancy (AOO) of 40 km^2. Most population of this species is stable, except for one subpopulation that is declining. However, it is observed that the quality and area of its habitat is declining due to overgrazing, and it is therefore assessed as Near Threatened.

Reason(s) for Change: None.

Bibliography and Sources:

- Al-Hemaid F. 2001. Notes on *Verbascum* L., from Saudi Arabia with description of eight new species. Pakistan Journal of Botany, 33(4), pp.315-328.
- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.

Appendix 5.15. Regional Saudi Arabia draft assessment

Verbascum sinaiticum Benth. in DC., Prodr., X, p. 236 (1846).

Ref: Bentham G. 1846. Scrophulariaceae. In: De Candolle, *Prodromus Systematis Naturalis Regni Vegetabilis*, Vol. x. Paris. https://doi.org/10.5962/bhl.title.286

Photograph: Yes.

General information

Synonyms: *Verbascum fasciculatum* Ehrenb. ex Sweet, Hort. Brit., ed. II. p. 381 (1830). *Verbascum ternacha* Hochst. In: A. Rich. Tent. Fl. Abyss. II: 108. (1851). *Verbascum barradense* Boiss., Fl. Orient. 4(2): 318 (1879). *Verbascum somaliense* Baker, Bull. Misc. Inform. Kew 1895(105): 222 (1895). *Verbascum nubicum* Murb., in Lunds Univ. Arsskrift, n. f. xxix. No. 2. 293 (1933).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: *Qetetina* (English); *Aithnah*, *Albusira* (Arabic) (Alzahrani *et al*., see Chapter 4).

Taxonomic notes: *Verbascum sinaiticum* is a distinct species in Saudi Arabia (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum sinaiticum* is found in Saudi Arabia, Eritrea, Ethiopia, Kenya, Somalia, Sudan, Niger, Egypt, Iraq, Jordan, Lebanon, and Syria, and it also has been introduced to other regions. This species is widespread in the northwest of Saudi Arabia with an extent of occurrence (EOO) of 2,217 km^2 and an area of occupancy (AOO) of 36 km^2.

Area of Occupancy (AOO): 36 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common species in northwest Saudi Arabia.

Extent of Occurrence (EOO): 2,217 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common species in northwest Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common species in northwest Saudi Arabia.

Elevation: 1500 – 2800 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of species seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows in rocky slopes or granite, hillside, beds of sandy wadis, black lava, and roadsides (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Desert -> Desert - Hot/ Resident/ Suitable/ Yes.

Decline in Habitat: No.

Qualification: Observed.

Justification: It is a common species in northwest Saudi Arabia.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the species in Saudi Arabia.

Selections for Threats: No past, ongoing, or future threats exist to this species.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. sinaiticum* occurs near or within Jabal Qaraqir, Harrat ‘Uwayrid, Jabal Al-Lawz Reserve and Hisma protected areas (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near or within Jabal Qaraqir, Harrat ‘Uwayrid, Jabal Al-Lawz Reserve and Hisma protected areas.

Percentage of population protected by PAs (0-100): 51- 60%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Land/water management -> Site/area management.

Research Needed:

- Monitoring -> Population trends.
- Monitoring -> Habitat trends.

Red List Assessment

Red List Criteria: LC

Rationale for the Red List Assessment: *Verbascum sinaiticum* is widespread throughout its distribution range distribution in Saudi Arabia as well as neighbouring countries, it is not currently experiencing any major threats and no significant future threats have been identified. This species is therefore assessed as Least Concern.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.

Appendix 5.16. Regional Saudi Arabia draft assessment

Verbascum transjordanicum Murb. in Lunds Univ. Arsskrift, n. f. xxxv. No. 1 54 (1939).

Ref: Murbeck S (1939) Weitere Studien über die Gattungen *Verbascum* und *Celsia*. Acta Univ. Lund. 35: 1 – 70

Photograph: Yes.

General information

Synonyms: None.

Common Names: *Transjordan Mullein* (English), *Abu Ain* (Arabic) (Alzahrani *et al*., see Chapter 4).

Taxonomic notes: *Verbascum transjordanicum* is a distinct species in Saudi Arabia (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum transjordanicum* is found in Jordan and Saudi Arabia. This species is an exceedingly rare, and it is known from one location in the northern Saudi Arabia, both its extent of occurrence (EOO) and area of occupancy (AOO) are 8 km^2.

Area of Occupancy (AOO): 8 km^2.

Decline: Yes.

Qualification: Observed.

Justification: It is known only from one location in Turaif province in northern Saudi Arabia.

Extent of Occurrence (EOO): 8 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known only from one location in Turaif province in northern Saudi Arabia.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 1.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: The species is found in one location in Turaif province, with continuing decline, and it is under threat of habitat disturbance from overgrazing and vehicle tracks.

Very restricted: Yes.

Justification: It is known only from one location in Turaif province in northern Saudi Arabia.

Elevation: 600 – 832 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: None.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of species seems to be declining.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Observed.

Number of mature individuals: less than 50.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The species grows on a limestone plateau with basalt rock (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Desert -> Desert - Hot/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The species' habitat seems to be declining due to habitat disturbance from overgrazing and vehicle tracks.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The species is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Threats are continuing affecting this species leading to a continuing decline; its habitat is threatened by overgrazing and vehicle tracks.

Selections for Threats: Yes.

- Agriculture & aquaculture -> Livestock farming & ranching -> Nomadic grazing/ Ongoing/ Minority (<50%)/ Causing/Could cause fluctuations/ 2.

Conservation

Conservation Actions Information: There are no current conservation actions for this species, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, *V. transjordanicum* occurs near the protected area (King Salman Bin Abdulaziz Royal Natural Reserve) (Alzahrani *et al*., (see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The species occurs near the protected area (King Salman Bin Abdulaziz Royal Natural Reserve).

Percentage of population protected by PAs (0-100): None.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications.
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.
- Research -> Threats.
- Conservation Planning -> Species Action/Recovery Plan.
- Monitoring -> Population trends.

Red List Assessment

Red List Criteria: CR B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum transjordanicum* is an exceedingly rare species, and it is known from one location in northern Saudi Arabia; both its extent of occurrence (EOO) and area of occupancy (AOO) are 8 km^2. The population of species seems to be declining, and its habitat is declining due to overgrazing and vehicle tracks. This species is therefore assessed as Critically Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.

- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1939. Weitere Studien über die Gattungen *Verbascum* und *Celsia*. Acta Univ. Lund. 35: 1 – 70

Appendix 5.17. Global draft assessment

Verbascum yemense var. ***asiricum***

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: *Verbascum asiricum* Hemaid, Pakistan J. Bot. 33(4): 316 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum yemense* var. *asiricum* can be distinguished from var. *yemense* by its long pedicels which are up to 15 mm long whereas var. *yemense* is up to 5 mm long (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum yemense* var. *asiricum* is an endemic variety to southwestern Saudi Arabia, occurring in four locations in Abha province; it presents an extent of occurrence (EOO) of 23 km^2 and an area of occupancy (AOO) of 20 km^2.

Area of Occupancy (AOO): 20 km^2.

Decline: Yes.

Qualification: Observed.

Justification: It is known from four locations in Saudi Arabia (Dalagan areas, near Souk Al-Ithnayn, Al-Fara, and near Tamniah village).

Extent of Occurrence (EOO): 23 km^2.

Decline: Yes.

Qualification: Estimated.

Justification: It is known from four locations in Saudi Arabia (Dalagan areas, near Souk Al-Ithnayn, Al-Fara, and near Tamniah village).

EOO estimate calculated from Minimum Convex Polygon: Yes.

Number of Locations: 4.

Continuing decline in number of locations: Yes

Qualification: Observed.

Justification: The variety is found in four locations in Saudi Arabia, with continuing decline, and the type locality in near Souk Al-Ithnayn is under threat caused by suburban and agricultural expansion, and by tourism and recreation, also its other location in Dalagan areas is under threat by tourism and recreation. However, the subpopulations in Al-Fara and near Tamniah village seems to be stable.

Very restricted: Yes.

Justification: It is known from four locations in Saudi Arabia (Dalagan areas, near Souk Al-Ithnayn, Al-Fara, and near Tamniah village).

Elevation: 1800 – 2500 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia.

Population

Population Information: The population of this variety seems to be declining. However, the subpopulations in Al-Fara and near Tamniah village seems to be stable.

Population: Decreasing.

Current Population Trend: Decreasing.

Current trend data derivation: Observed.

Number of mature individuals: Less than 250.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: It grows on roadsides and abandoned gardens (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Artificial/Terrestrial -> Artificial/Terrestrial - Rural Gardens/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Observed.

Justification: The quality and area of its habitat seems to be declining due to suburban and agricultural expansion, and by tourism and recreation.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: It is not used or traded in Saudi Arabia.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: Major threats to the type locality near Souk Al-Ithnayn include suburban and agricultural expansion, and tourism and recreation; the localities in the Dalagan areas are threatened by tourism destination and recreation.

Selections for Threats: Yes.

- Residential & commercial development -> Tourism & recreation areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.
- Residential & commercial development -> Housing & urban areas/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this variety, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, var. *asiricum* is not known to occur near or within existing protected areas (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: No. The variety is not known to occur near or within existing protected areas.

Percentage of population protected by PAs (0-100): None.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications
- Land/water management -> Site/area management.
- Species management -> Species recovery

Research Needed:

- Monitoring -> Population trends.

Red List Assessment

Red List Criteria: EN B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv); D

Rationale for the Red List Assessment: *Verbascum yemense* var. *asiricum* is an endemic variety known from four locations in Abha province in southwestern Saudi Arabia. It has an extent of occurrence (EOO) of 23 km^2 and an area of occupancy (AOO) of 20 km^2. The population of this variety near Souk Al-Ithnayn and Dalagan areas seems to be continuously declining; however, the subpopulations in Al-Fara and near Tamniah village seem to be stable. The type locality near Souk Al-Ithnayn include suburban and

agricultural expansion, and tourism and recreation; the localities in the Dalagan areas are threatened by tourism destination and recreation. It is therefore assessed as Endangered.

Reason(s) for Change: None.

Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.

Appendix 5.18. Global draft assessment

Verbascum yemense var. ***yemense***

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Photograph: Yes.

General information

Synonyms: *Verbascum chaudharyanum* Hemaid, Pakistan J. Bot. 33(4): 318 (2001).

Ref: Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.

Common Names: None.

Taxonomic notes: *Verbascum yemense* var. *yemense* can be distinguished from var. *asiricum* (Hemaid) A.Alzahrani by its short pedicels which is up to 5 mm long whereas var. *asiricum* is up to 15 mm long (Alzahrani *et al*., see Chapter 4).

Distribution

Geographic Range: *Verbascum yemense* var. *yemense* is an endemic variety which is widespread in the southwestern Arabian Peninsula (Saudi Arabia and Yemen), with an extent of occurrence (EOO) of 63,247 km^2 and an area of occupancy (AOO) of 136 km^2.

Area of Occupancy (AOO): 136 km^2.

Decline: No.

Qualification: Observed.

Justification: It is a common variety in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

Extent of Occurrence (EOO): 63,247 km^2.

Decline: No.

Qualification: Estimated.

Justification: It is a common variety in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

EOO estimate calculated from Minimum Convex Polygon: Yes.

Very restricted: No.

Justification: It is a common variety in Saudi Arabia and Yemen, in the southwestern Arabian Peninsula.

Elevation: 1800 – 2500 m.

Map: The distribution map was generated using QGIS software version 3.22. (2022).

Biogeographic Realm: Palearctic.

Hotspot: Horn of Africa and Eastern Afromontane.

UN MDG Region: Western Asia.

Occurrence

Countries of Occurrence: Saudi Arabia and Yemen.

Population

Population Information: The population of this variety seems to be stable with several subpopulations.

Population: Stable.

Current Population Trend: Stable.

Current trend data derivation: Observed.

Number of mature individuals: -.

Year of Population Estimate: 2022.

Habitats and ecology

Habitats and ecology: The variety grows on roadsides and abandoned gardens (Alzahrani *et al*., see Chapter 4).

Habitats Classification Scheme:

- Rocky areas (eg. inland cliffs, mountain peaks)/ Resident/ Suitable/ Yes.
- Artificial/Terrestrial -> Artificial/Terrestrial - Rural Gardens/ Resident/ Suitable/ Yes.

Decline in Habitat: Yes.

Qualification: Estimated.

Justification: The quality and area of its habitat seems to be declining due to human intrusions and disturbances caused by war and civil unrest in Yemen.

System: Terrestrial.

Wild relative of a crop: No.

Plant growth forms: Forb or Herb.

Trade

Use or trade: The variety is not used or traded in Saudi Arabia and Yemen.

Species not utilized: Yes.

No use/trade information for this species: Yes.

Threats

Threats Information: There are no known threats to the variety in Saudi Arabia; however, It is estimated that the quality and area of the habitat of this variety in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest.

Selections for Threats: Yes.

- Human intrusions & disturbance -> War, civil unrest & military exercises/ Ongoing/ Majority (50-90%)/ Causing/Could cause fluctuations/ 1.

Conservation

Conservation Actions Information: There are no current conservation actions for this variety, but seeds and DNA samples were collected and conserved in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023. In addition, var. *yemense* occurs near or within several protected areas, namely in Jabal Al-Balas, Ballasmar, Wadi Tayyah, Asir National Park and Hima Thumalah in Saudi Arabia, and Haraz Wildlife Sanctuary in Yemen (Alzahrani *et al*., see Chapter 4).

Action Recovery Plan: No.

Conservation Actions In-Place: No.

Occur in at least one PA: Yes. The variety occurs near or within existing protected areas (Jabal Al-Balas, Ballasmar, Wadi Tayyah, Asir National Park and Hima Thumalah in Saudi Arabia, and Haraz Wildlife Sanctuary in Yemen).

Percentage of population protected by PAs (0-100): 21 – 30%.

Subject to ex-situ conservation: Seeds and DNA collections were collected and stored in King Abdulaziz City for Science and Technology (MUZ) in Riyadh, Saudi Arabia in 2023.

Important Conservation Actions Needed:

- Species management -> Ex-situ conservation -> Captive breeding/artificial propagation.
- Species management -> Species recovery
- Land/water protection -> Site/area protection.
- Education & awareness -> Formal education.
- Education & awareness -> Awareness & communications
- Land/water management -> Site/area management.

Research Needed:

- Research -> Population size, distribution & trends.

Red List Assessment

Red List Criteria: LC

Rationale for the Red List Assessment: *Verbascum yemense* var. *yemense* is widespread throughout its distribution range distribution in Saudi Arabia and Yemen, it is not currently experiencing any major threats and no significant future threats have been identified in Saudi Arabia, but it is estimated that the quality and area of its habitat in Yemen is declining due to human intrusions and disturbances caused by war and civil unrest. This species is therefore assessed as Least Concern.

Reason(s) for Change: None.

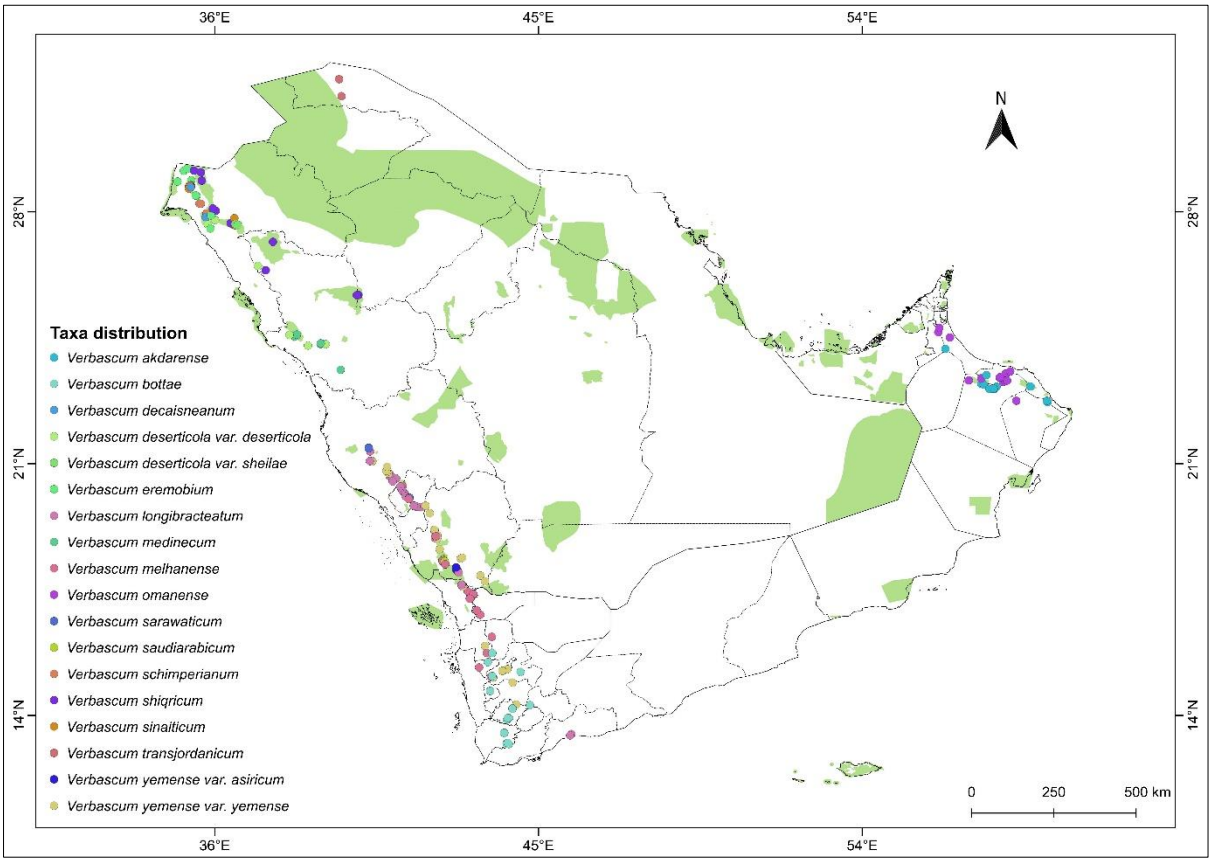
Bibliography and Sources:

- Alzahrani *et al*. (see Chapter 4). Taxonomic revision of *Verbascum* species in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 5). Red List assessment of the genus *Verbascum* in the Arabian Peninsula.
- Alzahrani *et al*. (see Chapter 3). DNA barcoding of the genus *Verbascum* (Scrophulariaceae) in the Arabian Peninsula.

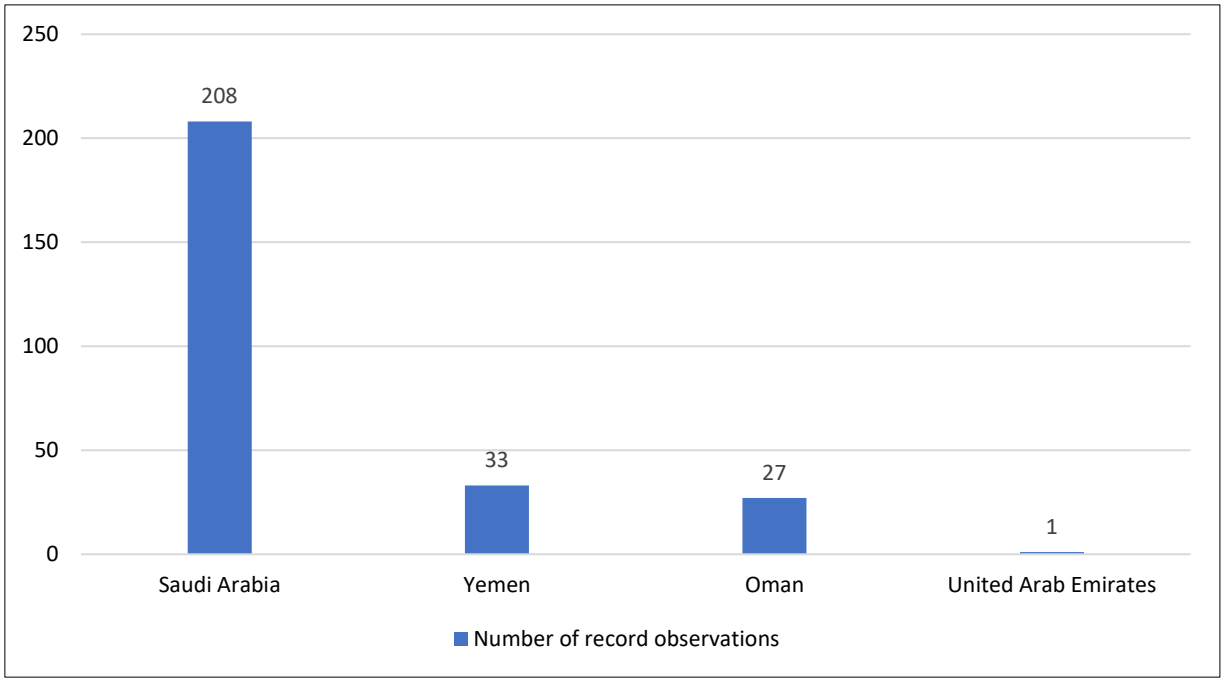
- Chaudhary S. 2001. Flora of the Kingdom of Saudi Arabia. National Herbarium, National Agriculture and Water Research Center, Riyadh.
- Collenette S. 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife, Conservation and Development, Kingdom of Saudi Arabia.
- Murbeck S. 1933. Monographie der Gattung *Verbascum*. Acta Univ. Lund. 29: 1 – 630.
- Wood J R I. 1997. A Handbook of the Yemen Flora. Royal Botanic Gardens, Kew.

Appendix 6.1. List of international and national genebanks and herbaria.

Code	Herbarium	Country	
BM	Natural History Museum	London, United Kingdom	Global
E	Royal Botanic Garden Edinburgh	Edinburgh, United Kingdom	Global
K	Royal Botanic Gardens Kew	London, United Kingdom	Global
KSU	King Saud University	Riyadh, Saudi Arabia	National
MUZ	King Abdulaziz City for Science and Technology	Riyadh, Saudi Arabia	National
OBG	Oman Botanic Garden	Muscat, Oman	National
ON	Natural History Museum	Muscat, Oman	National
RIY	National Agriculture and Water Research Center	Riyadh, Saudi Arabia	National
GBR004	Millennium Seed Bank / Royal Botanic Gardens Kew	London, United Kingdom	Global



Appendix 6.2. Distribution map of *Verbascum* taxa in the Arabian Peninsula.



Appendix 6.3. Number of record observations of *Verbascum* taxa in the Arabian Peninsula.

Appendix 6.4. Number of observational records of *Verbascum* taxa and their population within PAs in the Arabian Peninsula.

Taxa	Total number of records observation	Total number of records in PAs	O1	O2	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
V. akdarense	13	2	1	1												
V. bottae	19	0														
V. decaisneanum	3	3			2	1										
V. deserticola var. *deserticola*	9	1					1									
V. deserticola var. *sheilae*	14	14						14								
V. eremobium	8	1							1							
V. longibracteatum	44	9								3	3	3				
V. medinecum	13	3					3									
V. melhanense	43	13									7		6			
V. omanense	15	0														
V. sarawaticum	7	0														
V. saudiarabicum	3	2									2					
V. schimperianum	3	0														
V. shiqricum	11	9						1						4	1	3
V. sinaiticum	21	20			18			2								
V. transjordanicum	2	0														
V. yemense var. *yemense*	34	5								1	3	1				

V. yemense var. *asiricum*	7	0														
Total number of records observation	**269 (70%)**	**82 (30%)**	**1**	**1**	**20**	**1**	**4**	**17**	**1**	**4**	**15**	**4**	**6**	**4**	**1**	**3**
Number of *Verbascum* taxa	**18 taxa**	**12 taxa**	**1**	**1**	**2**	**1**	**2**	**3**	**1**	**2**	**4**	**2**	**1**	**1**	**1**	**1**

O1: Al Jabal Al Akhdar Scenic Reserve, **O2:** Al Serien Nature Reserve, **S1:** Jabal al-Lawz, **S2:** Jabal ad-Dubbagh, **S3:** Jabal Radwa, **S4:** Jibal Qaraqir, **S5:** Ra's Suwayhil/Ra's al-Qasbah, **S6:** Wadi Lajb/Jabal al-Qahar, **S7:** Asir National Park, **S8:** Jabal Uthrub/Al-Balas, **S9:** Raydah, **S10:** Hisma, **S11:** Harrat 'Uwayrid, **S12:** Harrat Khaybar/Wadi Hadiyah.

Appendix 6.5. Number of *Verbascum* taxa with less than five populations in the Arabian Peninsula.

Taxa	Total number of records observation	Total number of population in PAs
V. decaisneanum	3	3
V. saudiarabicum	3	2
V. schimperianum	3	0
V. transjordanicum	2	0

Appendix 6.6. The twelve environmental variables were used to generate the generalist ELC map of the 18 *Verbascum* taxa for the Arabian Peninsula.

Component	Code	Description	Unit	Source
Bioclimatic	bio_1	Annual Mean Temperature	°C	http://worldclim.org
	bio_6	Min Temperature of Coldest Month	°C	
	bio_11	Mean Temperature of Coldest Quarter	°C	
	vapr_annual	Water vapor pressure Annual	kPa	
Edaphic	t_oc_stock	Soil organic carbon stock in tons per ha topsoil	tonnes/ha	https://soilgrids.org
	depth_rock	Depth to bedrock (R horizon) up to 200 cm	cm	
	t_awc3	Available soil water capacity (volumetric fraction) for h3 - topsoil	%	
	t_oc_dens	Soil organic carbon density in kg per cubic-m topsoil	kg/cubic-m	
Geophysic	srad_1	Solar radiation January	MJ m-2	http://worldclim.org
	srad_11	Solar radiation November	MJ m-2	
	srad_12	Solar radiation December	MJ m-2	
	POINT_Y	Latitude for the cell centroid	-	-

Appendix 6.7. Number of *Verbascum* taxa and their population of ELC zones in and outside PAs in the Arabian Peninsula.

ELC zones	Total number of taxa	Total number of population	Total number of population in PAs	Total number of population outside PAs
1	3	5	1	4
2	NA	NA	NA	NA
3	NA	NA	NA	NA
4	3	22	3	19
5	NA	NA	NA	NA
6	NA	NA	NA	NA
7	6	22	4	18
8	NA	NA	NA	NA
9	NA	NA	NA	NA
10	NA	NA	NA	NA
11	NA	NA	NA	NA
12	NA	NA	NA	NA
13	2	7	0	7
14	NA	NA	NA	NA
15	NA	NA	NA	NA
16	4	17	0	17
17	1	2	0	2
18	NA	NA	NA	NA
19	8	66	46	20
20	4	8	3	5
21	1	2	1	1

22	4	48	1	47
23	NA	NA	NA	NA
24	NA	NA	NA	NA
25	8	61	13	48
26	NA	NA	NA	NA

Appendix 6.8. Total number of *Verbascum* taxa found in ELC zones in the Arabian Peninsula.

Taxa	**Total number of taxa found in ELC zones**	**ELC zones**
V. akdarense	3	7, 16, 25
V. bottae	2	7, 25
V. decaisneanum	1	19
V. deserticola var. *deserticola*	3	1, 19, 20
V. deserticola var. *sheilae*	1	19
V. eremobium	3	1, 19, 20
V. longibracteatum	6	4, 7, 13, 16, 22, 25
V. medinecum	3	1, 19, 22
V. melhanense	6	4, 7, 13, 16, 22, 25
V. omanense	4	7, 16, 17, 25
V. sarawaticum	1	22
V. saudiarabicum	1	25
V. schimperianum	1	19
V. shiqricum	3	19, 20, 21
V. sinaiticum	1	19
V. transjordanicum	1	20
V. yemense var. *yemense*	4	4, 7, 22, 25
V. yemense var. *asiricum*	1	25

Appendix 6.9. *Verbascum* taxa in complementary PAs in the Arabian Peninsula.

Rank	Complementary PAs	Designation	WDPA ID	IUCN Category	Total area (Km^2)	Province	Country	Taxa	Number of taxa
1	Asir National Park	National Park	864	VI	6490.7	Asir	Saudi Arabia	*V. saudiarabicum*, *V. longibracteatum*, *V. yemense* var. *yemense*, *V. melhanense*	4
2	Jabal Qaraqir	Special Nature Reserve	11981	Ia	1678.26	Tabuk	Saudi Arabia	*V. deserticola* var. *sheilae*, *V. sinaiticum*, *V. shiqricum*	3
3	Jabal Radwa	Natural Reserve	555624829	Ib	1673.02	Medina	Saudi Arabia	*V. deserticola* var. *deserticola*, *V. medinecum*	2
4	Jabal al-Lawz	Reserve	11982	VI	489.82	Tabuk	Saudi Arabia	*V. decaisneanum*	1
5	Al Jabal Al Akhdar Scenic Reserve	Nature Reserve	555580792	VI	122	Al Batinah South	Oman	*V. akdarense*	1
6	Ra's Suwayhil/Ra's al-Qasbah	Resource Use Reserve	11998	VI	3705	Tabuk	Saudi Arabia	*V. eremobium*	1

Appendix 6.10. Number of observational records of *Verbascum* taxa in the Arabian Peninsula and their population in complementary PAs, grid cells and OECMs.

Taxa	**Total number of records observation**	**Taxa population in complementary PAs**	**Taxa population in complementary grid**	**Taxa population in OECMs**
V. akdarense	13	1	1	0
V. bottae	19	0	0	2
V. decaisneanum	3	2	2	0
V. deserticola var. *deserticola*	9	1	1	0
V. deserticola var. *sheilae*	14	14	12	0
V. eremobium	8	1	0	1
V. longibracteatum	44	3	3	2
V. medinecum	13	3	3	0
V. melhanense	43	7	2	0
V. omanense	15	0	1	0
V. sarawaticum	7	0	0	2
V. saudiarabicum	3	2	1	0
V. schimperianum	3	0	1	0
V. shiqricum	11	1	1	0
V. sinaiticum	21	20	16	0
V. transjordanicum	2	0	0	1
V. yemense var. *yemense*	34	3	2	1
V. yemense var. *asiricum*	7	0	1	0
Total number of records observation	**269**	**58**	**47**	**9**
Number of *Verbascum* taxa	**18**	**12**	**14**	**6**

Appendix 6.11. *Verbascum* taxa in complementary grid within existing PAs in the Arabian Peninsula.

Rank	Complementary grid	Designation	WDPA ID	IUCN Category	Total area (Km^2)	Province	Country	Taxa	Number of taxa
1	Asir National Park	National Park	864	VI	6490.7	Asir	Saudi Arabia	*V. saudiarabicum*, *V. longibracteatum*, *V. yemense* var. *yemense*, *V. melhanense*	4
	Wadi Tayyah	Reserve	11968	VI	705.17	Asir	Saudi Arabia		
2	Jabal al-Lawz	Reserve	11982	VI	489.82	Tabuk	Saudi Arabia	*V. decaisneanum*, *V. sinaiticum*	2
3	Al Rustaq Wildlife Reserve	Nature Reserve	555720409	VI	253.58	Al Batinah South	Oman	*V. akdarense*, *V. omanense*	2
	Western Hajer Stars Lights Reserve	Nature Reserve	555720408	VI	386	Al Batinah South	Oman		
4	Jabal Radwa	Natural Reserve	555624829	Ib	1673.02	Medina	Saudi Arabia	*V. deserticola* var. *deserticola*, *V. medinecum*	2
5	Jabal ad-Dubbagh	Special Nature Reserve	17331	Ia	628.91	Tabuk	Saudi Arabia	*V. schimperianum*	1
6	Jabal Qaraqir	Special Nature Reserve	11981	Ia	1678.26	Tabuk	Saudi Arabia	*V. deserticola* var. *sheilae*	1

7	Hisma	Resource Use Reserve	555625664	VI	3699.29	Tabuk	Saudi Arabia	*V. shiqricum*	1
8	Asir National Park	National Park	864	VI	6490.7	Asir	Saudi Arabia	*V. yemense* var. *asiricum*	1

Appendix 6.12. *Ex situ* collections of *Verbascum* taxa in international and national genebanks.

Taxa	National genebanks	International genebanks
V. akdarense	1	0
V. bottae	0	0
V. decaisneanum	0	0
V. deserticola var. *deserticola*	0	0
V. deserticola var. *sheilae*	0	0
V. eremobium	0	0
V. longibracteatum	0	0
V. medinecum	0	0
V. melhanense	0	0
*V. omanense******	0	1
V. sarawaticum	0	0
V. saudiarabicum	0	0
V. schimperianum	0	0
V. shiqricum	0	0
V. sinaiticum	0	0
V. transjordanicum	0	0
V. yemense var. *yemense*	0	0
V. yemense var. *asiricum*	0	0
Number of ex situ collections	1	1

***** This species' seeds were deposited at Millennium Seed Bank under the incorrect name *V. schimperianum*, but the correct name is *V. omanense*.

Appendix 6a

6.3a Methods

Diversity and conservation gap analyses

To identify potential sites for *in situ* conservation, the DIVA-GIS 7.5 software programme (Hijmans *et al*., 2005) was used to conduct a complementarity analysis based on the Rebelo algorithm (Rebelo, 1994). Reserve selection was applied with a grid cell size of 0.50 degrees, equal weight, and unspecified maximum iterations, and the results were overlaid with the existing PAs in the Arabian Peninsula (UNEP-WCMC and IUCN, 2023). Potential areas for *ex situ* conservation were determined using DIVA-GIS 7.5 to generate prediction distribution maps for the genus *Verbascum* via the BioClim Model (Hijmans *et al*., 2005) and past climate data (1970–2000) at a resolution of 2.5 km2 and with 19 bioclimatic variables (Appendix 6.13) obtained from the WorldClim dataset (https://worldclim.org/). All maps originated from DIVA-GIS 7.5 and were generated with QGIS, version 3.22 (2022).

***In situ* and *ex situ* conservation gap analyses**

Complementarity analysis showed ten reserve sites to conserve *Verbascum* taxa in the Arabian Peninsula at a grid cell size of 0.5 degrees (Appendix 6.14), with the most reserve sites in Saudi Arabia (eight), followed by Yemen and Oman (one each). Seven potential reserve sites were selected within existing PAs, and 15 *Verbascum* taxa were found at these sites, representing 82 populations (30%; Appendices 6.15, 6.16). These sites included PAs, such as Jabal ad-Dubbagh, Asir National Park, Wadi Tayyah, Raydah, Jabal Qaraqir, Hisma, Jabal Batharah/Wadi Turabah, and Hima Bani Sar in Saudi Arabia, as well as Al Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve, and Al Jabal Al Akhdar Scenic Reserve in Oman. *V. longibracteatum*, *V. deserticola* var. *sheilae*, and *V. melhanense* had the most taxa populations in these reserve sites with 17, 14, and 13, respectively (Appendices 6.14, 6.17). Additionally, three reserve sites were selected outside of PAs, and these sites could be recommended to set up of genetic reserves for the conservation of *Verbascum* taxa not currently found in PAs.

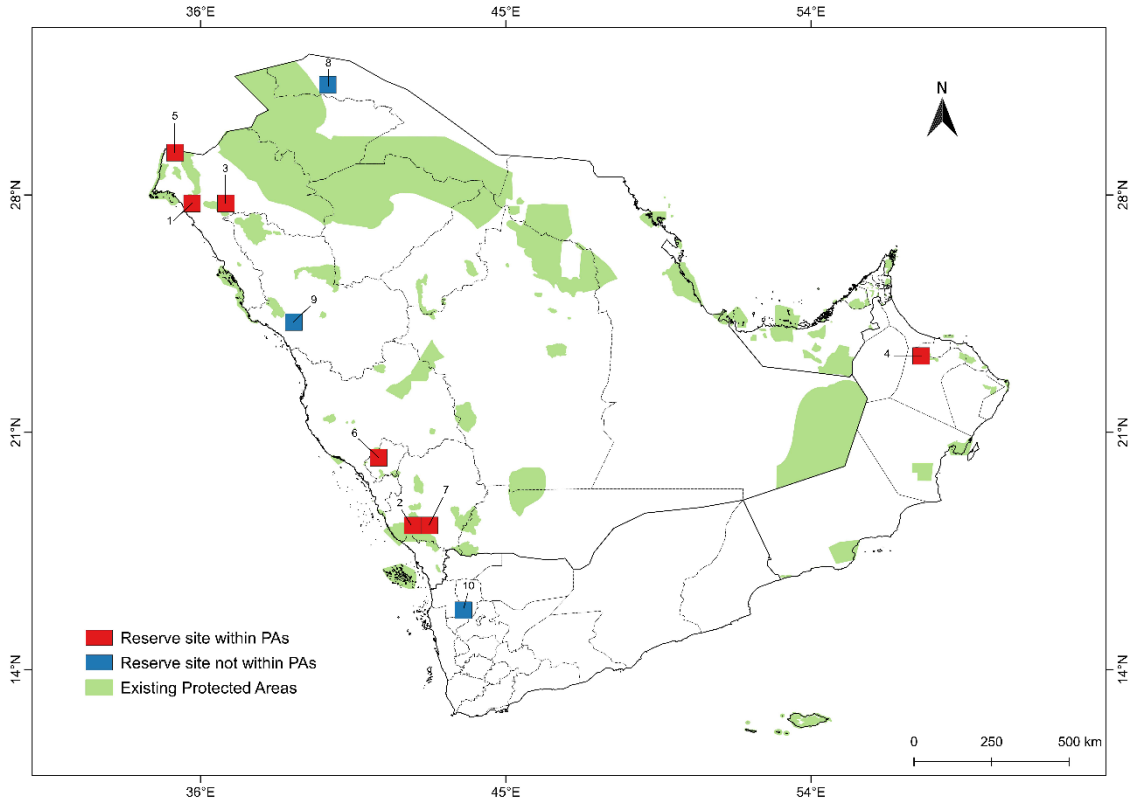
Unfortunately, the study's *ex situ* conservation gap analysis reveals that none of the Arabian *Verbascum* taxa are adequately represented in international and national genebanks and that only one sample of *V. akdarense* and *V. omanense* is from Oman (Appendix 6.12). In contrast, a potential distribution map was generated based on historical climatic data to aid in the identification of suitable regions for the further *ex situ* collection and conservation of *Verbascum* taxa in the Arabian Peninsula. The following regions exhibited high degrees of suitability: (i) the Asir Mountains in Asir Province, (ii) the Sarawat Mountains in Makkah Province, (iii) the southern Harrat 'Uwayrid in Medina Province, and (iv) Jabal Radwa and the adjacent areas between the Medina and Tabuk provinces (Appendix 6.18).

Potential distributions of *Verbascum* taxa in the Arabian Peninsula, based on climatic data, were to help identify suitable regions (Hijmans *et al*., 2005), which could reveal new areas that extend beyond the known range of these taxa (Semwal *et al*., 2021). Four regions of the

Arabian Peninsula were found to be highly suitable for the additional *ex situ* collection and conservation of *Verbascum* taxa: the Asir Mountains, the Sarawat Mountains, the southern Harrat 'Uwayrid, and the Jabal Radwa and its surrounding areas, which require particular attention from botanists.

Appendix 6.13. The 19 Bioclimatic variables for historical climate data (1970-2000) were used.

Code	Content
BIO1	Annual mean temperature
BIO2	Mean diurnal range
BIO3	Isothermality
BIO4	Temperature seasonality
BIO5	Max temperature of warmest month
BIO6	Min temperature of coldest month
BIO7	Temperature annual range
BIO8	Mean temperature of wettest quarter
BIO9	Mean temperature of driest quarter
BIO10	Mean temperature of warmest quarter
BIO11	Mean temperature of coldest quarter
BIO12	Annual precipitation
BIO13	Precipitation of wettest month
BIO14	Precipitation of driest month
BIO15	Precipitation seasonality
BIO16	Precipitation of wettest quarter
BIO17	Precipitation of driest quarter
BIO18	Precipitation of warmest quarter
BIO19	Precipitation of coldest quarter



Appendix 6.14. Complementary analysis of potential reserve sites for *in situ* conservation of *Verbascum* taxa within and outside PAs in the Arabian Peninsula.

Appendix 6.15. Potential reserve sites for *in situ* conservation of *Verbascum* taxa within PAs in the Arabian Peninsula.

Reserve site	Protected area	Number of observational records	Number of taxa within protected areas	Number of *Verbascum* taxa	Province	Country
1	Jabal ad-Dubbagh	6	1	4	Tabuk	Saudi Arabia
2	Asir National Park Wadi Tayyah, Raydah	15	4	4	Abha	Saudi Arabia
3	Jabal Qaraqir	16	2	2	Tabuk	Saudi Arabia
4	Al Rustaq Wildlife Reserve, Western Hajer Stars Lights Reserve, Al Jabal Al Akhdar Scenic Reserve	6	—	2	Al Batinah South	Oman
5	Hisma	3	1	1	Tabuk	Saudi Arabia
6	Jabal Batharah/Wadi Turabah, Hima Bani Sar	27	—	1	Makkah/Al-Baha	Saudi Arabia
7	Asir National Park	9	—	1	Asir	Saudi Arabia

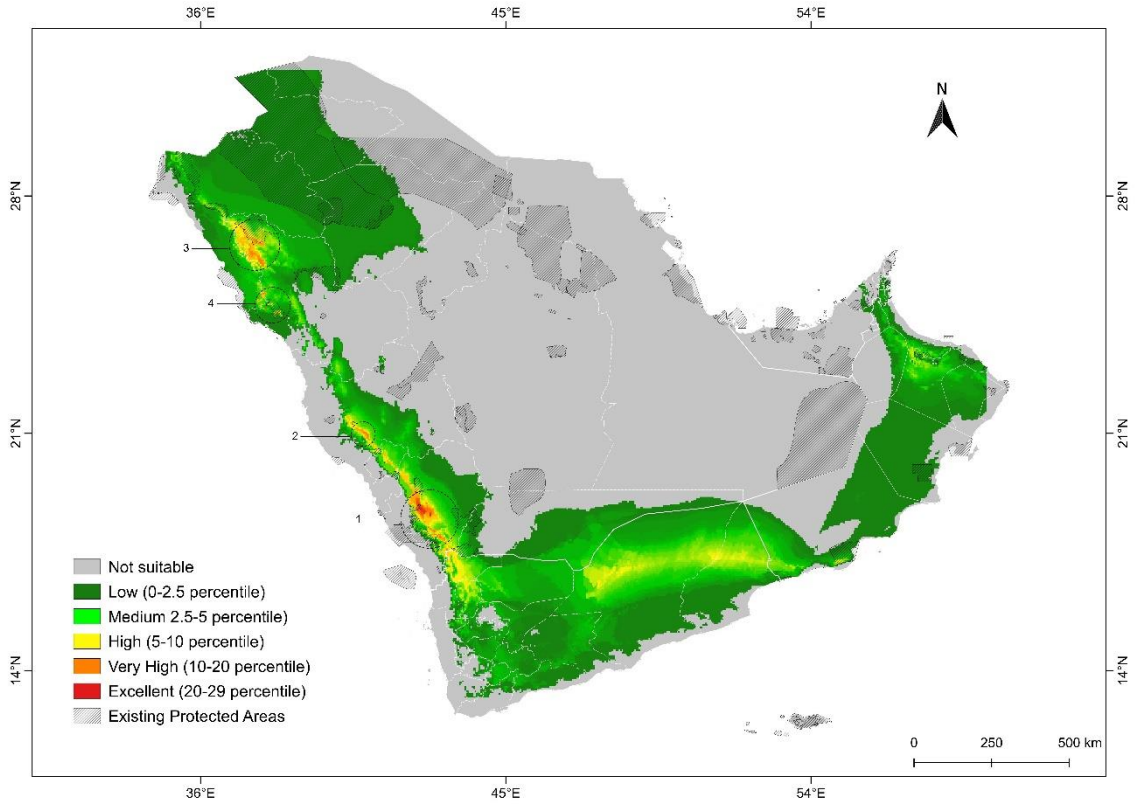
Appendix 6.16. *Verbascum* taxa reserve sites within PAs in the Arabian Peninsula.

Site	Protected Area	Designation	WDPA ID	IUCN Category	Total area (Km^2)	Province	Country	Verbascum taxa	Number of Verbascum taxa
1	Jabal ad-Dubbagh	Special Nature Reserve	17331	Ia	628.91	Tabuk	Saudi Arabia	*V. decaisneanum*, *V. eremobium*, *V. schimperianum*, *V. deserticola* var. *deserticola*	4
2	Asir National Park	National Park	864	VI	6490.7	Asir	Saudi Arabia	*V. saudiarabicum*, *V. longibracteatum*, *V. yemense* var. *yemense*, *V. melhanense*	4
	Wadi Tayyah	Reserve	11968	VI	705.17	Asir	Saudi Arabia		
	Raydah	Natural Reserve	19557	VI	9.33	Asir	Saudi Arabia		
3	Jibal Qaraqir	Special Nature Reserve	11981	Ia	1678.26	Tabuk	Saudi Arabia	*V. deserticola* var. *sheilae*, *V. sinaiticum*	2
4	Al Rustaq Wildlife Reserve	Nature Reserve	555720409	VI	253.58	Al Batinah South	Oman	*V. akdarense*, *V. omanense*	2
	Western Hajer Stars Lights Reserve	Nature Reserve	555720408	VI	386	Al Batinah South	Oman		

	Al Jabal Al Akhdar Scenic Reserve	Nature Reserve	555580792	VI	122	Al Batinah South	Oman		
5	Hisma	Resource Use Reserve	555625664	VI	3699.29	Tabuk	Saudi Arabia	*V. shiqricum*	1
6	Jabal Batharah/Wadi Turabah	Natural Reserve	11974	II	316.56	Makkah	Saudi Arabia	*V. sarawaticum*	1
	Hima Bani Sar	Hima/BR	555624823	V	3.38	Al-Baha	Saudi Arabia		
7	Asir National Park	National Park	864	VI	6490.7	Asir	Saudi Arabia	*V. yemense* var. *asiricum*	1

Appendix 6.17. Number of *Verbascum* taxa and their population in reserve sites within PAs in the Arabian Peninsula

Taxa	Total number of records observation	Taxa population in reserve site
V. akdarense	13	5
V. bottae	19	0
V. decaisneanum	3	1
V. deserticola var. *deserticola*	9	2
V. deserticola var. *sheilae*	14	14
V. eremobium	8	4
V. longibracteatum	44	17
V. medinecum	13	0
V. melhanense	43	13
V. omanense	15	1
V. sarawaticum	7	2
V. saudiarabicum	3	3
V. schimperianum	3	1
V. shiqricum	11	1
V. sinaiticum	21	2
V. transjordanicum	2	0
V. yemense var. *yemense*	34	9
V. yemense var. *asiricum*	7	7
Total number of records observation	269	82
Number of Verbascum taxa	18	15



Appendix 6.18. Potential areas for distribution, based on past climatic data and further *ex situ* collection of *Verbascum* taxa, in the Arabian Peninsula: (1) the Asir Mountains, (2) the Sarawat Mountains, (3) the southern Harrat 'Uwayrid, and (4) Jabal Radwa and its adjacent areas.