THE BASES OF GIZZU HERBS
ADAPTATION TO WATER LIMITED
ENVIRONMENT IN NORTH DARFUR
STATE, SUDAN

BY

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the Degree of Doctor of philosophy

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وَهُوَ الَّذِي أَنْزَلَ مِنَ السَّمَاءِ مَاءً فَآخَرَجْنَا بِهِ نَبَاتٌ كُلّ شَيْءٍ فَآخَرَجْنَا مِنْهُ حَضْرًا نُخْرِجُ مِنْهُ حَبْبًا مَّتَرَاكِبًا وَمِنْ النَّحلِ مِنْ طَعِينَهَا قَنْوَانٌ دَائِيَّةٌ وَجِنَّاتٍ مِّنْ أَعْنَابِ الْزَّيْتُونِ وَالْرُّمَّانِ مُشْتَبَهًا وَغَيْرِ مُشْتَبَهٍ إِنْ تَمُّ ذَٰلِكَ إِلَى ثُمَّ مَا أُنْهِرَ وَيَنْبِعُ إِنَّ فِي ذَٰلِكَ لَآيَاتٍ لَّكُمُ الْيَوْمِ الْآخِرِ
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ABSTRACT

A field survey was carried out in the Gizzu district, which lies in the Northern Darfur State, to determine species composition and distribution of Gizzu flora. The morphological characteristics of a selected group of herbs and grasses in the Gizzu area and their relation to water-limited adaptation were investigated. In addition, laboratory and glasshouse experiments were conducted to determine the effect of temperature and water stress on the performance of two species of Blepharis, namely B. linariifolia and B. ciliaris. The morphological, physiological and anatomical bases of adaptation were discussed.

The results indicated that the flora of the Gizzu district is composed of four types of vegetation namely; permanent trees and shrubs, perennial herbs and grasses, succulent and ephemeral (annual) plants.

The majority of Gizzu herbs and grasses were commonly observed on light soils (sandy soil) compared to the relatively heavy soils (Wadi soil). The distribution of the vegetation types were closely associated with the amount of rainfall and soil types in the Gizzu area. The variations in morphological characteristic of Gizzu herbs and grasses were due to their adaptive fitness to defined boundaries of soil and weather.

The seeds of Blepharis species germinated on a wide range of temperatures (15–45°C) and the percentages of germination were higher particularly when the seeds were soaked before sowing. The results also indicated that, the water-stressed plants of Blepharis had significantly reduced leaf surface area, and increased the number of hairs and prickles. They also showed low stomatal conductance, transpiration rate and leaf water potential. Moreover, the anatomical variations were particularly
evident in stressed plants specially in the thickness of the cuticular layer in leaves and the prederm in both roots and stems.
الخلاصة

دارفور شمال ولاية في الوجدان الجزوية المنطقة في ميدان دراسة عمل تم للبناء والانتشار النباتية.

المورفولوجيا الخصائص دراسة تم لجمعية وعلاقتها الجزوية المنطقة في والحشائش الأغصان ومن لمنشأة بمضمونها. 

فاضفة ذلك عند حرارة درجة تم لتحديد الزجاج وبيت المعمل في التجارب المائية والجهد على النبات من نوعين.

المنتخبيات الأمثلية طرقة توضيح تم وقائبة والتشريحي والفسيولوجيا المعروفة.

النتائج الأربعة عليها الجزوية المنطقة في النباتي الغطاء الأنواع النباتية الغضة النباتية المعمرة، والحشائش الأغصان والشجيرات، الأشجار. الخفيفة الربطة لأن وحش الآثمة والنجاعة والنظرية والを持って الجزوية الحديقة من），(وتم برنامج النباتية القوية بالربطة (.compare (الجزيرة المنطقة في الربطة (وان) وحش الآثمة الأنسجة والاعتماد، الثقوب والمبادي والحرارة، وثمانية روائدة وربطة (comparison (الجزيرة من شرطة (in 15 -45)م (و، نسبة الزراعة قبل الماء البدور في العالية النباتية. 

فجاء بعض النباتات وزيادة الورقة السطحة والشتائم (mykhels المبادية، وظهور النباتات في التشريحي الاختلافات بوضوح والساق وال(tab وتحديد السرعة في البريدي وطبيعة الأوراق في الكوبس السماك في الجمعية ( professionally. 

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كليتيمف (لأول مجموعات الأقلية وذوي الأيديولوجيا صناع كريج، لف ندلي كور أش. إزاء هذه فرامل فصول). وآلاي فين، 50 درجة كليلية نراجع.
CHAPTER ONE
INTRODUCTION

Deserts are one of the major terrestrial ecosystems on earth, amounting to about one-fifth of the total surface area of the planet. The distinctive and defining characteristic of all deserts is aridity. Deserts encompass land-scapes that are also subjected to extremes of temperature, high evapo-transpiration, unpredictable precipitation, and complex soil types. They comprise a wide variety of environments ranging from extreme arid regions to semi-desert shrublands and grasslands (Lowrey, 2002).

Sudan is a large country which occupies nearly one million square miles and lies between latitudes 3° 53 N and 21° 55° N and longitudes 21° 54° E and 38° 30° E with a wide variation in its habitats and vegetation (Appendix 1). The climate of the country is wholly tropical and varies from complete desert north of latitude 18° N through a region of semi-desert, passing southwards into a continental equatorial type of climate (Whiteman, 1971).
North Darfur State, which lies in the western parts of Sudan between latitudes 12° 30’ N and 21° 55’ N, belongs to the desert and semi-desert region with 10-12 arid months. Average precipitation ranges from traces in the north to some 377 mm in the south (Ibrahim, 1984). The desert region, which occupies about half of the area of Northern Darfur, is characterized by hot summer, cool winter and a short rainy season and is nearly void of life. Instead they abound with wonderfully adapted plants that have evolved various mechanisms for tolerating or avoiding the extremes of aridity and temperature. These adapted plants are composed mainly of trees and shrubs (limited to water streams) and a group of desert vegetation generally known as ‘Gizzu’ which usually grows after an occasional rainfall and continues growing in the dry season providing a good fodder for animals.

The average annual rainfall in the desert is less than 75 mm, and the vegetation is virtually absent (Harrison and Jackson, 1958) except in the water courses and as ephemeral herbs and grasses springing up after rain showers giving rise to a very valuable ‘Gizzu’ grazing. The rich grazable grasses ‘Gizzu’ are usually seen within the desert boundary lighter soil (Smith, 1949).

The Gizzu as a word is of an Arabic origin and it was mentioned in pre-Islamic poem of the poet Labid Ibn Rabee-a as Gizzan which changed to Gizzu to facilitate pronunciation (Najila, 1971). According to the previous studies of plant cover in Sudan, these plants were commonly reported in areas north of latitude 16° N. However, due to the desertification elements, these plants were dragged south to latitude 15° North. Generally the Gizzu plants exist around Howar Valley in the eastern parts of Northern Darfur State, particularly north of ALMalha town (Dar Meidob). The most important areas include, ALHara, Ein Bissaro, Groon Bagar, AlHamar Om Ter, Kirab Makin, Om laota ALZarga, Albuhera, AlKaresh, Goz Bilanar. In the western parts, Gizzu herbs and grasses are found north of the Tina town (Dar Zaghawa) mainly in Forawia, Boba, Karyari, Kantoush, AlDubab AlBurg, Jebel Ardi.

The majority of the Gizzu plants growing in the sandy soils include Neurada procumbens L. (ALSAADAN), Indigofera aculeata DC. (DARMA), Indigofera arenaria (KHESHIAN), Stipagrosits plumosa (HALEEF), Triraphis pumilio R.Br. (SALIAN) and Moltkiopsis ciliata (Forssk.) T.M. Johnston (HERESH). However, very few plants grow in the valleys of heavy soils (Wadi Hawar and
Wadi Magrour), and these include Panicum turgidum, and Francoeria crispa.

Gizzu plants normally grow after the rainy season which starts in August and September. They generally start growing in October where the Northern Winds bringing cold weather help in their growth. In November the Gizzu field becomes green and animals, mainly camels and sheep, can graze on it. Gizzu plants continue blossoming until February or March. When grazed by animals, regrowth is possible depending on quantity of rain and its distribution, and the length of winter season.

Camels and sheep depend on Gizzu herbs as a good fodder from November till March and require no drinking water during all these months but get all their moisture requirements from the grazing itself. The herdsmen depend for most of their food and moisture requirement on milk from camels and sheep. When camel and sheep feed on Gizzu plants such as Triraphis pumilio (ALSAALIAN), and Indigofera arenaria A.Rich (KHESHIAN), they become considerably fatter, and the wool of these animals become noticeably thicker and longer when fed on Indigofera aculeata DC. (DARMA). Some Gizzu herbs have medicinal values such as the two species of Blepharis spp. (BEGHIAL), Crotalaria aculeata De Wild (NATASH) and Citrullus colocynthis (L.) Schard. (HANDAL) as claimed by local people.

The tribes going to the Gizzu are Kababish, and Kawahla from Kordofan with Meidob, Zaghawa, Zayadia and Berti from Darfur and Guraan from Chad. Some Kababish travel 500 miles to the Gizzu, the longest seasonal migration of any Sudanese tribe. All herdsmen on the Gizzu are prepared to endure the intense cold and the hardship for the benefit of their animals (Harrison and Jackson, 1958).

The Gizzu herbs are the result of a series of very successful adaptation to local conditions of the desert. However, information about their mechanisms of adaptation were unknown. Therefore, the objectives of this study are:

1. To characterize and categorize the species composition of the Gizzu herbs.
2. To investigate the effects of the ecological factors on Gizzu herbs distribution.

3. To study the morphological, physiological and anatomical bases of Gizzu herbs adaptation to the water-limited environment.
CHAPTER TWO

THE STUDY AREA

1. Location:

North Darfur state lies in the western part of the Sudan between latitudes 12° 30’ N and 21° 55’ N and longitudes 23° E and 27° 30’ E and It is bound by Libyan Desert from the northwest, Chad from the west, South Darfur State from the south and North Kordofan State and Northern State from the east (Appendex 2).

The gizzu area in Sudan is located in the Northern parts of the North Darfur state, North Kordofan State and Northern State between latitudes 15° and 18° N (Fig.1). Gizzu district in North Darfur State includes Meidob area in the Eastern parts of Northern Darfur, Zaghawa area in the Western parts of North Darfur and all parts between the two areas particularly around Wadi Hawar (The longest ancient river in the Western Desert) as shown in figure (2).

2. Geology:

The main geological formations in the study area according to Awad (1987) are as follows:

2.1. Rock Basement:

The dominant rock types are granite and granetiferous gneisses, amphibolites, quartzo-feldospathics, pelitic schist and migmatites. Late organic granitic batholiths locally termed (Older Granite) are also reported. Quartz veins and pegmatites are well developed in some places. Marble outcrops were observed west of the northern part of Jebel Tageru in the northeastern part of the study area.

Fig (1) : North Darfur State
2.2. **Sedimentary Formation:**

The so-called Nubian sandstone formation of western Kordofan and Darfur regions has been reviewed by Whiteman (1971). It was described as being generally composed of friable to well consolidated sandstones, mudstones and conglomerates unconformably overlying the basement rocks. Karkanis (1971) advocated deposition of the sediments of the western Kordofan and Darfur regions in marine environment saying that the groundwater is saline in some areas. However, Whiteman (1971) attributed the salinity to the infiltration of the water through the outerlying Umm Rawaba Formation that is known to contain saline groundwater due to the clayey materials which are dominant in the formation.

2.3. **Volcanic Rocks:**

Basalts are the most common volcanic rocks observed in Darfur Region (Francis et al., 1973). The basaltic rocks in the study area occur as isolated plugs and erosional remnants capping the Tagabo and the Meidob Hills. The close similarity between the volcanic rocks in Tagabo and the Meidob hills with the early basaltic lava of Jebel Marra suggests that all the three are relics of formerly more extensive volcanic province of mid-Tertiary age (Francis et. al, 1973). In addition to that, the Rahib mountain area is considered as an important geological site in view of the nature of sedimentary and metamorphic rocks. The mount is composed of granite marble and gneisses rocks and it dates back to the protozoa age (Sudanese National Commission for UNESCO, 1998).

3. **Geomorphology:**

The geomorphology of the study area is a product of interaction of pleistocene, recent neotectonic movements and climatic fluctuation (Abd El Rahman, 1988). This is clearly seen from a consideration of the mean geomorphic units. Geomorphology of the study area is divided into three zones
3.1. **Darfur Dome:**

Darfur dome comprises the hilly chain of Jebel Marra, Berti and Meidob hills, that extend along the NE-SW direction, and with heights ranging from 1000 to 3000 meters above sea level (asl). The dome largely affected the rainfall, the drainage system and the climate of the area.

3.2. **Teiga plateau:**

Teiga plateau is flat-topped Wadi EL Milk outcrop (1000 m asl) bound by NE-SW escarpments, separating Wadi Hawar and Wadi Magrur basins. The denuded corridors, in between the hilly chains, developed by doming systems form generally flat flood plains.

3.3. **Flood plains:**

The invading sand dunes have reshaped the area, smoothened most of the clayey flood plains, blocked the drainage system, and accumulated around the hilly chains, extending as sheets, or elongated dune fields. The most striking features of the landscape are dendritic drainage system, developed upstream on the rocky hills and the flatness and peneplaned appearance downstream. The area generally slopes NE-wards, from a height of more than 1000 meters to less than 400 meters above sea level.

4. **Climate:**

The climate of Gizzu district is a desert characterized by hot summer, cool winter, and very short rainy season with low means and high annual variations. Meteorological data for the past thirty years (1971-2000) was obtained from Sudan and El Fashir Departments of Meteorological and are shown in Appendeces (4 and 5).
4.1. Rainfall:

Rainfall is the determinant factor for vegetation growth, water supply and range productivity. Rainfall is normally in the form of showers of varying intensity and duration, which does not exceed a few hours.

4.2. Wind:

The wind direction is northeast in the dry season and southeast in the rainy season. The mean monthly wind speed is about 4-6 m.p.h., and the maximum wind speed being in April.

4.3. Relative Humidity:

The mean annual relative humidity in the study area was 31% (1971-2000) whereas the mean monthly relative humidity lies between 18-61%, with the peak values in August and the lowest values in March and April.

4.4. Evaporation:

The mean annual evaporation during the period between 1971-2000 was 13.4 mm. The highest mean monthly evaporation was 17.9 mm recorded in April and May while the lowest value was 8.1 mm recorded in August.

4.5. Temperature:

The maximum temperature ranges between 40 and 44° C with sunshine of more than 10 hours/day and for more than 10 months/year. The highest daily temperature was 43.2° C recorded in May 1978 while the lowest daily temperature was 0.7° C recorded in January 1969.

5. Soils:
Ibrahim, (1984) classified the soils of the study area and distinguished four soil types as follows:

5.1. Immature desert soils:

These soils are generally immature and vary greatly according to the topography and the mineralogical composition of the substrata. The sandy soils of Wadi Hawar are more suitable for vegetation growth than the stoney area of northern Dar Zaghawa.

5.2. The Goz soils:

The Goz soils form a whole zone on the fixed old-dune belt, which extends from central Darfur to the Nile. The proportion of organic matter in the Goz soils is very low. Two kinds of Goz soils are recognized: The fine-grained Goz and the coarse-grained one. The latter occurs often in the close vicinity of its origin of rock, the Nubian sandstone. The finer Goz soil usually covers a longer transport distance by the wind. The fine-grained Goz soils are favorable for vegetation because of their ability to retain moisture for a long time in the root horizon because seepage is much slower than in the coarse-grained Goz soils.
5.3 Alluvial soils:

Alluvial soils occur in the basins of the Wadi soils and normally range between loose sands to massive clays. Alluvial soils are of higher fertility, and of better water-holding capacity, with high clay content and fine texture. In addition, Sandford (1935) stated that there is 'cotton-soil' in Wadi Hawar north of Mellit.

5.4 Volcanic soils:

The piedmont is covered with deep sediment of volcanic ashes, which are very well suited for cultivation, but they are also highly inclined to erosion.

6. Agriculture:

Agricultural activity in the study area is very limited and consists of millet (Pennisetum niloticum) cultivation during the rainy season in the southern and western parts. There are also small areas of vegetables cultivation around dams and hafirs (water collecting sites).

7. Livestock:

Livestock represents the backbone of the economy in the study area, and is comprised of camels, sheep and goats. Camels and sheep graze separately as the requirements of each are different (Appendix 11). Sheep and goats graze around Wadi Magrur and western parts of Wadi Hawar. Camels, which are used to long distance walking with prolonged interval of watering, graze on a wide range of different plant species (Trees, shrubs, herbs). The animal wealth in the study area contributes significantly to Sudan exports of camels and sheep.

8. Wild Animals:
Wild animals in the Gizzu area were observed during the survey. These include Dorcas gazelle (found in great numbers particularly in the eastern and middle parts of the study area) the common Jackal, Ground Squirrel, Cape Hare and Aardvark.

9. Nomadic Groups:

The nomadic tribes in the study area are of Arab and non-Arab origin.

9.1 Arab tribes:

Arab tribes going to the Gizzu are kababish (Atawia) and kawahla from Kordofan and they are usually found in places such as Gabarona, Zrird el Barrad, Zirrada, Hadda, and Um Amad. Also Mahria, Itiefat, Eragat and Zayadia from Darfur are found in places as El Salama, El Siraf, El Tordda, El Khitamawi, El ghibasha Um Siddir, Um Sayala and Um Orawge.

9.2 Non-Arab tribes:

Non-Arab tribes going to the Gizzu are Meidob, Zaghawa and Berti from Darfur, and they are normally found in places such as El Harra, Tigga plateau, Groon Bagar, Ein Besaro, Un Laoto El Zarga, Gabel Baeer, Sabaania Um Laota El Beida, Dubab El Gafal and Wadi Magrur with arab tribes like Zayadia.

Zaghawa and some Arab tribes are also found in places such as Forawia, Boba, and karyari, Sanaidia, Abu Shigara, El Nikala and Karab.

Generally Meidob and Zaghawa tribes occupied the southern parts of the Gizzu Area, (Meidob and Zaghawa District), while Arab tribes occupy the northern parts of the Gizzu Area. Nomadic groups come always in contact with each other over water sources and grazing.

At the beginning of the winter season in November, the nomadic tribes move to the Gizzu area where they spend a period
ranging from 3-6 months, depending on the availability of Gizzu pasture.

10. Water Sources:

North Darfur State generally suffers from acute water deficit in its annual water balance. Such deficit ranges from 200 mm in the north to about 1300 mm in the southern and eastern parts of the state (Ibrahim, 1984). Therefore, the scarcity of water is the major problem in the Gizzu District. Generally there are two sources of water in the Guzzu district:

10.1 Surface water:

Surface water is affected by rainfall amount and intensity, soil, temperature, topography and vegetation cover. Surface water is normally found in seasonal streams (Wadis), Qulta and Hafirs. The two major Wadis within the study area are Wadi Hawar and Wadi Magrur (Appendix 6). Wadi Magrur drain the western slopes of Jebel Berti and Meidob and flow NE-wards to end up in lake Siddig west of Jebel Tageru. Wadi Hawar is considered to be amongst the longest ancient rivers in the Western Desert. It extends for about 1200 kilometers, from Enedi Heights in eastern Chad to join the River Nile parallel to ancient Dongola with breadth ranging between less than 15 meters to 10 kilometers (Sudanese National Commission for UNESCO, 1998). For the purpose of the study, the valley may be divided into the Upper Wadi Hawar, Middle Wadi Hawar and lower Wadi Hawar.

(i) Upper Wadi Hawar:

Upper Wadi Hawar extends along the Sudanese Chadian boarder and inwards to the area of Sogart Tolon Mount, stream courses deep and clear. The valley contains water during the rainy season.
(ii) Middle Wadi Hawar:

Middle Wadi Hawar extends from the end of Upper Wadi Hawar to Rahib Mount. The width of the valley varies as it reaches near four kilometers at certain places.

(iii) Lower Wadi Hawar:

Lower Wadi Hawar extends from Meidob Mounts to River Nile. The length of this part exceeds 400 kilometers with a width of approximately 10 kilometers. The area of Wadi Hawar is termed Western Nubian and it contains the rocks of the Holocene era. The area of the valley is characterized by sedimentary rocks especially sand rocks. This is the reason for the water absorption through the rocks into sub-soil water reservoirs. The studies conducted in this area have proved the existence, in Wadi Hawar, of a huge stock of water supply from sub –soil water which could be utilized for projects in upper and middle Wadi Hawar where rain supplies sub-soil water.

Temporary surface pools are formed along the clay depressions, forming which is known locally as rahads or (Qulta) in the study area, such as Um Froot Qulta, Um Millahi Qulta, ElBarda Qulta, Sag ElZaraf Qulta, Nasur Qulta, and ElAsaker Qulta. Also temporary pools are formed where invaded dunes block Wadi courses, as is the case along Wadi Hawar and Magrur.

Surface pools, though mostly short-lived, the lakes of Magrur and part of Hawar used to keep water for most of the dry season (‘darat’ time) and extensively used by livestock grazing in the Gizzu areas. Surface water is the cheapest water source, especially for livestock.

10.2 Ground water:

Ground water occurs in the coarse to medium sandstones, generally under free water table conditions, and at depth ranging from 50 to less than 5 meters, depending on topography. Along the lower part of Wadi Hawar, the depth of water decreases to less than 2 meters, where it is obtained by shallow dug wells. Ground
water appears as natural springs forming Malha spring; Om Fara and Ein fara springs with low yields (ElSamani et. al., 1997)

Oases exist in desert areas characterized by soft rocks. The size of the oasis differs from place to another. There are many oases in the study area including Salima Oasis neighboring the Egyptian frontier, Awiu, ElNakhila and Atron.
CHAPTER THREE

LITERATURE REVIEW

1. Characterization of Gizzu herbs adaptation:

   In most sense, drought can be defined as a meteorological phenomenon, a period without rain long enough to cause significant reduction in soil moisture content and plant growth. Drought can be permanent, as in arid regions, or seasonal or even random. The period of time without rainfall, actually needed to produce drought, depends mainly on the water holding capacity of the soil and the rate of evapotranspiration (Jones, 1992; Larcher, 1995; Kozlowski and Pallardy, 1997).

   Plant water stress occurs when low plant water potentials develop and cell turgor begins to fall (Kozlowski and Pallardy, 1997). Plants must be able to cope with and survive drought conditions. There are two major strategies, drought avoidance and drought tolerance and many plants use a combination of both mechanisms (Gaspar et al., 2002).

   There are many morphological, anatomical and physiological characteristics of plants associated with the degree of zromorphism (Bolhor-Nordenkamp and Draxler, 1993). For example, leaf number, size and thickness, in addition to stomatal density and sensitivity may provide avoidance or tolerance against mild to severe water stress. The deep rooting habit of some plant species is clearly an important adaptive mechanism for plant survival in dry land. In desert and other dry environments, rapid root growth at the start of the growing season can also give a competitive advantage to annual plants (Kramer, 1983). The ability of the plant to absorb available water is also critical and various factors are involved in all water relations. The cell water status is normally assessed by the measurement of water potential, which is the water absorbing capacity of a plant.

2. Vegetation of Gizzu area:

   The vegetation of the Gizzu area which lies in the desert region of Sudan was not studied as a special area but has been
considered within the vegetation of the Sudan by Andrews (1948), Smith (1949) and Harison and Jackson (1958).

The type of vegetation of Sudan passes from thorny almost leafless drought-resistant types in the north to evergreen and deciduous forests in the south (Andrews, 1948). The true desert is void of vegetation, but two exceptions have been noticed, the Nubian Baiyuda Desert and the Gizzu vegetation (Harrison and Jackson, 1958).

Desert is used here in its narrowest sense to mean country where vegetation is virtually absent except in water courses and as ephemeral herbs and grasses springing up after rare rain showers (The average annual rainfall is normally less than 75 mm). The woody species are particularly absent in the desert region (Andrews, 1948) and the few to be found are usually deep rooted and often thorny (e.g., Fagonia cretica, Indigofera bracteolata, Aristida papposa, Leptadenia spartum, Panicum turgidum, Acacia flava, Capparis decidua, and Maerua crassifolia). These species occurred in coarse open sand sites in certain regions whereas the rich grazable grasses (Known in Northern Darfur as Gizzu) are seen within the desert boundary on the lighter soils (Smith, 1949).

The Gizzu is a unique and extremely interesting type of vegetation with grazing potential within the Darfur Desert (Ibrahim, 1984). The Gizzu land extends from the Teiga plateau to the northwest beyond Wadi Hawar far into Chad. They usually grow in the cool season, after the wet season has come to an end. On the journey to and from the Gizzu area, Wadi Hawar occupies a key position as a green belt within Sahara. Its trees and shrubs form a good source for camel browsing (Ibrahim, 1984). Only about one year in two is there sufficient rainfall to give a ‘Gizzu’ vegetation. Yet there is a time lag of about three months between the end of rains in August and the springing up of the “Gizzu” in November. The onset of the northern winds and the intense cold in October which are said to draw the moisture out of the soil, help the growth of the Gizzu vegetation (Harrison and Jackson, 1958).

3. Seed germination:

Different seeds have different temperature ranges within which they can germinate, and at temperatures extremes the
germination of all seeds is prevented. The precise sensitivity is very different according to the species (Mayer and Mayber, 1982). However, Gutterman (1972) stated that some species (e.g., Blepharis spp.) have seeds that can germinate in a wide range of temperature (8-40°C).

Generally rupturing of seed coat or increasing the oxygen content of the environment tends to shorten germination period in many species (Oata, 1957; Stanely, 1958; Stiles, 1960). Similarly a period of soaking may enhance germination, although protracted soaking may be inhibitory. Plants of drier habitats may also benefit from a short period of soaking. For example, Eric cinerea, a dwarf shrub from dry habitats, benefits from period of soaking of up to one day although there is no germination after two weeks of soaking (Bannister, 1963). Seeds that germinate after a very short period of imbibition have been found in Blepharis species where radicle penetrates the soil within a few hours. This fast germination enables the seeds of Blepharis to germinate during the same rain event that disperses the seeds (Gutterman et al., 1967; Gutterman, 1972).

4. Morphological and anatomical adaptation:

Unlike most other plants, desert species avoid water loss as a result of their specialized leaves. For example, waxy leaves help prevent water loss when evaporation demand is high. Similarly, small leaves can give little surface area for water loss. Some plants sprout leaves only after the commencement of rains. In paloverdes, drought causes the plants to lose their leaves, while the chlorophyll of the trunks and limbs help them continue to make food (Phillips and Comus, 2000). Even with the stomata closed, leaves may continue to lose water through the cuticle. However, in most humid species the cuticular resistance to water loss is much smaller than that of arid species (Cowan and Milthorpe, 1968). These high resistances are achieved by the presence of a thick layer of cutin and wax coatings on the leaves. The presence of leaf hairs tends to increase the boundary layer thickness which in turn increases the resistance to transpirational water loss (Gates, 1980; Fitter and Hay, 1987). Also, these hairs
are often found to be specifically clustered around the stomata to restrict the exchange of gases (Fitter and Hay, 1987).

Another path for conserving water is to adjust the properties of the leaf canopy. Plants can reduce water loss from one leaf surface by leaf rolling. Some plants such as Encelia farinosa grow hairy leaves during the dry part of the year and less hairy leaves during the rainy season (Fitter and Hay, 1987). A more extreme way of altering the plant canopy characteristics is represented by the drought deciduous plants (i.e. plants that loose their leaves during the drier part of the year). Many plants in desert regions drop their leaves on a non-seasonal basis during the dry periods of the year. Orshan (1963) found that some desert plants would not only shed their leaves on a periodic basis but that they grew different types of leaves during the summer and winter, and these leaves would drop off during different seasons.

Shade and succulent plants tend to have less stomatal density compared with plants with xeromorphic leaf structures. The small variations in number of stomata per leaf commonly observed in a single species suggests that higher stomatal density in xeromorphic is partly due to the smaller leaf blade (Davies, 1991). Variation in stomatal density and guard cell length are often used as screening strategy for drought hardy provenance. In general, xerophytes have a higher stomatal density than mesophytes (Abrams et. al., 1990), and the small size of the stomata is a general characteristic of xerophytes (Rudall 1987; Ristic and Gass, 1991). However, Abrams et. al., (1990) found mesic provenance with smaller guard cells than xeric provenance.

5. Plant water stress and physiological processes:

Water often comprises more than 70% of the fresh weight of plant tissues, and in some cases it exceeds 90%. As an essential constituent of cytoplasm, water is vital for the structural integrity of biological molecules participating either directly or indirectly in all metabolic activities of plants. Water also serves as a solvent for the various molecules transported within the plant and is involved in the development and maintenance of cell turgidity upon which growth and development of organisms depend (Baker, 1984).
5.1 Growth attributes:

The increase of leaf area is dependent on plant water status and is often influenced even by mild water deficit that plants experience on daily basis. Therefore, leaf growth is one of the most sensitive processes to water deficit and is frequently inhibited in field crops (Mathew, 1984). The magnitude of plant water loss is also related to leaf area, although a simple proportionality does not exist. In general, plants with a large area of foliage transpire more rapidly than those with a smaller leaf area, but the rate is often lower per unit of leaf area (Passioura, 1976). When growing under dry conditions, some plants shed their leaves to reduce the rate of transpiration (Ritchie, 1974). Many plants of arid habitats have a small leaf area, as a xeromorphic adaptation (Wikins, 1987).

The extensive root system of arid and semi-arid plants increases the ratio of absorbing root length to the area of transpiring leaves. This ratio can further be increased by reducing the plants leaf area. Consequently, this reduced the intercepted solar radiation which also decreases the rate of photosynthesis (Fitter and Hay, 1987). In some plants, this can be counterbalanced by the production of thick leaves which can provide more photosynthetic mesophyll to transpiring leaf surface area (Fitter and Hay, 1987).

Smaller leaves can actually make the problem of transpirational water loss worse because smaller leaves often have thinner boundary layers which reduce the resistance to water loss. They often have more stomata per unit area than do larger leaves (Fitter and Hay, 1987). The thickening of leaves mentioned above can help increase leaves resistance to water loss, but the equivocal impact of decreasing leaf size may indicate that smaller leaves will be adapted to temperature stress (Gates, 1980).

One of the most important consequences of the marked sensitivity of leaf expansive growth to water deficits is the substantial change in the biomass allocation patterns in favour of below-ground development. The reduction in leaf growth is commonly related to changes in cell wall extensibility, whereas Rhizopoula and Davies (1991) attributed the inhibition of leaf expansion in water-stressed Ceratina siligua seedlings to the stiffening of cell walls. These studies suggest that the shoot may respond to changes in the water status of the root through changes in cell wall extensibility. Loveys, (1983) attributed the
reduction in number of leaves to the accumulation of abscisic acid (ABA) which promoted leaf abscission.

There is also differential sensitivity of the various plant organs to water stress, with root growth generally being less sensitive (Westgate, and Boyer, 1985). Large increases in the root to shoot ratio have been reported for both herbaceous and woody plant species (Crips, 1971; Huck et. al, 1983; Seiler, 1985; Osonubi and Fasehun, 1987; Steinberg et. al., 1990). Moreover, increased root to shoot ratio in response to soil drying has not always been observed in pot experiments, presumably as a result of relatively faster imposition of water stress and a limited rooting volume. In water-stressed loblolly pine (Pinus taeda L.) seedlings, shoot growth was not affected statistically, compared to a significant reduction in root growth, with consequent decrease in root to shoot ratio (Seiler and Johnson ,1985). Wookey et. al., (1991) found decreased root to shoot ratio and decreased leaf growth in sunflower plants as a result of limited water supply.

The total amount of biomass produced is directly related to the total quantity of water utilized by the plants. The loss of water through stomata allows the intake of CO2, which in turn leads to production of photosynthetic materials. Studies showed that, biomass is linearly related to total water used by the canopy in transpiration (Beadle, 1990). When water supply is limited, plants that use a finite water more efficiently tend to grow more rapidly, and therefore, should have higher biomass productivity than plants with low water use efficiency (Jones, 1992). The reduction in dry matter production arising from stress at flowering and pod development phases is obviously due to the reduction in leaf area and the size of the reproductive sink which has bearing on translocation of photosynthates from the source (Ravindra et. al., 1990).

5.2 Stomatal conductance:

Water movement from root to the atmosphere is controlled by stomatal conductance of the components of the water pathway. The magnitude of the transient water stress depends
strongly on plant properties such as tissue capacitance, xylem resistance and stomatal conductance (Hinckley et. al., 1991).

Stomatal aperture or conductance depends on several variables, the values of which depend upon the rates of transpiration and photosynthesis. For example, stomatal conductance may depend upon the bulk leaf water content or water potential which may itself be a function of transpiration rate (Weatherley, 1970; Jarvis, 1975; Techawongston et al., 1992). Nambiar and Brown (1997) stated that water deficit causes loss of turgor in guard cell, which in turn leads to stomatal closure and consequently a reduction in stomatal conductance, with a proportional reduction in transpiration.

5.3 Water potential:

Fitter and Hay (1993) defined water potential as the free energy per unit volume of water assuming the potential of pure water as zero under standard conditions (ambient temperature and atmospheric pressure). The loss of water from plant is partly controlled by the stomata. As soil dries up, water potential decreases and uptake of water by the root is also decreased. If the situation continues, the water potential through the whole soil-root-shoot system will gradually be reduced until the leaf water potential falls sufficiently to cause stomatal closure, leading to a reduction in the transpiration rate (Passioura, 1992).

Leaf water potential varies greatly, depending upon the type of plant and upon environmental conditions. Several characteristics have received considerable attention, in particular, stomatal control of water loss (Jones, 1978), and maintenance of leaf water potential.

Hsiao et al., (1976) outlined a number of plant responses of water stress which occur well before desiccation becomes lethal. Most responses (e.g. cell growth, wall and protein synthesis, enzyme activities, etc.) are affected by leaf water potential reduction of less than 1.5 MPa. Passive plant control of desiccation itself occurs when stomatal closure results from reduced leaf water potential (Palge and Aspinall, 1981).
5.4 Transpiration:

Kramer and Kozlowski (1979) defined transpiration as the loss of water from plants in the form of water vapor and is basically an evaporation process. Both evaporation and transpiration are controlled by physical factors. For every kilogram of dry matter produced plants use hundred kilograms of water and about 95% of water is lost by transpiration (Kramer and Kozlowski, 1979). Plant structure that controls transpiration process can be linked with stomata apertures, and cuticular thickness. Pearcy et al., (1991) reported that transpiration is a primary determinant of leaf energy balance and plant water status and the linkage between CO\textsubscript{2} uptake and water loss is via stomatal pores. The usual pathway for water vapor leaving a leaf during transpiration, is therefore through stomata (Nobel, 1991). The stomata often tend to regulate water loss through excessive transpiration by partial closing as the relative humidity of the ambient air decreases.

High transpiration rates occur when leaf resistance is low. The modification of leaves that occur in response to different environments often resulted in changes in leaf resistance that do not act in the same direction. In dry habitats, plants often have smaller leaf dimension (Lewis, 1972). They, therefore, show decreased resistance to water loss. This may be partially compensated for by decreased stomatal size, increase in leaf thickness and deeper stomatal pores. However, the net result is that leaves of plants from drier habitats often have potentially high transpiration rates (Bannister, 1976).

High transpiration rates are favored by large root: shoot ratio which ensures that transpiring plant is supplied with adequate water. A well-developed root system is also advantageous under conditions of low water supply; high root: shoot ratios are observed in xerophytes and halophytes (Troughton, 1974).
CHAPTER FOUR

MATERIALS AND METHODS
1. Collection, preparation and identification of plant materials:

A general survey of the Gizzu district (Appendix 3) was carried out during a course of two years (2001-2002). During the survey, twenty species of Gizzu herbs and grasses were collected from the various parts of the Gizzu according to their importance and adaptation. The collected species were briefly described and notes on their habitats and distribution were taken. Moreover, the collected specimens were identified according to the standard available literature; viz: Andrews (1950, 1952, 1956), Broun, and Massey (1929), Hutchinson & Dalziel (1954, 1958, 1968), Jeffery (1967), Brenan (1967), Polhill (1974, 1987), Daoud (1985), and Braun et. al., (1991). Some of these species were later checked against labeled materials from the Herbarium of the Department of Botany, Faculty of Science, University of Khartoum. These species were generally belonged to 9 families and include perennial herbs and grasses, succulent plants and ephemerals.

Ripe seeds from two important and dominant species were collected for further experimentation under laboratory and glasshouse conditions. Soil samples from the Gizzu district (sandy & clay) were also collected and their physical and chemical properties are shown in Appendix (7).

2. Laboratory experiments:

The experiments were designed to study the effect of different temperatures on seed germination of Blepharis linariifolia Pers. (S1) and B. ciliaris (L.) Burtt.(S2). Seeds were either sown without any treatment or soaked in tap water for two hours before sowing. Seeds from each species in four replications of 50 seeds each, were germinated in plastic boxes filled with moist sandy soil. The seeds were then incubated for 10 days at 15°, 25°, 35°, 45° C temperatures. At the end of the incubation period, normal seedlings were counted to determine the germination percentage.

3. Glasshouse experiments:

Two experiments were conducted under glasshouse conditions to study the effect of water stress on morphological, anatomical and physiological characters of Blepharis linariifolia
(S₁) and B. ciliaris (S₂). In one experiment, the seeds were sown directly in the soil and in the other experiment the seeds were sown in pots, 15cm in diameter.

### 3.1 Layout of the experiments:

The experiments were arranged in a split-plot design with four replicates. The main plots were allotted for the watering treatments and the sub-plots to the species. Watering treatments consist of well-watered (WW) and water-stressed (WS) plants.

### 3.2 Husbandry:

Seeds of Blepharis linariifolia (S₁) and B. ciliaris (S₂) were soaked in tap water for 3 hours, thereafter the seed coats were removed. Three seeds were sown per pot on the second week of June 2002 in both experiments.

In the first experiment seedlings were irrigated every 7 days and the watering treatments were started two months after sowing. In well-watered (WW) treatment, plants were watered every 7 days and in water-stressed treatment (WS), water was withheld until the end of the experiment.

In the pot experiments, seedlings were kept watered every other day for two weeks and then every 3 days for 4 weeks. The watering treatment was started 40 days after sowing. Half of the plants were designated as well-watered (WW) and the other half was designated as water-stressed (WS) plants. The plants were then watered every three days with 600ml (WW) and 200 ml (WS) of water for the remaining period.

**Characters Studied:**

1. **Morphological characters:**

Four plants were randomly taken from each experimental unit and the following measurement were made:
1.1 **Shoot length:**

Measured from the base of the stem up to the terminal shoot point using a meter-tape.

1.2 **Root length:**

Measured from the base of the root up to the terminal root point using a meter-tape.

1.3 **Number of branches per plant:**

Four plants were randomly selected and the average number of branches per plant was counted.

1.4 **Number of leaves per plant:**

Four plants were randomly selected and the average number of leaves per plant was counted.

1.5 **Leaf length and leaf width:**

Four leaves from each plant were randomly selected and the length and width of each leaf were measured using a meter-tape.

1.6 **Number of flowers per plant:**

Four plants were randomly selected and the average number of flowers per plant was counted.

1.7 **Number of capsules per plant:**

Four plants were randomly selected and the average number of capsules per plant was counted.

1.8 **Capsule length:**

Four capsules were randomly selected from each plant and the length of capsules was measured using a meter-tape.

1.9 **Number of seeds per capsule:**

Four capsules were randomly selected from each plant and the number of seeds for each capsule was counted.
2. **Anatomical characters:**

   *Four plants of Blepharis linariifolia (S₁) and B. ciliaris (S₂) from each watering treatments were randomly selected to study the following characters:*

2.1 **Arrangement of tissues in root, stem and leaf:**

   These characters were studied by preparing specimens of root, stem and leaf from each treatment through the following steps:

   A. *Transverse sections of root, stem and leaf were cut, and placed in petri-dishes filled with water.*
   
   B. *The sections were mounted in a drop of water on clear slide and examined under the microscope.*
   
   C. *Suitable sections were chosen and were then treated as follows:*

   1- *The chosen sections were placed in 50% alcohol (1 min), and then transferred to a SAFRANIN solution and left for 10 min.*
   
   2- *They were then transferred to a series of alcohol concentration of 50%, 70%, and 96%, respectively.*
   
   3- *Sections were then transferred to Light Green (for one min), and were then washed in 90% and absolute alcohol.*
   
   4- *They were then transferred to a small XYLOL solution for a few minutes.*
   
   5- *The sections were then mounted in a drop of Canada Balsam.*
The prepared sections were used to study the arrangement of tissues in roots, stems and leaves under the microscope (ZEIS-West Germany). Light microscope (Leitz-DIALU×20) fitted with camera (EKTAR: 125) was used to photographs sections of these plant parts.

2.2 Stomatal density:

This was studied by preparing specimens from the leaf epidermis of S₁ and S₂ for each watering treatment as follows:

a- The agglutinant material (prepared by dissolved polythene in organic material such as benzene) was placed on the upper and lower surfaces of leaf.

b- The upper and lower epidermis was then removed and placed on slides.

The prepared specimens were used to estimate Stomatal density under microscope (ZEIS-West Germany) viewed in three rand field at magnification ×40. Light microscope (Leitz-DIALU×20) fitted with camera (EKTAR:125) was used to photographs stomata at magnification ×50.

3. Physiological characters.

In each treatment, four plants were randomly selected and tagged to study the following parameters:

3.1 Stomatal conductance:

Measurements were made on abaxial surface of fully expanded leaves with a Li-cor 6400 Portable Photosynthesis System (Lincoln, Nebraska, U.S.A) for each plant.

3.2 Transpiration:
Measurements were made on abaxial surface of fully expanded leaves with a Li-cor 6400 Portable photosynthesis System (Lincoln, Nebraska, U.S.A) for each plant.

3.3 Water potential:
From each treatment, the four youngest fully developed branches were cut by sharp razor blade and then inserted in a portable pressure chamber (Skye. SKPM. 1400, UK) with the cut end above. Then the pressure was increased until the water reappeared at the cut surface. The balancing pressure that was applied to force water to reappear at the cut surface was taken as equal to the bulk xylem water potential.

3.4 Leaf area (LA):
This was measured by a Delta-T leaf area meter (LI-300, Li-Cor, Lincoln, Nebraska, U.S.A.).

3.5 Specific leaf area (SLA):
The leaves were dried in an oven at 80°C for 48 hours and then weighed by electronic balance (METTLER PM 200 Stures). Specific leaf area was calculated by the following formula:

\[ \text{S.L. A} = \frac{\text{Total leaf area}}{\text{Total leaf dry weight}} \]

3.6 Leaf area ratio (L.A.R.):
Calculated by dividing leaf area by total biomass of the whole plant.

3.7 Leaf weight ratio (L.W.R.):
Calculated by dividing leaf dry weight by total biomass of the whole plant.

3.8 Dry weights (D.W.):
Each plant was separated into shoot and root before drying to constant weight in an oven at 80° C for 48 hours. Dry weights of shoot and root were determined by an electronic balance (Mettler PM 200-Stures). Total biomass was taken and the root and shoot dry weights were determined.

4. Statistical analysis:

Analysis of variance (ANOVA) appropriate for split-plot design was used according to Gomez and Gomez (1984). Means separation were carried out using the least significance difference (LSD) for the different characters. Correlations between root length, stomatal conductance, water potential, transpiration rate, leaf area and stomatal density were determined.

CHAPTER FIVE

RESULTS

Field survey:

1. Types of the vegetation:

There were four types of vegetation in the Gizzu area, viz: permenant vegetation of trees and shrubs, perennial herbs and grasses, succulent plants, and ephemeral herbs.

1.1 Permanent trees and shrubs:
The permanent vegetation of trees and shrubs were usually observed in Wadi Hawar and Wadi Magrur. They were also scattered in the southern parts of the Gizzu area. All species within this type are tough, able to cope with heat, wind and drought. They may be evergreen or deciduous or have small leaves and spines or thorns. The most abundant species were Acacia nilotica, Acacia tortilis, Acacia mellifera, Acacia seyal, Maerua crassifolia, Grewia tenax, Ziziphus spina christi, Boscia senegalensis, Capparis decidua, Balanites aegyptiaca, Salvador pesica and Albizia amara (Appendices 8 and 9). Their abundance decreased gradually to the east along Wadi Hawar and north-east along Wadi Magrur.

1.2 Perennial herbs and grasses:

Perennial herbs are spinescent woody plants with their roots piercing downward for more than two meters, and they usually remain dormant during most of the summer season but they can sprout rapidly after sufficient rain. The most important species in this type of vegetation were listed in table (1). They included Indigofera bracteolata DC. (DARMA), Crotalaria aculeata De Wild (NATASH), Moltikiopsis ciliata (Forssk.) Johnston (HERESH), Fagonia bruguieri DC. (UMSHEWAKA). Some of these plants grow rapidly, mature in a short period and produce copious amount of seed such as Blepharis linariifolia and B. ciliaris (L.) Burt.

Perennial grasses such as Pannicum turgidum (ELTOMAM) grow in dense tangled bushes with flaty root often covered with adherent sand, and remain dormant during the summer season (the dry period). Other perennial grasses were tufted with roots surrounded by densely wooly hairs. Their upper parts, above the ground, dry out and their underground parts remain dormant during the summer. These included Stipagrostis obtusa (Del.) Nees (AISHOP), S. plumosa (L.) Muntor ex T. Anders (HALEEF) and Triraphis pumilio R.Br (non Hack) Broun and Massey (ALSALIAN).
1.3 Succulent plants:

Although succulent plants are usually thought of when deserts are mentioned, these plants were generally not the most abundant species in Gizzu areas. Examples of the most dominant species were listed in table (2). Succulent plants normally store water during rainy season for use during the dry period, and different species stored water in different parts of the plant. Examples of these include leaf and stem succulents, such as Neurada procombens L. (ALSAADAN) and root succulents, such as Citrulus colosynthis (L.,) Schard (HANDAL). The shoot of the last species (HANDAL) dries out during the rainy period and becomes green in winter (Appendix 10).

1.4 Ephemerals:

These consisted of herbaceous, non-woody species (Table 3) such as Tribulus petrocappus Ehrenb exRoerm (DERASSAT GUTUB) Vigna vexillata Benth (MAGRAIN) and Indigofera arenaria A.Rich (KHESHIAN) (Table 3).

The majority of these plants usually grow in areas where the soil is of lighter constitution (Sandy soil) commonly noticed at the southern parts of the Gizzu area and normally grazed first by cattle in October.
<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific name and synonym</th>
<th>Vernacular name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthaceae</td>
<td>Blepharis ciliaris (L.) B.L. Burtt., Syn. B. persica (Burm.) Kuntz., B. edulis (Forssk.) Pers.</td>
<td>SAHIA, BEGHEEL (Ar.)</td>
</tr>
<tr>
<td></td>
<td>B. linariifolia Pers; B. maderaspatensis. Heyne.</td>
<td>GARBA (Za.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BORDI (Me.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAHIA, BEGHEEL (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GARBA (Za.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BORDI (Me.)</td>
</tr>
<tr>
<td>Asteraceae (compositae)</td>
<td>Francoeria crispa (Forssk.) Cass; Syn. Pulicaria crispa (Forssk.) Benth. et Hook. F.</td>
<td>GAS GAS (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HINI (Za.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DENUR, ROGOL (Me.)</td>
</tr>
<tr>
<td>Boraginaceae</td>
<td>Moltkiopsis ciliata (Forssk.) T.M. Johnston; Syn. Moltkia callosa (Vahl) Wettst., and ciliata Maire, Lithospermum callosum Vahl.</td>
<td>HERESH (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mori (Za.)</td>
</tr>
<tr>
<td>Fabaceae (Leguminosae)</td>
<td>Crotalaria thebaica (Del.) DC. Syn. C. aculeata De Wild</td>
<td>NATASH (Ar.)</td>
</tr>
<tr>
<td>SubFamily:</td>
<td></td>
<td>KORAK, KRIK (Me.)</td>
</tr>
<tr>
<td>Papilioideae</td>
<td>Indigofera bracteolata DC.</td>
<td>NATASH (Ar.)</td>
</tr>
<tr>
<td>(Lotoideae)</td>
<td></td>
<td>DARMA (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I.RI-MIE, BARI (Za.)</td>
</tr>
<tr>
<td>Geraniaceae</td>
<td>Monsonia nivea (Decne) Decne ex Webb.</td>
<td>GAREN (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BEY KORI (Za.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ODAR (Me.)</td>
</tr>
<tr>
<td>Poaceae (Graminaeae)</td>
<td>Panicum turgidum Forssk.</td>
<td>TAMAM (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NAJEELA (Me.)</td>
</tr>
<tr>
<td></td>
<td>Stipagrostis obtusa (Del.) Nees; Syn. Aristida obtusa Del.</td>
<td>AISHOP (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MORGEOY, MORGEOY (Za.)</td>
</tr>
<tr>
<td>Family</td>
<td>Scientific name and synonym</td>
<td>Vernacular name</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>Cucurbitaceae</strong></td>
<td>Citrullus colocynthis (L.) Schard; <em>Colocynthis vulgaris</em> Schard; <em>Cucumis colocynthis</em> L.</td>
<td><strong>HANDAL</strong> (Ar.)</td>
</tr>
</tbody>
</table>

**Table (2):** The scientific and vernacular names of the collected succulent herbs from the study area.
<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific name and synonym</th>
<th>Vernacular name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuradaceae</td>
<td>Neurada procumbens L.</td>
<td>ALSAADAN (Ar.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NAAL ARNAB (Me.)</td>
</tr>
</tbody>
</table>

**Table(3):** The scientific and vernacular names of the collected ephemeral herbs and grasses from the study area.
2. Distribution and description of selected herbs and grasses:
Generally the dominant families of the selected herbs and grasses from the Gizzu area are Fabaceae, Poaceae and Neuradacea. Plants belonging to these families were dominant in the northern parts of the study area where the annual rainfall did not exceed 50 mm and the soils were lighter. In contrast, plants belonging to the other families were dominant in the southern parts of the study area where the annual rainfall exceeded 100 mm.
Acanthaceae:

Blepharis ciliaris (L.,) B.L. Burtt.

Perennial spiny herb, up to 40 cm high, rigid branched. Leaves oblong to lanceolate, spiny dentate and four in each node. Spikes dense, 4-ranked, bracteate with blue flowers; calyx 4, silky hairy; corolla bluish, 3-lobed; anthers ciliate, capsule 2-seeded; seeds hairy; Root woody reaches 80 cm long.

B. linariifolia Pers.

Small, grey-pubescent perennial herbs, up to 30 cm high, rigid branched, leaves oblong to lanceolate, spiny and four in each node. Spike dense, 4-ranked, bracteolate, with bright blue flowers; calyx 4, silky hairs; corolla bluish, 3-lobed; anthers ciliate, capsule 2-seeded; seeds hairy; root woody reaches 70 cm long.

Asteraceae (Compositae):

Francoeuria crispa (Forssk.)

Perennial bushy herbs with densely white-wooly hairs, 1 meter high; stems appressed-canescence, corymbose above; leaves alternate, sessile, oblong linear. Inflorescences terminal heads; flowers yellow; achenes hairy.

Boraginaceae:

Moltkiopsis ciliata (Forssk.) Johnston.

Much branched woody herbs, 20-25 cm high, densely hispid of bulbous-based bristles and with snow-white angled branches. Leaves simple, subsessile, densely spiny-hispid on both surfaces. Flowers bisexual, sessile; calyx deeply 5-lobed, covered with hispid stiff and short hirsute; corolla blue or blue-organge, 5 lobed, hirsute on outer surfaces. Fruit 4 nutlets included in persistent calyx. Root pierces down for more than 2 meters.
Heliotropium supinum *L.*

Annual decumbent, densely hairy herbs. Leaves opposite or alternate, oval oblong, white bristly on both surfaces. Flowers white, small, indense short scorpioid cymes. Fruit of 1-2 nutlets, brown, enclosed in persistent hairy calyx.

**Brassicaceae (Cruciferae):**

*Farsetia aegyptia* Turra

Annual branched herbs, 60 cm high, closed with densely tomentose hairs. Leaves simple, linear. Flowers pale yellow; calyx 4, covered with densely white hairs; ovary superior, appressed hairy. Fruit dehiscent silicula; seeds 6, in two rows and winged.

**Cucurbitaceae:**

*Citrullus colocynthis* (L.) Schard.

Prostrate perennial herbs, grey, with long trailing branches. Stem angular covered with appressed coarse hairs. Leaves roughly scarbid, stipulate. Receptacle broadly compadate, covered with white hispid hairs. Fruit globose, 12 cm across, pulp bitter, pale yellow when ripe. Suffer from rainy season, but recover again in winter. Roots thick and pierce down for more than 1.5 meters.
Fabaceae (Leguminosae):

SubFamily Papilinoideae:

Crotalaria thebaica (Del.) DC.

Much branched herbs, 50 cm high, vilous with stiff, nearly spinescent branches. Leaves small, sessile, oblong to lanceolate, both surfaces densely silk. Flowers pale yellow, small, in racemes of 4-8 flowers each. Legumes pubescent, subglobose, 2-3 seeded. Roots pierce down to more than one meter.

C. aculeata De Wild.

Much branched spinescent, woody herbs, 70 cm high, covered with yellowish hairs; branches cylindrical, tapering to sharp spines at the distal end. Leaves very minute, simple, soon deciduous. Flowers yellow, calyx 5, covered with white dense hairs. Legumes ovoid, with white woody hairs, 1-2 seeded. Roots pierce down more than 1.5 meters.
**Indigofera arenaria** A. Rich.

Erect densely branched herb, 30 cm high. Leaves 3-foliolate, silvery hairy on both surfaces; flowers small, bright-purple. Pods narrow-linear, thinly silk, 4-6 seeded.

**I. bracteolata** DC.

Much branched herb, 30-50 cm long, suberect, branches slender, subterete, clothed with white pubescence. Leaves compound paripinnate with 2 or 3 pairs of leaflets. Leaflets ovate-oblong, grey-green, permanently clothed with appressed silky hairs. Flowers orange-red, small, calyx silky. Pods oblong mucronate, for 2-seeded, densely to mentose. Root woody pierce down more than 2 meters.

**Vigna vexillata** Benth.

Fairly strong twinters usually with a fusiform tuberous roots; stems usually clothed with spreading silky hairs. Leaflets 3, dark-green, with appressed strong silky hairs on both surfaces. Flowers pink or purplish turning yellow. Pods recurved linear and silky.

**Gerniaceae:**

**Monsonia nivea** (Decne) Decne ex Webb:

Perennial herbs, 15-25 cm high, small and silvery-canescence. Leaves pinnate nerved, narrow, ovate-oblong, plicate rosette. Peduncles naked, arising from the rosette and bearing 2-6 flowers. Petals flesh-edoured, obovate; stamens 15, all fertile; sepals short-cuspidate. Fruits with plumose beak 4 cm long.

**Neuradaceae:**

**Neurada procumbens** L.

Silky tomentose herbs with spreading prostrate branches, 70 cm long. Leaves compound; leaflets 2, unequal, ovate, densely
white-wooly tomentose. Flowers surrounded with setiform bracteoles, whitish. Fruits woody orbicular, 1.5 cm in diameter, margins and upper surfaces with nearly equal spines; seeds hairy.
**Poaceae (Gramineae):**

**Panicum turgidum** Forssk.

Perennial grasses, growing in dense tangled bushes up to one meter high; culms hard woody, red-like, densely branched, thickened at the nodes; ligules with dense ciliate rims often with rigid spines along the margin. Panicles oblong; Glumes equal. Rootlets flety, covered with adherent sand.

**Stipagrostis obtusa** (Del.) Nees (=Aristida obtusa Del.)

Much branched perennial herbs forming very dense tufts, from which erect, 1-noded, glabrous culms emerge up to 30 cm. Leaves short capillary, curved convolute crowded in dense basilar tufts; lower sheath short, persistent more or less woolly near the margins. Awns consisting of central feather and 2 lateral naked bristles. Roots surrounded by densely tomentose hairs.

**S. plumosa** (L.) Munro ex T. Anders.

Densely tufted perennial grasses; culms slender, 50-60 long, wooly, 2-3-noded. Leaf-blades rigid convolute, filiform, flexuous, often curved in a half or a full circle. Awn consisting of one central feather and 2 naked lateral bristles. Glumes 3-nerved. Root surrounded by densely tomentose hairs.

**Triraphis pumilio** R. Br.

Dwarf grasses about 12 cm, high, branched from the base with silvery purple-fushed. Leaf sheaths pilose with long bulbous-based hairs. Spikelets pedicellate in dense spike-like panicles; lemmas lobed, long-ciliate. Root surrounded by densely tomentose hairs.

**Zygophyllaceae:**

**Fagonia bruguieri** DC.
Pale green, procumbent, pubescent, 30 cm high perennial herbs, branches jointed at the nodes. Leaves opposite, 1-3 foliolate; leaflets bright-green, linear to lanceolate, acute at the apex; stipules spinescent, longer than the leaves. Flowers solitary, axillary. Fruits about 5 mm long, calyx persistent. Root pierced down reaching 1.5 meter.

**Tribulus petrocarpus** *Ehrenb ex Koern.*

Prostrate herbs; branches hispid-pilose, with unequal spreading short hairs. Leaves pinnate, opposite. Flowers yellow. Fruits roundish-ovoid, winged, wings crenulate.

**Laboratory experiments:**

1. **Germination percentage:**

   Statistical analysis showed that all treatments had no significant effects on mean germination percentages of the two species (Fig.3). However, the germination percentage was relatively higher in S1 compared to S2 in all the range of tested temperatures (Fig.3a). On the other hand, although the soaked seeds had higher mean total germination percentage compared with unsoaked seeds at all temperatures, there were no significant difference between them (Fig. 3b).

2. **Seedling length:**

   The effect of temperature on seedling length followed similar pattern as described for germination percentage (Fig. 4). However, unlike the germination percentage, seedling length were relatively higher in S2 compared to S1 in each temperature (Fig. 4a). Similarly, soaking results in greater seedling length comared to nonsoaked treatment (Fig. 4b).
Fig. (3): Effect of temperature (a) and water-soaking (b) on germination percentage of *Blepharis linariifolia* (S1) and *B. ciliaris* (S2).
**Fig. (4):** Effect of temperature (a) and water-soaking (b) on seedling length of *Blepharis linariifolia* (S₁) and *B. ciliaris* (S₂).
Glasshouse experiments:

1. Morphological and physiological characters:

1.1 Shoot length:

Statistical analysis revealed that water stress had a highly significant effect on mean shoot length in both experiments. In this regard, water stress resulted in a significantly lower mean shoot length compared to the well-watered treatments in both experiments (Table 4). Differences due to species were only significant in the field experiment, and $S_1$ was shorter than $S_2$ (Table 4).

1.2 Root length:

Analysis of variance showed that water stress had significant effect on mean root length in both experiments. In the field experiment water stress treatment increased the mean root length compared with the well-watered treatment and the reverse was true in the pot experiments (Table 4). In all treatments, $S_1$ had smaller mean root length compared to $S_2$ in both experiments (Table 4).

1.3 Root/shoot ratio:

In both experiments, water stress significantly increased the mean root:shoot ratio compared to the well-watered treatments. However, no significant differences between $S_1$ and $S_2$ species in this character were observed in both experiments (Table 4).
**Table (4):** Mean shoot length, root length and root/shoot ratio of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoot length</strong></td>
<td><strong>Shoot length</strong></td>
</tr>
<tr>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td>S₁</td>
<td>32.2</td>
</tr>
<tr>
<td>S₂</td>
<td>35.8</td>
</tr>
<tr>
<td>Mean</td>
<td>34.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LSD (0.05) W  4.9*            3.0*            0.1*            17.5*            6.6*            0.09*  
LSD (0.05) S  ns                  ns                  ns                15.6*            5.3*            ns  
LSD (0.05) WS  ns                  ns                  ns                ns                ns                ns

Means with the same letter are not significantly different at 0.05 level of probability.
1.4 **Number of branches per plant:**

In both experiments, water stress significantly decreased the mean number of branches per plant relative to the well-watered treatments (Table 5).

Although the difference between the two species was insignificant, $S_1$ consistently had lower mean number of branches per plant than $S_2$ in both experiments (Table 5).

1.5 **Number of leaves per plant:**

In both experiments, the overall mean number of leaves per plant was greatly reduced by water-stress treatment compared with well-watered treatment particularly in the pot experiment (Table 5).

Analysis of variance showed that, watering treatments had a highly significant effect on mean number of leaves per plant in both experiments (Table 5). In contrast, no significant differences were observed between $S_1$ and $S_2$ on mean number of leaves per plant in both experiments (Table 5).

1.6 **Leaf length and leaf width:**

The overall mean leaf length and leaf width were reduced by water-stressed treatments in both experiments (Table 6).

Statistical analysis showed that, watering treatments had no significant effect on these leaf traits particularly in the field experiment (Table 6). Although there were no significant differences between $S_1$ and $S_2$ on mean leaf length and leaf width in the both experiment, $S_1$ had smaller mean leaf length relative to $S_2$ plants (Table 6).
Table (5): Mean number of leaves per plant and branches per plant of *Blepharis linariifolia* (S₁) *Bepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of leaves per plant</td>
<td>Number of branches per plant</td>
</tr>
<tr>
<td><strong>WW</strong></td>
<td><strong>WS</strong></td>
</tr>
<tr>
<td>S₁</td>
<td>120.0</td>
</tr>
<tr>
<td>S₂</td>
<td>134.8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>127.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LSD (0.05) W 20.7* 5.4* 50* 11.9*
LSD (0.05) S ns ns ns ns
LSD (0.05) WS ns ns ns ns

Means with same letter are not significantly different at 0.05 level of probability.

Table (6): Mean leaf length and leaf width of *Blepharis linariifolia* (S₁) and *Bepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.
<table>
<thead>
<tr>
<th>Pot Experiment</th>
<th>Leaf length (cm)</th>
<th>Leaf width (cm)</th>
<th>Field Experiment</th>
<th>Leaf length (cm)</th>
<th>Leaf width (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td>S₁</td>
<td>6.7</td>
<td>4.5</td>
<td>5.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>S₂</td>
<td>10.2</td>
<td>8.3</td>
<td>9.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Mean</td>
<td>8.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LSD (0.05) W ns ns 3.1* ns
LSD (0.05) S 1.8* ns ns ns
LSD (0.05) WS ns ns ns ns

Means with same letter are not significantly different at 0.05 level of probability.
1.7 Number of flowers per plant:

In the two experiments the mean number of flowers per plant was affected by watering treatments. In this respect, water stress insignificantly reduced the mean number of flowers per plant relative to the well-watered treatment (Table 7). The $S_1$ plants had higher mean number of flowers per plant compared to $S_2$ in both experiments (Table 7).

1.8 Number of capsules per plant:

The effect of water stress treatment on mean number of capsule per plant was similar to it’s effect on mean number of flowers per plants (Table 7). However, a highly significant difference between $S_1$ and $S_2$ on mean number of capsules was observed in the pot experiment only (Table 7).

1.9 Length of capsule:

In both experiments, water stress insignificantly decreased the length of capsule compared with the well-watered treatment (Table 7). Similarly the differences between the two species were insignificant but $S_1$ consistently had higher mean capsule length than $S_2$ plants (Table 7).

1.10 Number of seeds per capsule:

Statistical analysis showed no significant effect of water stress on mean number of seeds per capsule in both experiments (Table 7). In contrast, $S_1$ had significantly higher mean number of seeds per capsule compared to $S_2$ in both experiments (Table 7).
Table (7): Mean number of flowers per plant, capsules per plant, seeds per capsule and length of capsules of *Blepharis linariifolia* (S1) and *Blepharis ciliaris* (S2) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

Means with same letter are not significantly different at 0.05 level of probability.

Pot Experiment

<table>
<thead>
<tr>
<th></th>
<th>Number of flowers per plant</th>
<th>Number of capsules per plant</th>
<th>Number of seeds per capsule</th>
<th>Length of capsule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
<td>WW</td>
</tr>
<tr>
<td>S1</td>
<td>136.8</td>
<td>128.0</td>
<td>145.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.0</td>
</tr>
<tr>
<td>S2</td>
<td>95.0</td>
<td>82.0</td>
<td>88.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.5</td>
</tr>
<tr>
<td>Mean</td>
<td>129.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>105.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (0.05) WS</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Field Experiment

<table>
<thead>
<tr>
<th></th>
<th>Number of flowers per plant</th>
<th>Number of capsules per plant</th>
<th>Number of seeds per capsule</th>
<th>Length of capsule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
<td>WW</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
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<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Table (7) continued:
<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>310.0</th>
<th>232.0</th>
<th>271.0̊</th>
<th>40.3</th>
<th>39.0</th>
<th>39.9̊</th>
<th>17.3</th>
<th>14.5</th>
<th>15.9̊</th>
<th>8.2</th>
<th>7.4</th>
<th>7.8̊</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S2</td>
<td>224.5</td>
<td>202.0</td>
<td>213.3̊</td>
<td>33.5</td>
<td>32.0</td>
<td>32.8̊</td>
<td>12.8</td>
<td>12.5</td>
<td>12.6̊</td>
<td>9.1</td>
<td>7.5</td>
<td>8.3̊</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>267.3̊</td>
<td>217.0̊</td>
<td>37.1̊</td>
<td>35.5̊</td>
<td>15.0̊</td>
<td>13.5̊</td>
<td>8.6̊</td>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD (0.05) W  ns  ns  ns  ns
LSD (0.05) S  48.9*  ns  2.8*  ns
LSD (0.05) WS ns  ns  ns  ns

Means with same letter are not significantly different at 0.05 level of probability.
1.11 Transpiration rate:

The mean transpiration rate was significantly reduced by water-stress treatment compared to the well-watered treatment in both experiments (Table 8).

Although there were no significant difference recorded between the two species, $S_1$ had a higher mean transpiration rate than $S_2$ particularly in the pot experiment (Table 8).

1.12 Water potential:

For the two experiments, the mean water potential was greatly reduced by water-stress treatment compared to the well-watered treatment (Table 9).

Analysis of variance showed that watering treatment had a highly significant effect on mean water potential in both experiments (Table 9). Although there were no significant difference between the mean water potential of the two species, $S_1$ had higher (less negative) values than $S_2$ in both experiments (Table 9).

1.13 Stomatal conductance:

Statistical analysis showed that, watering treatments had a highly significant effect on mean stomatal conductance in both experiments (Table 10). In this regard, stomatal conductance was greatly decreased by the water-stress treatment as compared to the well-watered treatment (Table 10).

Although the difference between the two species was insignificant, $S_1$ had a higher mean stomatal conductance than $S_2$ particularly in the pot experiment (Table 10).
Table (8): Mean transpiration rate of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th>Table (8)</th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transpiration rate m mol m⁻²s⁻¹</td>
<td>Transpiration rate m mol m⁻²s⁻¹</td>
</tr>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td>S₁</td>
<td>8.0</td>
<td>2.8</td>
</tr>
<tr>
<td>S₂</td>
<td>3.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Mean</td>
<td>5.9</td>
<td>2.5</td>
</tr>
</tbody>
</table>

LSD (0.05) W 2.2* 0.92*  
LSD (0.05) S ns ns  
LSD (0.05) WS 1.5* ns  
Means with the same letter are not significantly different at 0.05 level of probability.

Table (9): Mean water potential of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.
### Table (10): Mean stomatal conductance of *Blepharis linariifolia* (S₁) and *Blepharis clarias* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th>.</th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water potential Mpa</td>
<td>Water Potential Mpa</td>
<td></td>
</tr>
<tr>
<td>WW</td>
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<td>Mean</td>
</tr>
<tr>
<td>S₁</td>
<td>-1.7</td>
<td>-2.6</td>
</tr>
<tr>
<td>S₂</td>
<td>-2.1</td>
<td>-2.9</td>
</tr>
<tr>
<td>Mean</td>
<td>-1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

LSD (0.05) W 0.4* 0.7*
LSD (0.05) S ns ns
LSD (0.05) WS ns ns

Means with the same letter are not significantly different at 0.05 level of probability.
<table>
<thead>
<tr>
<th></th>
<th>WW</th>
<th>WS</th>
<th>Mean</th>
<th>WW</th>
<th>WS</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S_1)</td>
<td>128.3</td>
<td>45.8</td>
<td>87.0(^a)</td>
<td>39.5</td>
<td>13.8</td>
<td>26.6(^a)</td>
</tr>
<tr>
<td>(S_2)</td>
<td>61.3</td>
<td>35.0</td>
<td>48.2(^a)</td>
<td>35.6</td>
<td>9.1</td>
<td>22.4(^a)</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>94.8(^a)</td>
<td>40.4(^b)</td>
<td>46.6(^a)</td>
<td></td>
<td></td>
<td>11.5(^b)</td>
</tr>
</tbody>
</table>

LSD (0.05) W

35.4\(^*\) 16.4\(^*\)

LSD (0.05) S

ns  ns

LSD (0.05) WS

17.3\(^*\)  ns

Means with the same letter are not significantly different at 0.05 level of probability.
1.14 *Relative water content (RWC)*:

In the field experiment, the mean relative water content was reduced by water-stress compared to the well-watered treatment (Table 11).

Analysis of variance showed that watering treatment had a highly significant effect on mean relative water content in both species (Table 11). Although there were no significant difference between the two species on mean relative water content, $S_1$ had a higher mean value than $S_2$ plants (Table 11).

1.15 *Leaf area*:

The overall mean leaf area was significantly reduced by water stress compared to the well-watered treatment in both experiments (Table 12). Differences due to species on mean leaf area were highly significant particularly under field condition (Table 12). In this regard, $S_2$ had a higher mean leaf area than $S_1$ in both experiments (Table 12).

1.16 *Specific leaf area*:

Statistical analysis showed water stress treatment had a significant effect on mean specific leaf area particularly in the field experiment (Table 13). Although there was no significant difference between $S_1$ and $S_2$ in the field experiment, $S_1$ had a significantly higher mean specific leaf area than $S_2$ in the pot experiment (Table 13).

1.17 *Leaf area ratio* :

Analysis of variance showed that both watering treatments and species had no significant effect on mean leaf area ratio in both experiments (Table 13).
**Table (11):** Mean relative water content of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th></th>
<th>Relative water content</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>S₁</td>
<td>59.1</td>
<td>50.6</td>
<td>54.9a</td>
<td></td>
</tr>
<tr>
<td>S₂</td>
<td>68.8</td>
<td>46.8</td>
<td>57.8a</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>63.9a</td>
<td>48.9b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD (0.05) W: 5.6*
LSD (0.05) S: ns
LSD (0.05) WS: 4.1*

Means with the same letter are not significantly different at 0.05 level of probability.
Table (12): Mean leaf area of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th></th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaf area</td>
<td>Leaf area</td>
</tr>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td>S₁</td>
<td>168.7</td>
<td>79.6</td>
</tr>
<tr>
<td>S₂</td>
<td>231.2</td>
<td>120.3</td>
</tr>
<tr>
<td>Mean</td>
<td>199.9ᵃ</td>
<td>99.9ᵇ</td>
</tr>
</tbody>
</table>

LSD (o.05) W  52.8*  883.9*
LSD (o.05) S  ns  745.8*
LSD (o.05) WS ns  ns

Means with the same letter are not significantly different at 0.05 level of probability.

Table (13): Leaf area ratio (LAR), specific leaf area (SLA) and leaf weight ratio (LWR) of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th></th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LAR (cm²g⁻¹)</td>
<td>SLA (cm²g⁻¹)</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
</tr>
<tr>
<td>S1</td>
<td>25.5</td>
<td>27.9</td>
</tr>
<tr>
<td>S2</td>
<td>41.9</td>
<td>40.6</td>
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<tr>
<td>Mean</td>
<td>33.7a</td>
<td>34.2a</td>
</tr>
</tbody>
</table>

LSD (0.05) W ns ns ns 27.8* ns
LSD (0.05) S 9.6* 13.1* 0.1* ns ns
LSD (0.05) WS ns ns ns ns ns

Means with the same letter are not significantly different at 0.05 level of probability.
1.18 Leaf weight ratio:

Although water stress increased the leaf weight ratio compared to well-watered treatment, the difference were not significant (Table 13). Differences due to species was significant only in the pot experiment (Table 13).

1.19 Dry matter production:

In both experiments, water-stress treatment reduced the mean shoot dry weight and the total dry weight compared to the well-watered treatment (Table 14).

Statistical analysis showed a highly significant effect of water treatments on the mean shoot dry weight and mean total dry weight in the pot experiment, but no significant effect was observed in the field experiment (Table 14). Moreover, the difference between the species was significant and S2 consistently had higher mean shoot dry weight and mean total dry weight than S1 (Table 14).

1.20 Seed characteristics:

Statistical analysis showed no significant effect of water stress on mean 100 seed weight, seed length and seed width in both experiments (Table 15).

In both experiments S1 species had a significantly lower 100 seed weight, seed length and mean seed width than S2 species (Table 15).
Table (14): Mean shoot dry weight and total dry weight of *Blepharis linariifolia* (S1) and *Bepharis ciliaris* (S2) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th></th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Shoot dry weight (gm)</td>
<td>Total dry weight (gm)</td>
</tr>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td><strong>S1</strong></td>
<td>4.6</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>S2</strong></td>
<td>5.6</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>5.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (0.05) W</td>
<td>1.1&lt;sup&gt;*&lt;/sup&gt;</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05) S</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05) WS</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Means with same letter are not significantly different at 0.05 level of probability.

Table (15): Mean 100 seed weight, seed length and seed width of *Blepharis linariifolia* (S1) and *Bepharis ciliaris* (S2) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.
<table>
<thead>
<tr>
<th></th>
<th>100 Seed Weight (g)</th>
<th>Seed Length (mm)</th>
<th>Seed Width (mm)</th>
<th>100 Seed Weight (g)</th>
<th>Seed Length (mm)</th>
<th>Seed Width (mm)</th>
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<td></td>
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<td>WW</td>
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<td>Mean</td>
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<td></td>
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<tr>
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<td>3.5</td>
<td>7.6</td>
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<td>3.6</td>
<td>3.3</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>S2</td>
<td>5.6</td>
<td>5.9</td>
<td>5.7</td>
<td>10.6</td>
<td>10.9</td>
<td>10.8</td>
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<td></td>
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<td>4.7</td>
<td>5.7</td>
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<td>5.8</td>
</tr>
<tr>
<td>Mean</td>
<td>4.5</td>
<td>4.7</td>
<td>9.1</td>
<td>4.1</td>
<td>4.2</td>
<td>9.2</td>
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<td>4.2</td>
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<tr>
<td><strong>Field Experiment</strong></td>
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<tr>
<td></td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
<td>WW</td>
<td>WS</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>3.6</td>
<td>3.4</td>
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<td>9.2</td>
<td>4.1</td>
<td>4.2</td>
<td>9.3</td>
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<td></td>
<td>4.1</td>
<td>4.2</td>
<td>9.3</td>
<td>4.1</td>
<td>4.2</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
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<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

LSD (0.05) W ns ns ns
LSD (0.05) S 0.08* 0.03* 0.08* 0.03
LSD (0.05) WS ns ns ns

Means with the same letter are not significantly different at 0.05 level of probability.
1.21. Stomatal density:

Statistical analysis showed that, water stress had a higher significant effect on mean stomatal density in the two experiments (Table 16). In this respect, the mean stomatal density was reduced by water stress compared to the well-watered treatment (Table 16). In addition, S₁ had a significantly lower mean stomatal density compared to S₂ in both experiment (Table 16).

Correlation analyses:

A highly significant and positive correlations were found between stomatal conductance, transpiration rate, leaf area and root length (Table 17). In contrast, a highly significant and negative correlations were also found between stomatal conductance, transpiration rate and root length (Table 17).
Table (16): Stomatal density of *Blepharis linariifolia* (S₁) and *Blepharis ciliaris* (S₂) under well-watered (WW) and water-stressed (WS) conditions. Values are means of four replicates.

<table>
<thead>
<tr>
<th></th>
<th>Pot Experiment</th>
<th>Field Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stomatal density</td>
<td>Stomatal density</td>
</tr>
<tr>
<td></td>
<td>WW</td>
<td>WS</td>
</tr>
<tr>
<td>S₁</td>
<td>25.8</td>
<td>10.5</td>
</tr>
<tr>
<td>S₂</td>
<td>42.3</td>
<td>22.0</td>
</tr>
<tr>
<td>Mean</td>
<td>34.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (0.05) W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (0.05) S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (0.05) WS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different at 0.05 level of probability.
Table (17): Correlation analyses between root length, stomatal conductance, water potential, transpiration rate, leaf area and stomatal density of Blepharis spp.

<table>
<thead>
<tr>
<th></th>
<th>Root length</th>
<th>Stomatal conductance</th>
<th>Water potential</th>
<th>Transpiration rate</th>
<th>Leaf area</th>
<th>Stomatal density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root length</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stomatal conductance</td>
<td>-0.47**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Water potential</td>
<td>-0.06</td>
<td>-0.38*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Transpiration</td>
<td>-0.49**</td>
<td>0.99**</td>
<td>-0.36*</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Leaf area</td>
<td>0.85**</td>
<td>-0.31</td>
<td>-0.32</td>
<td>-0.35*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stomatal density</td>
<td>-0.26</td>
<td>0.41**</td>
<td>-0.21</td>
<td>0.42*</td>
<td>-</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*, ** significant at 0.05 and 0.01 level of probability, respectively.
2. Anatomical characters:

2.1. Arrangements of tissues in the leaf:

In the water stress treatment, the cutin layer of the leaf was thicker and with more hairs (Plate 1b) compared to the leaf of the well-watered treatment (Plate 1a). Moreover, the leaf epidermal cells of the water stress plants were smaller and packed close together, whereas the collenchyma cells were present on both sides of the mid-rib beneath the epidermis. In addition, the mid-rib region of the leaf was enlarged with very large parenchyma cells in the water stress treatment (Plate 1b).

Under both treatments, stomata were found in a cavity covered with trichomes mainly on the bottom surfaces of the leaf and they were more numerous particularly in the water stress treatment (Plate 2).

2.2. Arrangements of tissues in the stem:

In the water stress treatment the cutin layer was thicker and with more hairs compared to well-watered plants (Plate 3). Also, the epidermal cells were smaller and closely-packed together and had thick cell walls and cuticle. In contrast, there were large parenchyma cells in the cortex and pith under both treatments (Plate 3). At advanced stage of development, the periderm was very large particularly in water stress plants (Plate 4). In addition, the pith appeared to be filled with water cavities resulting from the destruction of the parenchyma cells (Plate 4).
Plate (1a): Leaf cross section of *Blepharis spp.* under well-watered ×50

Plate (1b): Leaf cross section of *Blepharis spp.* under water stress condition ×100

P≡ Parenchyma cells  
C≡ Collenchyma cells  
H≡ Hairs  
M≡ Mesophyll
Plate (2a): Stomata of *Blepharis spp.* under well-watered condition ×50

Plate (2b): Stomata of *Blepharis spp.* under water stress condition ×50
Plate (3a): Stem cross section of *Blepharis spp.* under well-watered ×100.

- P  = Paranchyma cells
- C  = Collenchyma cells
- Pt  = Pith
- Ph  = Phloem
- En  = Endoderms
- Ep  = Epidermis

Plate (3b): Stem cross section of *Blepharis spp.* under water stressed condition ×100.
Plate (4a): Stem cross section of *Blepharis spp.* under well-watered \( \times40 \).
Plate (4b): Stem cross section of *Blepharis* spp. in advanced stage under water stress condition×100.

Pr = Periderm  Ph = Phloem  X = Xylem
2.3. Arrangements of tissues in the root:

In the water stressed treatment, the root tissues in the transverse section had thicker endodermis and periderm in the cortex compared to the well-watered plants (Plate 5).
Plate (5a): Root cross section of *Blepharis spp.* under well-watered condition ×40

P≡ Paranchyma cells    Ph≡Phloem    En≡ Endoderms    X≡ Xylem

Plate (5b): Root cross section of *Blepharis spp.* under water stressed condition ×100.

Pr = Periderm    Ph=Phloem    X= Xylem
CHAPTER SIX

DISCUSSION

Field Survey:

Since the Gizzu area lies in the desert zones, its vegetation is affected by three main factors namely: rainfall, temperature and soil type. Rainfall usually occurs during a short period of time (August, September), and the average amount is about 75 mm per year and decreases gradually to the north. It appears that, rainfall affects the distribution of the Gizzu plants, and increases in rainfall over just a few years would very likely result in the establishment of greater numbers of Gizzu plants, while decreases in rainfall would result in the disappearance of some species of Gizzu plants such as Vigna vexillata Benth. (MAGRIAN) and Indigofera arenaria A. Rich. (KHESHIAN).

In the southern area of the Gizzu, the rainfall may reach 100 mm per year and plants of these areas are drought-avoiding ephemerals such as Monsonia nivea (Decne) Decne ex Webb. (GAREN), and Fagonia bruguieri DC. (OM SHWEEKA).

In the northern area of the Gizzu, rainfall is less than 75 mm per year, and drought-tolerant plants were noticed (perennial herbs) whose underground parts could stay dormant in the soil for 2-3 years and grow upon the onset of rains. These included the most important species of the Gizzu such as Neurada procumbens L. (ALSAADAN), Indigofera bracteolata DC. (DARMA), Crotalaria thebaica (Del.) DC. (NATASH), Triraphis pumilio R.Br. (ALSALIAN), Stipagrostis plumosa (L.) Munor ex T.Anders (HALEEF) and S. obtusa (Del.) Nees. (AISHOOP).

The permanent trees and shrubs were usually observed in the upper part of Wadi Hawar, at Oases such as Atron Oases and along Wadi Magrur, which lies at the southern part of the Gizzu area. Wadi soil contained more clays and consequently retained more water. Also, the amount of rainfall in the southern part of the Gizzu area was greater compared to that in the northern parts. On the other hand, soil texture and structure affect permeability and
soil moisture retention capacity and its effect may be as great as that of rainfall. Oliver (1986) reported that gravel, sand or rock desert soils allow rainfall to percolate rapidly in the soil with no or very little evaporation.

In the present study the majority of the species studied were collected from sandy soils (about 18 species) and very few from Wadi soil (2 species). It appeared that, the sandy soil (light soil) had the greatest number of the Gizzu herbs. This might be due to the fact that water moves downward through sandy soil rapidly and the roots of plants can penetrate deeply before soil surface dries out. Ibrahim (1984) reported that Goz soils (sandy soils) are favorable for vegetation because of their ability to retain moisture for along time in the root horizon.

In addition, temperature in the Gizzu area can reach upto 43oC in May, or fall to about 1oC in January and may be more vital than the presence or lack of rain. Generally, a rise in temperature affects the moisture content of soil and plants by increasing evapotranspiration which decreases the water content of cells and tissues. In contrast, the effect of low temperature on soil moisture content is said to draw the moisture out of the sandy soil. It also decreases evapotranspiration therefore increases the time during which the plants of the Gizzu would stay green.

**Adaptation of Gizzu herbs and grasses:**

Since adaptation is a shift in function or form to insure fitness in a certain environment, the Gizzu plants have adapted their physical structure, through special mechanisms to accommodate the scarcity of water. Therefore, it is difficult to generalize regarding the Gizzu plants adaptation to the water deficit because different species have different adjustments. One of the most common adaptation characteristic is the low plant surface area with mainly small leaves or no leaves most of the year. Another important adaptation characteristic is the presence of numerous hairs, spines and prickles. An additional adaptation mechanism, is full or partial dormancy during the dry period. For example, some species have needle-like leaves such as Blepharis spp., while others such as Crotalaria spp., have small leaves not more than a few millimeters in area. The leaves of Crotalaria spp. fall off when conditions get too dry and the plants remain leafless during the dry
periods (Appendix 12), and when it rains they produce new leaves. This observation is in line with the previous studies of Phillips and Comus (2000). They reported that many plants in the desert, drop their leaves during the dry period of the year and would thus have no leaves at all for most of the year and depend for photosynthesis on stem tissues.

In addition, the Gizzu herbs are characterized by the presence of hairs on the outer surfaces of the leaf. This trait reduces the evaporation of moisture from the surface of leaves by reflecting sunlight and inhibiting air movement. All species of the Gizzu herbs also grow hairy leaves during the dry period and less hairy leaves during the rainy season.

In this study it was noticed that many species of the Gizzu herbs in addition to the presence of hairs, rolled their leaves during the dry period, perhaps the presence of large epidermal cells similar to motor cells may play a role in this. This observation is in line with the results reported by Fitter and Hay (1987), who showed that plants could reduce water loss from one-leaf surface by leaf rolling.

In some species, stems are covered with dense hairs or numerous small spines. These characters act as an insulator restricting air movement and hence increase resistance to transpirational water loss. Branches of Crotalaria aculeata (Del.) DC. (NATASH) bear fleshy tops when young and taper to sharp spines at the ends in the dry period (Appendix 12). Stems of some species of the Gizzu herbs often are very woody as a result of hardening of the outer cells. This is probably due to the presence of thick periderm which dies to form bark, as observed in Indigofera bracteolata DC. (DARMA) and Moltkiopsis ciliata (Forrsk.) Johnston (HERESH).

The fibrous roots of Stipagrostis spp. and Triraphis pumilio R.Br. (ALSALIAN) were surrounded by dense wooly hairs (Appendix 13). These roots draw water from near the soil surface, which dries up during the drought period. Therefore, dense wooly hairs probably increase absorption area of roots, since roots provide the primary moisture-gathering ability of most plants. The taproots of perennial herbs penetrate deeply into the soil, reaching 2 meters to extract water from deep soil profile during the dry period. Kramer (1983) reported that deep rooting is an important
adaptive mechanism for plant survival in dry lands. El Samani et al., (1997) reported that along the lower part of Wadi Hawar (extends from Meidob to River Nile) the depth of the ground water decreases to less than 2 meters.

Some species such as Neurada procumbens have thick leaves probably to provide more photosynthetic mesophyll, particularly during the dry period when their stomata remain closed partially or completely to conserve water. Fitter and Hay (1987) reported that some desert plants have thicker leaves which can provide more photosynthetic mesophyll. Other species such as Citrulus colosynthis (L.) Schard, have thick roots, probably to store water during rains for use during the dry period, and that is why these species dry out during the rainy season and become green in winter.

Flowers of most Gizzu herbs have hairs or prickles on the calyx, or corolla and hirsute on the outer surface of the flower such as those observed in Indigofera bracteolata DC.(DARAMA) and Moltkiopsis ciliata (Forrsk.) Johnston, (HERESH). This is probably an adaptation mechanism against water loss as stomata are preocular in floral parts.

Pods of many species are densely pubescent such as Coratalaria spp., and Idigofera spp. In other species, fruits are woody and the upper surface covered with spines such as Neurada procumbens. This is probably an adaptation to prevent water loss.

Generally, seeds have the highest resistance to drought conditions during the plant life cycle compared to the seedlings. This might explain the unique characteristics of the seeds of the Gizzu plants. In this respect, the seeds of most species of the Gizzu herbs are hairy and with extremely tough coats (Appendix 14), which can only be removed with adequate moisture as observed in Blepharis species. Gutterman (1993) reported that desert plants have survival mechanisms that will enable seeds to germinate when the chance of seedling establishment is very high and the risk is relatively low. For example, the seeds of Neurada procumbens L., (ALSAADAN) and Blepharis spp. (BEGHIEL), germinate only after large amount of rains and in other plants the seeds were relatively large and protected against many granivores.
Effect of temperature on seed germination:

The results indicated that the seeds of Blepharis species germinated in a wide range of temperature (15-45°C). This is in line with the finding of Gutterman (1993) who reported that the seeds of Blepharis spp. germinate in a similar range of temperature (8-40°C) under both light and dark conditions. The upper temperature for germination in this study, however, exceeded that reported by Gutterman (1993). This may reflect a greater adaptation of this species to the high temperature in the study area which may exceed 45°C particularly during the summer.

The highest germination percentage and speed of germination for unsoaked seeds of the two species were at 45°C, and the lowest values were at 15°C. High temperature is reported to break seed dormancy in many species (Evenari 1952; Burdett 1972; Gutterman 1972; Tool, 1973; Cantliff et al, 1984; Small and Gutterman 1991, 1992a). In contrast, low temperature is reported to reduce the speed of germination of annual and perennial plants (Evenari et al. 1982; Tevis 1958 b). On the other hand soaked seeds of the two species, gave 100% germination after less than 24h. This result agreed with Gutterman (1972) finding who stated that the germination percentage of Blepharis spp. reached 100% after 24h. from imbibition in constant temperatures.

Seedling length (shoot and root) reached 3.5-10.3 cm within 24h. in both species under soaked and unsoaked conditions, respectively. This fast germination helps Blepharis spp. to use available moisture in the surface layer of soil before it dries out following the usually scanty rainfall. Mayer and Poljakoff-Mayber (1989) reported that in arid regions fast and early germination of plants give the seedling ample time to establish themselves while conditions are still suitable. The death of seedlings at high temperature (45°C) is probably due to the effect of high temperature on protein structure and enzymatic reaction.

Effect of water stress on the physiological, morphological and anatomical characters of Blepharis species:
In the present study water stress caused significant reduction in the seedling water potential of plants under both pot and field conditions. This reduction was associated with a significant reduction in stomatal conductance and transpiration rate. This is in line with the findings of Passioura (1992), who reported that as soil dries up, the uptake of water by the root decreases and the water potential falls sufficiently to cause stomatal closure, leading to a reduction in transpiration rate. Also Glinka (1971) reported that, if water is withheld from a plant for several days, its water potential falls to a low value.

The reduction in stomatal conductance depended upon the water potential and transpiration. Because, as soil dries and the availability of adequate water is reduced, stomatal conductance declines resulting in lower values of transpiration rate and hence reduced water loss. This is in line with previous studies which reported that stomatal control of water loss as a result of feedback mechanism in which the rate of transpiration affects the aperture of stomata (Jones, 1980; Cowan et. al., 1982). Similarly, Techawangstein et. al., (1992) concluded that stomatal conductance and leaf water potential decrease under water deficit.

The reduction in specific leaf area under water stress conditions observed in this study revealed an adaptation mechanism to the drought, as this character was associated with reduction in transpiring surface area. This result agreed with Li (1999) who reported that, the smaller the leaf surfaces area the lesser would be the risk of lethal desication by extreme drought. Fotteli et. al., (2000) recorded that the small leaf area characteristic of plants which grow under drought conditions is considered an adaptation of xeric sites. Similarly, the significant reductions in number of leaves and branches per plants under water stress observed in this study might be partially attributed to leaf senescence and abscission. Loveys (1983) reported that the reduction in number of leaves per plant under water deficit may be attributed to accumulation of ABA which promoted leaf abscission.

The non significant reductions on shoot, root length and root to shoot ratio under water deficit observed in this study could be considered as a drought tolerance mechanism in these species, specially root length which is needed to extract water. Similarly the
non significant effect of water stress on reproductive attributes observed in this study may be considered more correctly a survival mechanism.

In contrast, the significant reduction in the total dry weight under water deficit may be attributed to the reduction in photosynthesis and shedding of leaves. Similar findings were reported by Ravindera, et. al., (1990) who concluded that, the reduction in dry matter under drought is associated with reduction in leaf area and size of reproductive sink. Other studies, showed that plants that use a finite water, should have higher biomass productivity than plants with low water use efficiency (Jones, 1992). This finding was further substantiated by the positive correlation between leaf area and root length observed in this study.

On the other hand, the positive correlation between stomatal conductance and transpiration rate observed in this study, is in line with the findings of Nambiar and Brown (1997). who reported that water deficit causes a reduction in stomatal conductance, with a proportional reduction in transpiration rate. The negative correlations between stomatal conductance, transpiration rate and root length found in the present study could be considered as a drought tolerance mechanism in these species.

In this study stained sections showed large paranchyma cells in the midrib of leaf and cortex of stem and root, which are probably used for water storage. The presence of thick periderm, collenchyma cells and thick cuticle in water stressed plants may be considered as an adaptation mechanism to protect plants against water loss. Previous studies (Cowan and Milthorpe, 1968) reported that, arid species have high cuticular resistance to water loss by development of thick layers of cutin and thick coatings of wax on leaves.

Moreover, in the present study stomatal density decreased in water-stressed plants constituting another mechanism of adaptation because decreases in stomatal density increases leaf resistance to water loss. This result is in line with the findings of Gates (1980) , Fitter and Hay (1987) who reported that increases in stomatal density reduced leaf resistance to water loss.

In addition, the presence of hairs in water-stressed plants may contribute to the increased resistance to transpirational water
loss. This is in line with previous studies by Gates (1980) and Fitter and Hay (1987) who reported that the presence of leaf hairs tends to increase the boundary layer thickness which in turn increases the resistance of transpirational water loss. Also, these hairs are often found to be specifically clustered around the stomata and hence tend to restrict gas exchange through the stomata.
This work was conducted in Northern Darfur State to study species composition and distribution of Gizzu flora. The variation in morphological characteristics and their relation to adaptation were also investigated on a selected group of herbs and grasses together with anatomical and physiological adaptation. The effect of temperature and water stress on germination and plant performance of two species of *Blepharis* were studied under glasshouse conditions.

1. Field survey data indicated that the flora of Gizzu consisted of four types of vegetation: permanent trees and shrubs, perennial herbs and grasses, succulent plants and ephemerals.

2. The distribution of these vegetation types is distinctly dependent on the amount of rainfall and soil types.

3. Some of Gizzu herbs and grasses remain as seeds over a long periods and only germinate when conditions becomes suitable for development. In contrast, seedlings of perennial herbs and grasses survived by becoming dormant during the dry periods.

4. The relative abundance of herbs and grasses in the Gizzu area was greater in lighter sandy soils compared to the wadi soils. Therefore, these plants may be used to combat desertification.

5. Considerable variations in morphological traits were observed among Gizzu herbs and grasses suggesting that the adaptive fitners of these species is restricted to defined boundaris of soil and weather.

6. The high germination percentages of *Blepharis spp.* on a wide range of temperature (15-45°C) may explained the relative abundance and vast distribution of these species in the Gizzu area.

7. *The common adaptation characteristics of Gizzu herbs and grasses to water deficit was reduced leaf surface area as a
result of small leaves or no leaves most of the year. Another important adaptation characteristic is the presence of numerous hairs, spines and prickles and full or partial dormancy during the dry period.

8. The number of leaves, number of branches, stomatal conductance, transpiration rate and water potential of the two species of Blepharis were significantly reduced with soil drying and no significant reduction in shoot length, root length, and stomatal density were observed. This might represent a drought tolerance mechanism of these species to water-limiting environment.

9. Further insitu work is needed on the morphological, anatomical and physiological bases of Gizzu herbs and grasses adaptation under conditions of limited water supply.

REFERENCES


Ravindera, V. Nautiyal, P.C. and Joshi, (1990). physiological analysis of drought resistance and yield of


نجلة حسن
1971
("الثالثة الطبيعية")
دار منشورات بيروت
الحياة
160-167.
167-160، كازنوف.
Annual Rainfall for the period 1971-2000

Source: Meteorological Department
APPENDIX (5): Daily maximum and minimum temperature, mean monthly evaporation (mm), relative humidity (R.H.) and wind speed of the study area for the period (1971-2000).

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Evaporation (mm)</th>
<th>R.H. %</th>
<th>Wind (m.p.h.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>37.7</td>
<td>0.7</td>
<td>11.6</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Feb.</td>
<td>40.1</td>
<td>1.4</td>
<td>14.0</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Mar.</td>
<td>42.2</td>
<td>6.5</td>
<td>16.3</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Apr.</td>
<td>43.0</td>
<td>8.2</td>
<td>17.9</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>May</td>
<td>43.2</td>
<td>12.8</td>
<td>17.9</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Jun.</td>
<td>42.5</td>
<td>15.7</td>
<td>15.9</td>
<td>33</td>
<td>5</td>
</tr>
<tr>
<td>Jul.</td>
<td>41.7</td>
<td>15.6</td>
<td>10.5</td>
<td>52</td>
<td>5</td>
</tr>
<tr>
<td>Aug.</td>
<td>39.7</td>
<td>13.5</td>
<td>8.1</td>
<td>61</td>
<td>4</td>
</tr>
<tr>
<td>Sep.</td>
<td>40.2</td>
<td>15.5</td>
<td>10.4</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>Oct.</td>
<td>39.8</td>
<td>7.1</td>
<td>13.5</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Nov.</td>
<td>38.0</td>
<td>5.6</td>
<td>12.2</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>Dec.</td>
<td>36.5</td>
<td>2.0</td>
<td>11.2</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Mean</td>
<td>40.3</td>
<td>8.3</td>
<td>13.4</td>
<td>31</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Elfashir Meteorological Department

Appendix (8): The scientific and vernacular names of the collected Trees and Shrubs from the Gizzu Arae
<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific Name</th>
<th>Vernacular name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asclepidaceae</td>
<td>Clotropis procera <em>(Ait)</em> Ait.</td>
<td>USHAR</td>
</tr>
<tr>
<td></td>
<td>Leptadenia pyrotechnica <em>(Forssk)</em> Decne.</td>
<td>MARAKH</td>
</tr>
<tr>
<td>Balanitaceae</td>
<td>Balanites aegyptiaca <em>Del.</em></td>
<td>HEGLIG</td>
</tr>
<tr>
<td>Boraginaceae</td>
<td>Cordia sinensis <em>Lam.</em></td>
<td>ANDARAB</td>
</tr>
<tr>
<td>Capparidaceae</td>
<td>Boscia senegalensis <em>(Pers)</em> Lam.</td>
<td>MUKHIET</td>
</tr>
<tr>
<td></td>
<td>Capparis sinensis <em>Lam.</em></td>
<td>TUNDUB</td>
</tr>
<tr>
<td></td>
<td>Maerua crassifolia <em>Forssk</em></td>
<td>SARAH</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>Acacia mellifera <em>(Vahl.)</em> Benth.</td>
<td>KITR</td>
</tr>
<tr>
<td></td>
<td><em>A.. nilotica (L.)</em> Willd.</td>
<td>GARAD</td>
</tr>
<tr>
<td></td>
<td><em>A.. nubica</em> Benth.</td>
<td>SEAL</td>
</tr>
<tr>
<td></td>
<td><em>A . raddiana</em> Savi.</td>
<td>TALIH</td>
</tr>
<tr>
<td></td>
<td><em>A . seyal</em> <em>Del.</em></td>
<td>ARAD</td>
</tr>
<tr>
<td>Palmae</td>
<td><em>A . tortilis</em> <em>(Forsk)</em> Hayne</td>
<td>BALAH</td>
</tr>
<tr>
<td>Rhamnaceae</td>
<td>Albizia amara <em>(Roxb.)</em> Boiv.</td>
<td>SIDR</td>
</tr>
<tr>
<td>Salvadoraceae</td>
<td>Phoenix datilifera <em>L.</em></td>
<td></td>
</tr>
<tr>
<td>Tiliaceae</td>
<td><em>Ziziphus spina-christi (L.)</em> Desf.</td>
<td>ARAK</td>
</tr>
</tbody>
</table>
| **Salvadora persica** *L.*  
| **Grewia tenax** *Forssk.* |  
|  | **GEDAIM** |
Appendix (9a): Trees and shrubs on heavy soil (Wadi Magrur)

Appendix (9b): Herbs and grasses on sandy soils.
Appendix (10b): Collected succulent plants, root of Citrullus colocynthis (L.) Schard.
Appendix (11a): Animals grazing on the Gizzu plants, Camels on herbs on sandy soils.

Appendix (11b) Animals grazing on the Gizzu plants, Sheeps on plants on heavy soils (Wadi Magrur).
Appendix (12a): *Crotalaria aculata* (Del.) DC., in dry period.
Appendix (12b): *Crotalaria aculata* (Del.) DC., in rainy period.

Appendix (13a): *Stipagrostis spp.*, with hairs surrounded their roots in dry period.
Appendix (13b): *Triraphais pumilio* R. Br. with hairs surrounded their roots in dry period.

Appendix (14): Seeds of *Neurada procumbens* L., with spines on the upper surface of seed