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Checklist and life forms of plant species in contrasting climatic zones of Libya

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Abstract

Little is still known about the composition and distribution of vegetation in the Mediterranean and Sahara regions of Libya, the two dominant climatic areas. In this study we identified the plant species and life form from a typical site in each region to assess the current state of the vegetation type. In the Mediterranean site, 238 plant species were found; therophytes formed 59% of the species identified, and included 11 endemic species, i.e. 15 % of all Libyan endemic species. In the Saharan site, only 167 plant species and 2 endemic species were found, also dominated by therophytes (49%). Three new record species for Libya were identified in the Saharan site. This study represents the first stage to explore a recently neglected flora.

Key words: Vegetation distribution, Plant species, Libya, Mediterranean, Sahara.

1. Introduction

Libya occupies a relatively large area of Northern Africa, *c*. 1 759 540 km^2, with a Mediterranean shore line of about 93000 km^2. The Libyan Mediterranean coast has only a moderate biodiversity when compared with the in-land Saharan flora. Past vegetation surveys are restricted to a few studies between 1824 and 1965 (Blake and Atwood, 1963), and a few after 1965 including the most recent *Flora of Libya* (Ali and Jafri, 1977; Jafri and El-Gadi, 1986; El-Gadi, 1989).

Fordin (2001) reviewed most of the studies on Libyan vegetation published before 1945, including Domenico Viviani in 1824, Paul Ascherson in 1881, Ernest Durand and Gastave Barratte in 1910, Renato Pampanini 1914-1938 and Roberto Corti in 1942. Many other studies were carried out, particularly, in the grand Sahara the southern and western areas of Libya (Maire, 1952; Quézel and Santa, 1962; Ozenda, 1991).

Keith (1965) produced a preliminary checklist of Libyan flora. Boulos (1972) presented a list of 791 species as a flora of Libya, preceded by a brief review of general features and botanical resources. Shortly after, the current *Flora of Libya* was published in 147 parts. Hammer *et al.* (1988) used published literature and their own observations, made between 1980 and 1983, to produce a checklist of 279 cultivated plant species which were mostly found in the four major regions, Tripolitania, Cyrenica (Mediterranean sectors), Fezzan and Kufra (Saharan sectors). Several vegetation surveys have been undertaken more recently (e.g. El-Barasi *et al.*, 2011) but these have been restricted to coastal valleys in Al-Jabal Al-Akhdar. These works have shown that the Southern Mediterranean region of the Libyan coast are fairly rich in wild medicinal plant species: 151 species were recorded along the Libyan coast including 19 endemic, 25 rare, 15 noteworthy and 10 threatened species (Louhaichi et al., 2011).

Despite these studies, the vegetation of Libya is still poorly known and new records of plant species are still to be made in different regions of Libya (Qaiser and El-Gadi, 1984). In addition, the vegetation is threatened by global warming and other factors are contributing to desertification in Mediterranean and Sahara areas (Alao, 2009; Saad *et al.*, 2011).

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In this study, we compare plant species diversity and ecology of typical valleys (wadis) located in the two different climatic regions, the costal and Saharan.

2. Materials and methods

Area of study

Collections of this study were carried out in two main areas:

1) **Wadi Jarjar Amma** is located in the coastal area of Al-Jabal Al-Akhdar (NE Libya), sometimes written as Jabal Al-Akhdar, El-Jabal El-Akhdar, El-Jabal El-Akhadar or, in English translation, as The Green Mountain (El-Barasi *et al.*, 2011; Hegazy *et al.*, 2011). The coastal end of this valley is located at 32º47´N, 21º28´E and elev. 0-380 m (Fig. 1), twenty five km south of the Qaser Libya area and 7 km west of Al Haniyah. The valley is about 20 km long and ranges between 1 and 6 km in width. Along this valley, the red upper layer of soil is mixed with calcareous gravels and rocks, and rich in oxides and silica; the colour of soil is attributed to the high level of iron and low organic matter. Silt is the second most major component of the soil, especially on the floor of the valley, where it consists of loamy, clay and gravel (Buru, 1968). The climate in the first site is mainly Mediterranean, characterised by dry summers (June-October) and relatively wet winters (November-May). The highest mean monthly rainfall in December and January is 63 and 62 mm, respectively. The mean annual rainfall is around 300 mm although very spatially erratic. The mean humidity rises just before spring, reaching 32% in March. The mean maximum monthly temperature reaches 41 ºC in June and decreases to 21 ºC and 22 ºC in January and December, respectively. The lowest mean minimum monthly temperature is recorded in January and December at 6 ºC and 7 ºC, respectively (Benina Metrological Station, 1977-2000).

2) **Wadi Tanezzuft**, located in the far southwest of Libya, lies on the west and north sides of Jabal Acacus (Highlands) and contains three big oases (Ghat, Al Barkat and Fehouet) which as Saharan sites are quite rich of vegetation. The main part of the valley studied covers an area more than 160 km long extends between Isine in the south and Tahala in the north and ended in a large flat area about 60 km the northern fringe of the Tadrast Acacus massif and 125 km north of Ghat (Cremaschi and Zerboni, 2009), centred at 26º00´N, 10º20´E, elev. 595 m (Fig. 1). Sand dunes formed by wind are a dominant feature of the valley. The topsoil of the flat areas consists of clay, gravel and sandstones. Some areas consist of dry saline flats covered with a soil crust. Most of vegetation found on this site occurs at the base of the cliffs or on the top of small hummocks located between the sand dunes. It seems that age-old cultivation at the nearby oases has played a huge role in building up a considerable cover of organic-rich soils (Burdon, 1980; Brooks, 2006). At this site where the Saharan climate is dominant, the monthly rainfall ranges between 2 and 3 mm in winter and none in the summer giving a total annual rainfall of 10 mm. The mean monthly maximum temperature exceeds 35 ºC between May and September and the lowest monthly mean recorded in January is 20 ºC. The mean minimum monthly temperature decreases in winter to 5 and 7 ºC in January and December, respectively, accompanied by relatively high humidity of 43 and 40% (Ghat Metrological Station, 1989-2002). Rainfall available to the vegetation is difficult to estimate since erosion features of the surface topography deliver sporadic runoff arising from the Acacus highlands in the east and southeast and Tasili highlands in the west and southwest. How much of the runoff comes from nearby areas and from much higher ground is still uncertain (Burdon, 1980).

Collections: Between 2001 and 2006, a minimum of six collection trips were made to the Mediterranean site during periods between October and May, samples were randomly collected along the valley between the shore line and Qaser Libya village. At least two long trips were made annually to the Saharan site between December and May from 2002 to 2004. At least one trip was made to each site during summer (August and September) in 2002 and 2003. Collection survey covered all vegetational areas between Ghat and Tahala, >100 km long and 3 km width, samples were randomly collected. Specimens were preserved in a plant press and identified using the *Flora of Libya* (Ali and Jafri, 1977; Jafri and El-Gadi, 1986; El-Gady, 1989) and the *Flora of Egypt* (Boulos, 1999) for those species not found in the former. Specimens were deposited in the Cyrenica Herbarium, Botany Department, Benghazi University (specimens from both sites) and the herbarium of the Botany Department, Sebha University (for specimens from the Saharan site). Plant life-form was categorised using Raunkiaer (1934).

3. Results

Three hundred and ninty two plant species were found over both wadis, 238 in the Mediterranean site and 167 species in the Saharan site (Table 1). Only 15 species were collected from both valleys; this included 2 phanerophytes: *Tamarix aphylla*, *T. arborea* (*Tamaricaceae*); 1 chamaephyte: *Ziziphus loyus* (*Rhamnaceae*); 1 hemicryptophyte: *Cressa cretica* (*Convolvulaceae*); and 11 therophytes: *Centaurium pulchellum*, *Chenopodium murale*, *Crepis senecioides*, *Euphorbia dracunculoides*, *Linum bienne*, *Lotus glinoides*, *Lysimachia arvensis*, *Malva parviflora*, *Paronychia arabica*, *Paronychia argentea*, *Scorzoneroides simplex* (Table 1).

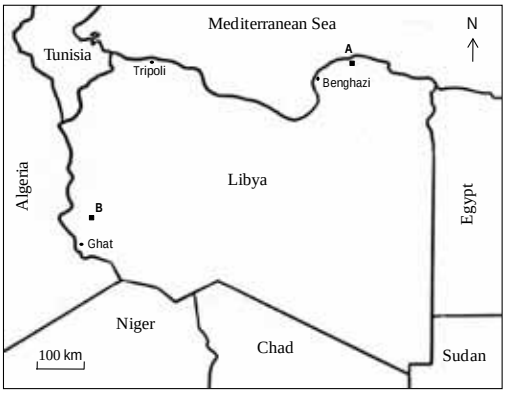

Figure 1. Map of Libya shows both areas of study. A) Wadi Jarjar Amma on the northern-east coast, 100 km west of Albayda city. B) Wadi Tanezzuft, in the far south west and only 125 km north east Ghat city.

Table 1. The checklist of plant species for Wadi Jarjar Amma (Mediterranean site) and Wadi Tanezzuft (Saharan site) in Libya. The study was undertaken between 2002 and 2006. * = endemic species to the Libyan flora. ** = new records for Libya.

Species	Family	Site	
		Jarjar Amma	Tanezzuft
Aerva javanica (Burm. f.) Juss ex J. A. Shultes var. *javanica*	*Amaranthaceae*		√
Aerva javanica var. *bovei* Webb.	*Amaranthaceae*		√
Amaranthus viridis L.	*Amaranthaceae*		√
Bassia muricata (L.) Asch.	*Amaranthaceae*		√
Beta vulgaris L.	*Amaranthaceae*		√
Caroxylon tetrandrum (Forssk.) Akhani & Roalson	*Amaranthaceae*		√
Chenolea arabica Boiss.	*Amaranthaceae*		√
Chenopodium album L.	*Amaranthaceae*	√	
Chenopodium murale L.	*Amaranthaceae*	√	√
Salsola schweinfurthii Solms	*Amaranthaceae*		√
Suaeda vermiculata Forssk. ex J.F.Gmel.	*Amaranthaceae*		√
Pistacia atlantica Desf.	*Anacardiaceae*	√	
Pistacia lentiscus L.	*Anacardiaceae*	√	
Rhus tripartita (Ucria) Grande	*Anacardiaceae*	√	
Ammi majus L.	*Apiaceae*	√	
Ammi visnaga (L.) Lam.	*Apiaceae*	√	
Apium graveolens L.	*Apiaceae*	√	
Conium maculatum L.	*Apiaceae*	√	
Deverra denudatus (Viv.) Pfistrer & Podlech	*Apiaceae*		√
Eryngium campestre L.	*Apiaceae*	√	
Pimpinella peregrina L.	*Apiaceae*	√	
Scandix australis L.	*Apiaceae*	√	
Scandix pecten-veneris L.	*Apiaceae*	√	
Smyrnium olusatrum L.	*Apiaceae*	√	
Torilis arvensis (Huds.) Link	*Apiaceae*	√	
Torilis leptophylla (L.) Rchb.f.	*Apiaceae*	√	
Torilis nodosa (L.) Gaertn.	*Apiaceae*	√	
Apteranthes europaea (Guss.) Murb.	*Apocynaceae*	√	
Calotropis procera (Ait.) W.T.Aiton	*Apocynaceae*		√
Leptadenia pyrotechnica (Forssk.) Decne.	*Apocynaceae*		√
Nerium oleander L.	*Apocynaceae*		√
Pergularia tomentosa L.	*Apocynaceae*		√
Periploca angustifolia Labill.	*Apocynaceae*	√	
Solenostemma arghel (Delile) Hayne	*Apocynaceae*		√
Arisarum vulgare Targ.Tozz.	*Araceae*	√	
Arum cyrenaicum Hruby	*Araceae*	√*	
Asparagus acutifolius L.	*Asparagaceae*	√	
Bellevalia sessiliflora (Viv.) Kunth	*Asparagaceae*	√	
Drimia maritima (L.) Stearn	*Asparagaceae*	√	
Oncostema peruviana (L.) Speta	*Asparagaceae*	√	
Ornithogalum kochii Parl.	*Asparagaceae*	√	
Prospero autumnalis (L.) Speta	*Asparagaceae*	√	
Anthemis secundiramea Biv.	*Asteraceae*	√	
Anvillea garcinii (Burm.f.) DC.	*Asteraceae*		√
Artemisia monosperma Delile	*Asteraceae*		√

Table 1. (Continued)

Asteriscus graveolens (Forsk.) Less.	*Asteraceae*		√
Atractylis phazaniae Corti	*Asteraceae*		√*
Bellis annua L.	*Asteraceae*	√	
Bellis sylvestris Cirillo	*Asteraceae*	√	
Brocchia cinerea (Delile) Vis.	*Asteraceae*		√
Calendula arvensis (Vaill.) L.	*Asteraceae*	√	
Carduus argentatus L.	*Asteraceae*	√	
Carlina lanata L.	*Asteraceae*	√	
Carthamus eriocephalus (Boiss.) Greuter	*Asteraceae*	√	
Carthamus lanatus L.	*Asteraceae*	√	
Centaurea alexandrina Delile	*Asteraceae*	√	
Centaurea maroccana Ball	*Asteraceae*		√
Centaurea sphaerocephala L.	*Asteraceae*		√
Chiliadenus glutinosus (L.) Fourr.	*Asteraceae*		√
Cichorium pumilum Jacq.	*Asteraceae*	√	
Cladanthus arabicus (L.) Cass.	*Asteraceae*		√
Conyza bonariensis (L.) Cronq.	*Asteraceae*		√
Conyza canadensis (L.) Cornq.	*Asteraceae*	√	
Cotula anthemoides L.	*Asteraceae*		√
Crepis libyca (Pamp.) Shabet	*Asteraceae*	√	
Crepis nigricans Viv.	*Asteraceae*	√	
Crepis pusilla (Sommier) Merxm.	*Asteraceae*	√	
Crepis senecioides Delile	*Asteraceae*	√*	√*
Cynara cyrenaica Maire & Weiller	*Asteraceae*	√*	
Dittrichia viscosa (L.) Greuter	*Asteraceae*	√	
Filago desertorum Pomel	*Asteraceae*	√	
Filago lutescens Jordan	*Asteraceae*	√	
Hedypnois rhagadidoides (L.) F.W.Schmidt	*Asteraceae*	√	
Helichrysum stoechas (L.) Moench	*Asteraceae*	√	
Hyoseris scabra L.	*Asteraceae*	√	
Hypochaeris achyrophorus L.	*Asteraceae*	√	
Hypochaeris glabra L.	*Asteraceae*	√	
Ifloga spicata (Forssk.) Schultz Bip.	*Asteraceae*		√
Ismelia carinata (Schousb.) Sch.Bip.	*Asteraceae*	√	
Laphangium luteoalbum (L.) Tzvelev	*Asteraceae*		√
Launaea capitata (Spreng.) Dandy	*Asteraceae*		√
Launaea procumbens (Roxb.) Ramayya & Rajagopal	*Asteraceae*		√
Leontodon tuberosus L.	*Asteraceae*	√	
Notobasis syriaca (L.) Cass.	*Asteraceae*	√	
Onopordum cyrenaicum Maire & Weiller	*Asteraceae*	√*	
Pallenis cyrenaica Alavi	*Asteraceae*	√*	
Pallenis hierichuntica (Michon) Greuter	*Asteraceae*	√	
Pallenis spinosa (L.) Cass.	*Asteraceae*	√	
Phagnalon rupestre (L.) DC.	*Asteraceae*	√	
Phagnalon rupestre subsp. *graecum* (Boiss) Batt	*Asteraceae*	√	
Picris asplenioides L.	*Asteraceae*	√	
Pluchea dioscoridis (L.) DC.	*Asteraceae*		√**
Podospermum laciniatum (L.) DC.	*Asteraceae*		√
Ptilostemon gnaphaloides (Cirillo) Sojak	*Asteraceae*	√	
Pulicaria undulata (L.) C.A.Mey. subsp. undulata	*Asteraceae*		√
Pulicaria vulgaris Gaertner	*Asteraceae*	√	
Rhagadiolus stellatus (L.) Gaerrtner	*Asteraceae*	√	
Scorzoneroides simplex (Viv.) Greuter & Talavera	*Asteraceae*	√	√
Senecio gallicus subsp. *coronopifolius* (Maire) Alexander	*Asteraceae*	√	
Senecio glaucus L.	*Asteraceae*		√
Sonchus oleraceus L.	*Asteraceae*		√
Tolpis virgata (Desf.) Bertol.	*Asteraceae*	√	
Tourneuxia variifolia Cosson	*Asteraceae*		√
Urospermum dalechampii (L.) F.W.Schmidt	*Asteraceae*	√	
Anchusa aegyptiaca (L.) DC.	*Boraginaceae*	√	
Borago officinalis L.	*Boraginaceae*	√	
Cynoglossum cheirifolium L.	*Boraginaceae*	√	
Echium angustifolium Mill.	*Boraginaceae*	√	
Echium sabulicola Pomel	*Boraginaceae*	√	
Heliotropium bacciferum Forssk.	*Boraginaceae*		√
Heliotropium ramosissimum (Lehm.) DC.	*Boraginaceae*		√
Trichodesma africanum (L.) R.Br.	*Boraginaceae*		√
Biscutella didyma L.	*Brassicaceae*	√	

Table 1. (Continued)

Didesmus aegyptius (L.) Desv.	*Brassicaceae*	√	
Farsetia aegyptiaca Turra	*Brassicaceae*		√
Henophyton deserti (Coss. & Durieu) Coss. & Durieu	*Brassicaceae*		√
Hirschfeldia incana (L.) Lag.-Foss.	*Brassicaceae*	√	
Lepidium niloticus (Del.) Spreng.	*Brassicaceae*		√
Lobularia libyca (Viv.) Meisner	*Brassicaceae*		√
Matthiola longipetala (Vent.) DC.	*Brassicaceae*	√	
Pseuderucaria teretifolia (Desf.) O.E.Schulz	*Brassicaceae*		√
Raphanus raphanistrum L.	*Brassicaceae*	√	
Rapistrum rugosum (L.) All.	*Brassicaceae*	√	
Savignya parviflora (Delile) Webb ssp. *parviflora*	*Brassicaceae*		√
Schouwia purpurea (Forssk.) Schweinf.	*Brassicaceae*		√
Sinapis alba L.	*Brassicaceae*	√	
Sinapis flexuosa Pior.	*Brassicaceae*	√	
Sinapis pubescens L.	*Brassicaceae*	√	
Zilla spinosa (L.) Prantl	*Brassicaceae*		√
Ceratonia siliqua L.	*Caesalpiniaceae*	√	
Senna italica Mill.	*Caesalpiniaceae*		√
Senna occidentalis (L.) Link	*Caesalpiniaceae*		√
Campanula erinus L.	*Campanulaceae*	√	
Wahlenbergia campanuloides (Delile) Vatke	*Campanulaceae*		√
Cleome amblyocarpa Barr. & Murb.	*Capparaceae*		√
Fedia caput-bovis Pomel	*Caprifoliaceae*	√	
Fedia cornucopiae (L.) Gaertn.	*Caprifoliaceae*	√	
Viburnum tinus L.	*Caprifoliaceae*	√	
Paronychia arabica (L.) DC.	*Caryophyllaceae*	√	√
Paronychia argentea Lam.	*Caryophyllaceae*	√	√
Petrorhagia illyrica (Ard.) Ball & Heywood	*Caryophyllaceae*	√	
Polycarpaea repens (Forssk.) Asch. & Schweinf.	*Caryophyllaceae*		√
Polycarpaea robbairea (Kuntze) Greuter & Burdet	*Caryophyllaceae*		√
Polycarpon prostratum (Forssk.) Asch. & Schweinf.	*Caryophyllaceae*	√	
Polycarpon tetraphyllum (L.) L.	*Caryophyllaceae*	√	
Silene muscipula L.	*Caryophyllaceae*		√
Silene rubella L.	*Caryophyllaceae*		√
Silene villosa Forssk.	*Caryophyllaceae*		√
Spergula fallax (Lowe) Krause	*Caryophyllaceae*	√	
Cistus incanus L.	*Cistaceae*	√	
Cistus parviflorus Lam.	*Cistaceae*	√	
Cistus salviifolius L.	*Cistaceae*	√	
Fumana arabica (L.) Spach	*Cistaceae*	√	
Helianthemum ruficomum (Viv.) Spreng.	*Cistaceae*	√	
Helianthemum salicifolium (L.) Mill.	*Cistaceae*	√	
Helianthemum syriacum (Jacq.) Dum.Cours.	*Cistaceae*	√	
Helianthemum virgatum (Desf.) Pers.	*Cistaceae*	√	
Convolvulus althaeoides L.	*Convolvulaceae*	√	
Convolvulus humilis Jacq	*Convolvulaceae*	√	
Convolvulus oleifolius Desr.	*Convolvulaceae*	√	
Convolvulus siculus L.	*Convolvulaceae*	√	
Cressa cretica L.	*Convolvulaceae*	√	√
Cuscuta epithymum (L.) L.	*Convolvulaceae*		√
Cuscuta europaea L.	*Convolvulaceae*	√	
Cuscuta planiflora Ten.	*Convolvulaceae*	√	
Sedum album L.	*Crassulaceae*	√	
Sedum caespitosum (Cav.) DC.	*Crassulaceae*	√	
Sedum sediforme (Jacq.) Pau	*Crassulaceae*	√	
Umbilicus horizontalis (Guss.) DC.	*Crassulaceae*	√	
Umbilicus rupestris (Salisb.) Dandy	*Crassulaceae*	√	
Citrullus colocynthis (L.) Schrad.	*Cucurbitaceae*		√
Cupressus sempervirens L.	*Cupressaceae*	√	
Juniperus phoenicea L.	*Cupressaceae*	√	
Cyperus conglomeratus Rottb.	*Cyperaceae*		√
Cyperus laevigatus L.	*Cyperaceae*		√
Cyperus michelianus (L.) Link	*Cyperaceae*		√**
Schoenoplectus litoralis (Schrad.) Palla	*Cyperaceae*		√
Scirpoides holoschoenus (L.) Sojak	*Cyperaceae*		√
Sixalix arenaria (Forssk.) Greuter & Burdet	*Dipsacaceae*	√	
Sixalix libyca (Alavi) Greuter & Burdet	*Dipsacaceae*	√*	
Arbutus pavarii Pamp.	*Ericaceae*	√*	

Table 1. (Continued)

Chrozophora tinctoria (L.) Raf.	*Euphorbiaceae*		√
Euphorbia calyptrata Coss. & Kralik	*Euphorbiaceae*		√
Euphorbia chamaesyce L.	*Euphorbiaceae*		√
Euphorbia characias L.	*Euphorbiaceae*	√	
Euphorbia dendroides L.	*Euphorbiaceae*	√	
Euphorbia dracunculoides Lam.	*Euphorbiaceae*	√	√
Euphorbia falcata L.	*Euphorbiaceae*	√	
Euphorbia granulata Forssk.	*Euphorbiaceae*		√
Euphorbia helioscopia L.	*Euphorbiaceae*	√	
Euphorbia peplis L.	*Euphorbiaceae*	√	
Mercurialis annua L.	*Euphorbiaceae*	√	
Ricinus communis L.	*Euphorbiaceae*		√
Acacia nilotica (L.) Willd. ex Delile	*Fabaceae*		√
Acacia tortilis (Forssk.) Heyne	*Fabaceae*		√
Alhagi maurorum subsp. *graecorum* (Boiss.) Awmack & Lock	*Fabaceae*		√
Anthyllis henoniana Coss. Ex Batt.	*Fabaceae*	√	
Argyrolobium uniflorum (Decne.) Jaub. & Spach	*Fabaceae*		√
Astragalus peregrinus Vahl	*Fabaceae*		√
Astragalus trigonus DC.	*Fabaceae*		√
Astragalus vogelii (Webb) Bornm.	*Fabaceae*		√
Bituminaria bituminosa (L.) C.H.Stirt.	*Fabaceae*	√	
Calicotome villosa (Poir.) Link	*Fabaceae*	√	
Coronilla repanda (Poir.) Guss.	*Fabaceae*	√	
Coronilla scorpioides (L.) Kock	*Fabaceae*	√	
Crotalaria saharae Coss.	*Fabaceae*		√
Cullen plicatum (Delile) C.H.Stirt.	*Fabaceae*		√
Ebenus pinnata Ait.	*Fabaceae*	√	
Hippocrepis areolata Desv.	*Fabaceae*	√	
Hymenocarpos circinnatus (L.) Savi	*Fabaceae*	√	
Lathyrus aphaca L.	*Fabaceae*	√	
Lathyrus cicera L.	*Fabaceae*	√	
Lens culinaris Medik.	*Fabaceae*	√	
Lotus creticus L.	*Fabaceae*	√	
Lotus cytisoides L.	*Fabaceae*	√	
Lotus edulis L.	*Fabaceae*	√	
Lotus glinoides Del.	*Fabaceae*	√	√
Lotus ornithopodioides L.	*Fabaceae*	√	
Lupinus digitatus Forssk.	*Fabaceae*		√
Medicago arabica (L.) Huds.	*Fabaceae*	√	
Medicago italica (Mill.) Fiori	*Fabaceae*	√	
Medicago littoralis Loisel.	*Fabaceae*	√	
Medicago orbicularis (L.) Bart.	*Fabaceae*	√	
Medicago truncatula Gaertn.	*Fabaceae*	√	
Medicago turbinata (L.) All.	*Fabaceae*	√	
Melilotus indicus (L.) All	*Fabaceae*		√
Melilotus sulcatus Desf.	*Fabaceae*	√	
Onobrychis crista-galli (L.) Lam.	*Fabaceae*	√	
Ononis natrix L.	*Fabaceae*	√	
Ononis serrata Forssk.	*Fabaceae*	√	
Rhynchosia malacophylla (Spreng.) Bojer	*Fabaceae*		√**
Scorpiurus muricatus L.	*Fabaceae*	√	
Spartium junceum L.	*Fabaceae*	√	
Tetragonolobus purpureus Moench.	*Fabaceae*	√	
Trifolium angustifolium L.	*Fabaceae*	√	
Trifolium arvense L.	*Fabaceae*	√	
Trifolium campestre Schreb.	*Fabaceae*	√	
Trifolium dasyurum C.Presl	*Fabaceae*	√	
Trifolium purpureum Loisel.	*Fabaceae*	√	
Trifolium stellatum L.	*Fabaceae*	√	
Trifolium tomentosum L.	*Fabaceae*	√	
Trigonella anguina Delile	*Fabaceae*		√
Trigonella stellata Forssk.	*Fabaceae*		√
Tripodion tetraphyllum (L.) Fourr.	*Fabaceae*	√	
Vicia monantha Retz.	*Fabaceae*	√	
Vicia parviflora Cav.	*Fabaceae*	√	
Vicia peregrina L.	*Fabaceae*		√
Vicia sativa L.	*Fabaceae*		√
Vicia villosa Roth	*Fabaceae*	√	

Table 1. (Continued)

Quercus coccifera L.	*Fagaceae*	√	
Centaurium pulchellum (Swartz) Druce	*Gentianaceae*	√	√
Centaurium spicatum (L.) Fritsch	*Gentianaceae*	√	
Erodium glaucophyllum (L.) L´Herit	*Geraniaceae*	√	
Erodium neuradifolium Delile ex Godr.	*Geraniaceae*	√	
Geranium molle L.	*Geraniaceae*	√	
Globularia alypum L.	*Globulariaceae*	√	
Globularia alypum subsp. *arabica* (Jaub. & Spach) Dobignard	*Globulariaceae*	√	
Hypericum empetrifolium Willd.	*Hypericaceae*	√	
Juncus acutus L.	*Juncaceae*	√	
Juncus maritimus Lam.	*Juncaceae*		√
Ballota andreuzziana Pamp.	*Lamiaceae*	√*	
Ballota pseudodictamnus (L.) Benth.	*Lamiaceae*	√	
Calamintha incana (Sm.) Boiss. Ex Benth	*Lamiaceae*	√	
Marrubium vulgare L.	*Lamiaceae*	√	
Micromeria juliana (L.) Rchb.	*Lamiaceae*	√	
Micromeria nervosa (Desf.) Benth.	*Lamiaceae*	√	
Nepeta vivianii (Coss.) Beg. & Vacc.	*Lamiaceae*	√	
Phlomis floccosa D. Don	*Lamiaceae*	√	
Prasium majus L.	*Lamiaceae*	√	
Rosmarinus officinalis L.	*Lamiaceae*	√	
Satureja thymbra L.	*Lamiaceae*	√	
Stachys rosea (Desf.) Bioss.	*Lamiaceae*	√	
Teucrium brevifolium Schreber	*Lamiaceae*	√	
Teucrium compactum Lag.	*Lamiaceae*	√	
Lemna minor L.	*Lemnaceae*		√
Limeum obovatum Vicary	*Limeaceae*		√
Linum bienne Mill.	*Linaceae*	√	√
Linum nodiflorum L.	*Linaceae*	√	
Linum strictum L.	*Linaceae*	√	
Linum usitatissimum L.	*Linaceae*	√	
Lythrum hyssopifolia L.	*Lythraceae*		√
Malva parviflora L.	*Malvaceae*	√	√
Marsilea aegyptica Willd.	*Marsileaceae*		√
Ficus salicifolia Vahl	*Moraceae*		√
Neurada procumbens L.	*Neuradaceae*		√
Nitraria retusa (Forssk.) Aschres.	*Nitrariaceae*		√
Boerhavia diffusa L.	*Nyctaginaceae*		√
Olea europaea L.	*Oleaceae*	√	
Oxalis articulata Savig.	*Oxalidaceae*	√	
Papaver rhoeas L.	*Papaveraceae*	√	
Pinus halepensis Mill.	*Pinaceae*	√	
Kickxia aegyptiaca (L.) Nabelek	*Plantaginaceae*		√
Plantago cyrenaica Durand & Barratte	*Plantaginaceae*	√*	
Plantago lagopus L.	*Plantaginaceae*	√	
Limonium vaccarii Brullo	*Plumbaginaceae*	√	
Anisantha rubens (L.) Nevski	*Poaceae*		√
Aristida funiculata Trin. & Rupr.	*Poaceae*		√
Avena sterilis L.	*Poaceae*		√
Catapodium hemipoa (Spreng.) Lainz	*Poaceae*		√
Catapodium marinum (L.) C.E.Hubb.	*Poaceae*		√
Cenchrus ciliaris L.	*Poaceae*		√
Centropodia forskalii (Vahl) Cope	*Poaceae*		√
Cutandia memphitica (Spreng.) Benth.	*Poaceae*		√
Cynodon dactylon (L.) Pers.	*Poaceae*		√
Dactyloctenium aegyptium (L.) Willd.	*Poaceae*		√
Desmostachya bipinnata (L.) Stapf	*Poaceae*		√
Dichanthium annulatum (Forssk.) Stapf	*Poaceae*		√
Dichanthium foveolatum (Delile) Roberty	*Poaceae*		√
Eragrostis aegyptiaca (Willd.) Delile	*Poaceae*		√
Eragrostis pilosa (L.) P.Beauv.	*Poaceae*		√
Hordeum vulgare L.	*Poaceae*	√	
Imperata cylindrica (L.) Raeuschel	*Poaceae*		√
Lolium multiflorum Lam.	*Poaceae*		√
Panicum turgidum Forssk.	*Poaceae*		√
Phalaris minor Retz.	*Poaceae*		√
Phragmites australis (Cav.) Trin. ex Steud	*Poaceae*		√
Polypogon monspeliensis (L.) Desf.	*Poaceae*		√

Table 1. (Continued)

Rostraria festucoides (Link) Romero Zarco	*Poaceae*		√
Rostraria rohlfsii (Asch.) Holub	*Poaceae*		√
Sorghum halepense (L.) Pers.	*Poaceae*		√
Stipagrostis scoparia (Trin. & Rupr.) De Winter	*Poaceae*		√
Stipagrostis shawii (H.Scholz) H.Scholz	*Poaceae*		√
Calligonum polygonoides subsp. *comosum* (L´Her.) Soskov	*Polygonaceae*		√
Emex spinosa (L.) Camped	*Polygonaceae*	√	
Polygonum argyrocoleum Steud. ex Kunze	*Polygonaceae*	√	
Polygonum aviculare L.	*Polygonaceae*	√	
Polygonum balansae Boiss.	*Polygonaceae*	√	
Polygonum equisetiforme Sibth. & Sm.	*Polygonaceae*		√
Portulaca oleracea L.	*Portulacaceae*		√
Potamogeton hoggarensis Dandy	*Potamogetonaceae*		√
Potamogeton nodosus Poir	*Potamogetonaceae*		√
Potamogeton perfoliatus L.	*Potamogetonaceae*		√
Potamogeton schweinfurthii A.Benn.	*Potamogetonaceae*		√
Potamogeton trichoides Cham. & Schltdl.	*Potamogetonaceae*		√
Zannichellia palustris ssp. *pedicellata* Wahlenb & Rosen	*Potamogetonaceae*		√
Cyclamen rohlfsianum Asch.	*Primulaceae*	√*	
Lysimachia arvensis (L.) U.Manns & Anderb	*Primulaceae*	√	√
Lysimachia linum-stellatum L.	*Primulaceae*	√	
Lysimachia monelli (L.) U.Manns & Anderb	*Primulaceae*	√	
Adonis dentata Delile	*Ranunculaceae*	√	
Delphinium halteratum Sm.	*Ranunculaceae*	√	
Ranunculus asiaticus L.	*Ranunculaceae*	√	
Ranunculus bullatus L.	*Ranunculaceae*	√	
Ranunculus cyclocarpus Pamp.	*Ranunculaceae*	√*	
Ranunculus paludosus Poiret	*Ranunculaceae*	√	
Ranunculus trilobus Defs	*Ranunculaceae*	√	
Caylusea hexagyna (Forssk.) M. L. Green	*Resedaceae*		√
Reseda arabica Boiss	*Resedaceae*		√
Reseda lutea L.	*Resedaceae*		√
Reseda villosa Coss.	*Resedaceae*		√
Rhamnus lycioides L.	*Rhamnaceae*	√	
Ziziphus lotus (L.) Lam.	*Rhamnaceae*	√	√
Ziziphus spina-christi (L.) Desf.	*Rhamnaceae*		√
Sanguisorba minor Scop.	*Rosaceae*	√	
Sarcopoterium spinosum (L.) Spach	*Rosaceae*	√	
Asperula arvensis L.	*Rubiaceae*	√	
Galium murale (L.) All.	*Rubiaceae*	√	
Galium verrucosum Huds.	*Rubiaceae*	√	
Plocama calabrica (L.f.) M.Backlund & Thulin	*Rubiaceae*	√	
Valantia hispida L.	*Rubiaceae*	√	
Salvadora persica L.	*Salvadoraceae*		√
Scrophularia canina L.	*Scrophulariaceae*	√	
Verbascum ballii (Batt.) Hub.-Mor.	*Scrophulariaceae*	√	
Verbascum sinuatum L.	*Scrophulariaceae*	√	
Smilax aspera L.	*Smilacaceae*	√	
Hyoscyamus muticus L.	*Solanaceae*		√
Solanum nigrum L.	*Solanaceae*		√
Tamarix aphylla (L.) Karst.	*Tamaricaceae*	√	√
Tamarix arborea (Sieber ex Ehrenb.) Bunge	*Tamaricaceae*	√	√
Tamarix parviflora DC.	*Tamaricaceae*	√	
Tamarix passerinoides Desv.	*Tamaricaceae*		√
Tamarix tetragyna Ehrenb.	*Tamaricaceae*		√
Thymelaea hirsuta (L.) Endl.	*Thymelaeaceae*	√	
Forsskaolea tenacissima L.	*Urticaceae*		√
Urtica dioica L.	*Urticaceae*	√	
Urtica pilulifera L.	*Urticaceae*	√	
Urtica urens L.	*Urticaceae*	√	
Vahlia dichotoma (Murray) Kuntze	*Vahliaceae*		√
Vahlia geminiflora (Delile) Bridson	*Vahliaceae*		√
Centranthus calcitrapae (L.) Dufresne	*Valerianaceae*	√	
Verbena supina L.	*Verbenaceae*		√
Asphodelus fistulosus L.	*Xanthorrhoeaceae*		√
Balanites aegyptiaca (L.) Del.	*Zygophyllaceae*		√
Fagonia arabica L.	*Zygophyllaceae*		√
Fagonia bruguieri DC	*Zygophyllaceae*		√

Table 1. (Continued)

Fagonia glutinosa Delile	*Zygophyllaceae*		√
Fagonia indica Burm.f.	*Zygophyllaceae*		√
Seetzenia lanata (Willd.) Bullock	*Zygophyllaceae*		√
Tetraena simplex (L.) Beier & Thulin	*Zygophyllaceae*		√
Tribulus mollis Ehrenb. ex Schweinf	*Zygophyllaceae*		√
Tribulus pentandrus Forssk. Var. *pentandrus*	*Zygophyllaceae*		√
Tribulus terrestris L.	*Zygophyllaceae*		√

The Mediterranean site (Wadi Jarjar Amma) was higher in species richness and included 51 plant families. Of the 238 species found in this valley, 139 were therophytes and 51 chamaephytes, 20 phanerophytes, 15 cryptophytes, 10 hemicryptophytes and 3 geophytes (Table 2). The therophytes formed 59% of the vegetation in this valley, followed by the chamaephytes with 21% (Fig. 2). *Asteraceae*, *Fabaceae*, *Lamiaceae* and *Apiaceae* had the highest number of plant species: 41, 41, 14 and 12, respectively (Table 3). The *Poaceae* and *Zygophyllaceae* were almost absent from this wadi (Table 3).

In the Saharan site (Wadi Tanezzuft), therophytes dominated the area with 83 species followed by chameaphytes with 49 species; these formed the key character of the vegetation across this Saharan area. There were 12 phanerophyte species, restricted to shrubs and small trees capable of growing in such an extreme environment: *Acacia nilotica*, *A. tortilis*, *Balanites aegyptiaca*, *Ficus salicifolia*, *Nerium oleander*, *Nitraria retusa*, *Ricinus communis*, *Salvadora persica*, *Tamarix aphylla*, *T. arborea*, *T. passerinoides*, *T. tetragyna* and *Ziziphus spina-christi*. The vegetation contained species of 43 plant families, 31 of which were represented by only one or two species. Families such as *Poaceae*, *Asteraceae*, *Fabaceae* and *Zygophyllaceae* contained a high number of species (26, 23, 17 and 10, respectively) while members of the *Lamiaceae* and *Ranunculaceae* were not found in this wadi (Table 3). The therophytes formed 49% of the vegetation in this area, followed by the chamaephytes with 29%; phanerophytes formed only 7% of the vegetation (Fig. 2).

Eleven Libyan endemic species were found in the coastal wadi of Jarjar Amma: *Arbutus pavarii*, *Arum cyrenaicum*, *Ballota andreuzziana*, *Crepis senecioides*, *Cyclamen rohlfsianum*, *Cynara cyrenaica*, *Onopordum cyrenaicum*, *Pallenis cyrenaica*, *Plantago cyrenaica*, *Ranunculus cyclocarpus* and *Scabiosa libyca*. Only three endemic species, however, were found in Wadi Tanezzuft: *Atractylis phazaniae* and *Crepis senecioides.* Three new records for Libya were collected from Wadi Tanezzuft: *Cyperus michelianus*, *Pluchea dioscoridis* and *Rhynchosia malacophylla*.

Table 2. Life-form and percentage of plant species within each site.

Life-form	Percent of species	
	Jarjar Amma	Tanezzuft
Phanerophytes	8	7
Chamaephytes	21	29
Hemicryptophytes	4	8
Cryptophytes	6	5
Geophytes	1	1
Therophytes	59	49

Table 3. The most dominated plant families in both sites, the rest of plant families collected contained 5 or less species.

Jarjar Amma			Tanezzuft	
Asteraceae	1		*Poaceae*	26
Fabaceae	1		*Asteraceae*	23
Lamiaceae	4		*Fabaceae*	17
Apiaceae	2		*Zygophyllaceae*	10
Brassicaceae			*Amaranthaceae*	9
Cistaceae			*Brassicaceae*	8
Convolvulaceae			*Caryophyllaceae*	7
Euphorbiaceae			*Euphorbiaceae*	6
Ranunculaceae			*Convolvulaceae*	1
Caryophyllaceae			*Apiaceae*	1
Amaranthacea			*Cistaceae*	0
Poaceae			*Lamiaceae*	0
Zygophyllaceae			*Ranunculaceae*	0

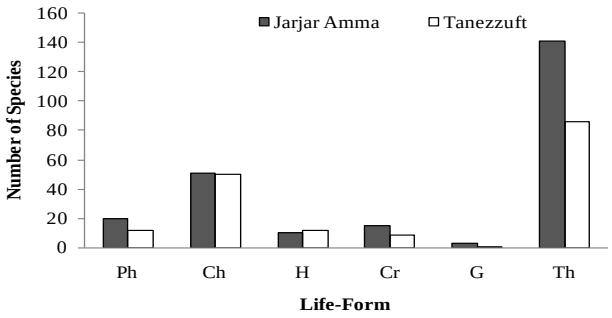

Figure 2. Life-form and number of plant species collected from the each site. Raunkiaer's life-form system was used for categorising the plants. (Ph) = Phanerophyte, (Ch) = Chamaeophyte, (H) = Hemocryptophyte, (Cr) = Cryptophyte, (G) = Geophyte and (Th) = Therophyte.

4. Conclusions

The Mediterranean site was richer in species than the Saharan site (238 and 167 species, respectively). Annuals were prominent at both sites reflecting climatic similarites of the two regions. All the phanerophytes found in the Saharan site were shrubs or facultative shrubs, more precisely, nanophanerophytes which are 25 cm to 2 m tall (Cain, 1950). These species have the capability to survive the extremely dry soils with a wide range of salinity gradients (Zahran and Willis, 1992; Shaltout *et al.*, 2003; El-Bana and Al-Mathnani, 2009). By comparison, the vegetation of the wetter Wadi Jarjar Amma was markedly Mediterranean in composition and characterised by phanerophytes forming fragmented patches of *Cupressus sempervirens*, *Juniperus phoenicea*, *Olea europaea*, *Quercus coccifera*, *Ceratonia siliqua* and *Pinus halepensis*. This includes *Juniperus phoenice* which is considered as one of the threatened trees in the Mediterranean Basin (El-Bana *et al.*, 2010).

The mountainous location of Wadi Jarjar Amma (on the first and second terraces of the northern slope), explains why desert species such as *Asphodelus* spp., that commonly appear on the lower southern slopes were not found on this site (Gimingham and Walton, 1954). It is likely that the vegetation of this mounatinous site reflects the wider region since, with 238 species, it is similar to that found in the El-Marj zone (189 species) about 100 km to the west (El-Barasi *et al.*, 2011). In both places the families of *Asteraceae* and *Fabaceae* are dominant, forming 29% of species in El-Marj compared to 34% at Jarjar Amma. Other valleys in these highlands have species numbers ranging from 189 to 336 (El-Barasi *et al.*, 2011), increasing with elevation as on the northern slopes of Al-Jabal Al-Akhdar (Hegazy *et al.*, 2011). The structure of the valley topography also affects vegetation composition since small pools of salt marshes and sand dunes at the coastal end contributed to the appearance of xerophytic and halophytic species (Brullo and Furnari, 1981).

Despite the Sahara in Libya being one of the most barren spots in the world, a few wet days are sufficient for the bulbous *Asphodelus fistulosus* to start appearing, followed by the annuals *Zilla spinosa* and *Erodium glaucophyllum* within a few weeks (Thomas, 1921). Surprisingly, this desert site had a higher number of plant species than expected (Thomas, 1921; El-Bana and Al-Mathnani, 2009) perhaps due to cultivation of the nearby oases and the development of a high cover of organic-rich soils (Burdon, 1980; Brooks, 2006). This would also explain the high number of graminosea found in the valley. Moreover, it seems that the heterogeneity of local topography and soil properties, in terms of salinity, silt, clay, organic matter and moisture, contribute to the diverse communities of this area (El-Bana and Al-Mathnani, 2009). Occurance of *Nitraria retusa* and *Tamarix* spp. has assisted the building of large sand hillocks in the sandy flat areas which increases the plant diversity of this outstanding ecosystem even further (Batanouny, 2001). In this valley, we recorded *Acacia tortilis* ssp *raddiana* which is considered one of the most endangered species in the Middle East (Wiegand *et al.*, 1999). The presence of this species maintains the richeness of perennial plants growing in its vicinity (Ward and Rohner, 1997). The vegetation of this valley shows great similatrity to that in oases and valleys located in the western Sahara in Egypt (Kassas and Girgis, 1965; Abd El-Ghani, 2000; Woldewahid *et al.*, 2007).

The 15 species common to both sites are mostly those capable of growing in very salty soils and, as thermophulous plants, also have the capability to occupy wide areas of arid regions (Batanouny, 2001; Kassas and Girgis, 1965; Zahran and Willis, 1992). In Wadi Jarjar Amma, those species were only found in the flat areas that are close to the shore line and characterised by sandy hillocks. However, those species only formed 6% of plant species found in this valley.

Endemic species were less frequent in Tanezzuft (1% of the Libyan endemic species), compared to Jarjar Amma (19%). Indeed, the wider Al-Jabal Al-Akhdar region has been recorded as containing 50% of Libyan endemic species (Qaiser and El-Gadi, 1984).

Dominance of the annuals clearly reflects the dry climate aspect in these two areas, due to the lack of precipitation, strong winds and high temperatures increasing evaporation, and to the erratic distribution of rainfall (Kassam, 1981). However, the higher precipitation of the coastal area, the location of the valley on the northern slope of the mountain, and the variation in elevation along the valley leads to the dominance of species of chamaephyte and phanerophyte characteristic of the Mediterranean. The sand dunes and some patches of salt marshes further added to

species diversity. The Saharan site was comparatively species poor, but remarkaly rich for the Sahara. This is attributed to the unique composition of soil, water runoff concenrated by the unique topography and the agricultural activities in the nearby oases during the last few decades (Hammer and Perrino1985; El-Bana and Al-Mathnani 2009).

The two climatic types within Libyan boundaries have almost the same pattern of family-class occurance, but not genera. Morover, the Saharan site is characterised with 31 out of 43 plant families being represented by only one species. For the first time, this study gives an understanding of the similarities and differences between these two cliamtic areas. However, more quantative studies addressing species abundance, frequency and coverage are now needed to determine the composition, structure and functioning of plant community in these two areas. Only then can conservation measures be realistically put into place.

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