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Ecology of Invasive Species in Saudi Arabia, *Calotropis procera* (Ait) W.T. Ait.: Floristic Composition and Associated Plant Communities

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Abstract: The present study aims at evaluating the state of *Calotropis procera* to adapt different environmental conditions; surveying the associated wild plants and recognizing the plant communities which are associated with it. Seventy five stands were selected along Taif region and its adjacent area to represent the environmental variations that are associated with the distribution of *Calotropis procera*. The abundance of species, life forms, chorotype and economic uses were determined. Two trends of multivariate analysis were applied: classification (TWINSPAN) and ordination (DECORANA). The total number of recorded species associated with *Calotropis procera* in the study area is 55 species belonging to 48 genera and 27 families. 74.5% of the recoded species are perennials and 25.5% are annuals. The families Fabaceae, Poaceae, Solanaceae have the highest contributions followed by Asteraceae and Zugophyllaceae. Chamaephytes life form had the highest contribution followed by therophytes, phanerophytes and gephytes, while hemicryptophytes were the lowest. The economic uses of the recorded species could be arranged descendingly as follows: grazing → medicinal→ fuel → other uses→human food. The mono-regionals species were the highest followed by pluri-regional species, while the bi-regional and cosmopolitans were the lowest. Ten of the mono-regional species are Sudano-Zambezian species and 6 species are belonging to Saharo-Arabian and Mediterranean regions. The application of TWINSPAN on the cover estimates of 55 species recorded in 75 stands led to the recognition of 7 vegetation groups (A: *Themeda triandra*, B: *Cynodon dactylon*, C: *Commicarpus ambiguus*, D: *Amaranthus viridis*, E: *Acacia tortilis*, F: *Argemone ochraleuca* and G: *Verbesina encelioides* groups).

Keywords: *Calotropis procera*, Saudi Arabia, Invasive, Multivariate Analysis, Medicinal Plants

1. Introduction

Saudi Arabia extends over an area of 2026213 sq. km, and occupies almost two-thirds of the Arabian peninsula (16°-32° N and 35°-56° E). The area occupied by the country represents about 1.5% of the total land area, about 5% of Asia and about 5% of the area of the arid zones in the world.The genus *Calotropis* consists of common weeds which occur in arid ecosystems but it has become naturalized in warm climates, where it grows commonly in disturbed areas. *Calotropis* is a wasteland weed of world-wide distribution. It is abundant in the tropics and sub-tropics, and rare in cold countries [1]. It prefers open habitats where there is little competition from other plants. Since these conditions can be generated following heavy grazing by cattle and other livestock. It can become particularly abundant on badly degraded areas such as abandoned cultivation, generally on sandy soils in areas of low rainfall [2]. However, there is evidence that *C. procera* can invade land with good pasture cover. However, it seems best adapted to areas that have sparse ground cover. Research is required to more fully assess its recruitment success in competition with pasture.

Calotropis species are drought [3] and salt tolerant [4]; however, the mechanism behind their successful distribution across arid regions is not well understood [5]. Although the *C. procera* is a drought resistant and salt tolerant to a relatively high level, but its distribution across the semi-arid and arid regions, can be a major reason behind its degradation [6]. It quickly becomes established as a weed along degraded roadsides, lagoon edges and in overgrazed native pastures through wind and animal dispersed seeds. It is often dominant in areas of abandoned cultivation especially sandy soils in areas of low rainfall; and assumed to be an indicator of over-cultivation and overgrazing [7]. It prefers disturbed sandy soils [8]. It also grows at altitude: up to 1300 m, with the mean annual rainfall at 300-400 mm. It is not frost tolerant [2].

C. procera is native to tropical and subtropical Asia and Africa (Weed Identification undated). According to [9], its native range includes: Macaronesia (Cape Verde), Northern Africa (Algeria, Egypt, Libya, Morocco), North-east tropical Africa (Eritrea, Ethiopia, Somalia, Sudan), East tropical Africa (Kenya, Tanzania, Uganda), West-Central tropical Africa (Cameroon, Equatorial Guinea–Bioko), West tropical Africa (Gambia, Ghana, Guinea-Bissau, Mauritania, Nigeria, Senegal, Sierra Leone), Arabian Peninsula (Oman, Saudi Arabia, United Arab Emirates, Yemen), Western Asia (Afghanistan, Egypt–Sinai, Iran, Israel, Jordan, Syria), Indian subcontinent (India, Nepal, Pakistan) and Indochina (Myanmar, Thailand, Vietnam). The species' naturalized range includes California, Central and South America (Brazil), the Caribbean, the Seychelles, Mexico, Thailand, Vietnam, Australia and many Pacific Islands, including Hawaii Antigua and Barbuda, Argentina, Australia, Bahamas, Barbados, Bolivia, Brazil, Chile, Colombia, Cuba, Dominica, Dominican Republic, Ecuador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Surinam, Trinidad and Tobago, Uruguay, Venezuela, Virgin Islands (US). [2, 9, 10].

The different parts of *C. procera* had been widely used in traditional medicine due to its pharmacological active compounds found in all plant parts; barks, roots, leaves and especially its milky latex which exudates from damaged and broken leaves and stems ([6]; [11]). Because of these active chemical compounds, *C. procera* has been used for treatment of a number of diseases, such as ulcers, tumors, leprosy, piles and diseases of the spleen, liver and abdomen [12]. The milky sap is used as a rubefacient and is also strongly purgative and caustic. The latex is used for treating ringworm, guinea worm blisters, scorpion stings, venereal sores and ophthalmic disorders; also used as a laxative. The twigs are applied for the preparation of diuretics, stomach tonic and anti-diarrhoetics and for asthma. Also it used in abortion, as an anthelmintic, for colic, cough, whooping cough, dysentery, eadache, lice treatment, jaundice, sore gums and mouth, toothache, sterility, swellings and ulcers [13].

The plant yields valuable hydrocarbons which could be converted into diesel substitutes [14, 15]. Evaluation of different parts viz. latex, stem, leaves and pods, of *Calotropis procera* as a source of hydrocarbons has been studied [16]. The biodiesel derived from *C. procera* is free from NOx gases, SO_2 and suspended particulate matter (SPM) and has high cetane value [17-20]. *C. procera* has big inflorescence with very prominent purplish pink flowers. These occur throughout the year. No studies on the available flower biomass and biocrude are reported. So a preliminary study to explore the possibility of using flowers for producing hydrocarbons, an alternate source of energy was undertaken.

The present study aims to evaluate the state of *Calotropis procera* to adapt different environmental conditions in Saudi Arabia, survey, identify of wild plants and recognize the plant communities associated with it on one hand and correlation between this species and the prevailing environmental variables on the other hand.

2. Material and Methods

2.1. Study Area

Saudi Arabia extends over approximately 16° degrees of latitude, from 16° 22' at the borders with Yemen in the south; to 32° 14' at the Jordanian border in the north, and between 34° 29'E and 55° 40` E. Longitude. (Figure 1). Taif region is located in the central foothills of the western mountains at an altitude of up to 2500 m above sea level. It is an important place for the people due to its scenic views and fertile valleys which support the growth of a favorable fruits and vegetables. Agriculture has been the prime economic income in Taif. Historically the tribes of Taif grew wheat, barley and fruits such as lime, apricot, orange, olive, peaches, pomegranate, watermelons, grapes, almonds and dates. However, the agricultural development has to pay a heavy price for the natural vegetation of Taif region. Over the years, vast areas of virgin lands have turned into agricultural lands, which resulted in the disappearance of many wild species including medicinal plants.

Climate of the area is tropical and arid. The monthly mean of climatic variables that recoded in Taif meteorological station (1997 – 2009) indicated that the monthly average of minimum and maximum ambient temperatures ranged from 7.9±1.2 to 23.4±0.8°C and 22.9±1.1 to 36.3±0.8°C, respectively with a total monthly mean of 23.2±5.1°C (Table 1). The mean maximum temperature (± SD) was between 2006 and 2008 was 36.33 ± 1.15°C, while average values for the period between 1991 and 2005 were 33.60 ± 3.03°C. During the same period, mean monthly humidity ranged from approximately 19.6±4.2 to 60.0±6.0%. The data from last 10 years shows considerable inter-annual variation in the monthly amount (range 4.3±5.7-294.1±383.8mm mo^{-1}) and timing of rainfall. The yearly amount of rainfall ranges from 83.3 mm yr^{-1} in 2007 to 3312 mm yr^{-1} in 2001.

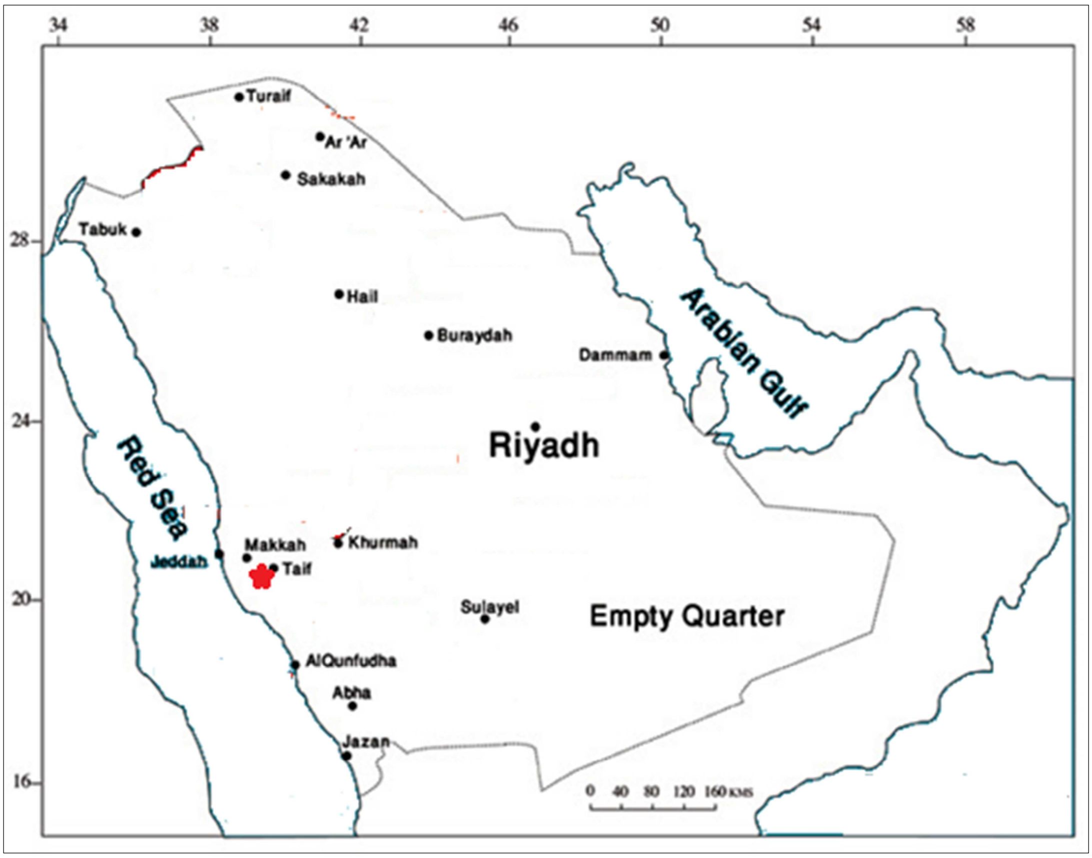


Figure 1. *Map showing The study area (red point) (modified after Al-Sodany et al. 2013)[62].*

Table 1. *Monthly variation in air temperature (℃), relative humidity (%), weed speed (km hr^{-1}) and rainfall (mm month^{-1}) as recorded at Taif meteorological station located in the study area. The data are long term averages from Climatological Normals for KSA, 1997 – 2007 (Anonymous, 2008). The F-value for each variable are calculated (ANOVA), ***: P≤0.001.*

Month	Temperature (℃)			RH (%)	WS (km hr^{-1})	RF (mm mo^{-1})
	Max.	Min.	Mean			
Jan.	22.9±1.1	7.9±1.2	15.4±1.0	58.7±5.6	5.5±0.5	12.1±12.0
Feb.	25.8±1.3	10.1±1.4	17.9±1.1	52.2±4.7	6.7±0.6	283.0±392.2
Mar.	27.5±0.9	12.0±1.2	19.8±0.7	46.5±7.1	7.2±0.9	22.5±23.7
Apr.	30.8±1.0	15.3±0.9	23.0±0.7	43.2±4.5	6.7±0.6	93.5±227.8
May	34.1±1.2	18.4±0.7	26.3±1.2	33.1±7.4	6.2±0.8	97.9±227.9
Jun.	36.3±0.8	22.2±0.9	29.4±0.6	19.6±4.2	8.3±0.6	141.8±314.4
Jul.	35.6±1.0	23.2±0.9	29.1±0.9	21.8±4.6	10.6±1.2	73.7±233.5
Aug.	36.3±0.5	23.4±0.8	29.5±0.4	27.5±4.4	9.7±0.9	92.8±229.2
Sep.	35.3±0.6	20.3±0.9	28.0±0.4	29.6±4.1	6.2±0.4	294.1±383.8
Oct.	31.2±0.7	15.3±0.6	23.5±0.6	39.7±7.9	5.0±0.4	88.0±231.8
Nov.	27.2±1.0	12.0±1.1	19.6±0.5	55.5±8.4	5.1±0.3	155.6±308.1
Dec.	24.4±1.4	9.3±1.0	16.7±1.1	60.0±6.0	5.1±0.7	4.3±5.7
Total mean	30.6±4.8	15.8±5.5	23.2±5.1	40.6±14.8	6.9±1.9	113.3±257.4
F-value	270.2***	348.3***	457.5***	63.8***	73.1***	1.5

2.2. Vegetation Sampling and Measurements

Seventy five stands were selected along Taif region and its adjacent area to represent the environmental variations that associated with the distribution of *Calotropis procera*. The stand size was about 20 x 20 m (approximates the minimal area of the plant communities). In each stand, the following data were recorded: 1- list of species, 2- first and second dominant species, 3- a visual estimate of the total cover (%) and the cover of each species according to Braun-Blanquet scale, [22], and 4- the physical changes occurred in each stand (e.g., grazing, cutting and firing, etc.). The data were compiled into a raw table containing the recorded species (55 species) in the examined stands (75 stands). Nomenclature was according to [21, 23-33]. The herbarium sheets of the recorded species are kept in the Herbarium of Biology Department, Faculty of Science, Taif University.

Life forms of the species were identified following the Raunkiaer scheme [34]. The global geographical distribution of the recorded species in the study area was determined from [29, 30, 33, 35-38]. This will help in assessing the rarity forms of these species. The global distribution (i.e. floristic regions) was coded as follows: Cosmopolitan (COSM), Euro-Sibarian (ES), Europian (EU), Indian (IN), Irano-Turanian (IT), Mediterranean (ME), Med-Irano-Turanian (MIT), Paneotropic (PAN), Saharo-Arabian (SA), Sudano-Zambezian (SU) and Tropical (TR). The potential and actual economic uses of wild plants were assessed on three bases; field observations, information collected from local inhabitants, and literature review [36-42]. Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were applied to the cover estimates of 191 species in 100 stands to recognize the plant communities in the study area [43-46].

2.3. Soil Analysis

Soil samples were collected from each stand as a profile (composite samples) at a depth of 0-50 cm below the soil surface. The soil samples were brought to the laboratory in plastic bags shortly after collection, spread over sheets of paper, air dried, passed through 2 mm sieve to remove gravel and debris, then packed in paper bags ready for physical and chemical analysis. Soil water extracts at 1: 5 were prepared for determination of soil salinity (EC), soil reaction (pH), chlorides and sulfates. Soil reaction (pH) was estimated using a glass electrode pH-meter. Salinity was evaluated by a direct indicating conductivity bridge (mmhos/cm). Chlorides were estimated by direct titration against silver nitrate using 5% potassium chromate as indicator. Carbonates and bicarbonates were evaluated by direct titration against 1N HCl using phenolphthalein and methyl orange as indicators.

3. Results

The recorded species in the study area, their families, vernacular names, life forms, habits, chorotypes, abundance and their uses are listed in (Table 2). The total number of recorded species associated with *Calotropis procera* in the study area is 55 species belonging to 48 genera and 27 families. 74.5% of the recoded species are perennials (41 species) and 25.5% are annuals (14 species) (Figure 2) The families Fabaceae, Poaceae, Solanaceae have the highest contributions to the total flora (9.1% of the total species), followed by the Asteraceae and Zugophyllaceae (7.3%). Sixteen (16) families have were represented only by one species; 2 families were represented by two species; and 4 families were represented by three species. Eleven species were recorded in more than 15% of the total stands (*Acacia tortolis, Indigofera spinosa, Cynodon dactylon, Argemone ochraleuca, Fagonia schweinfurthia, Erodium sp., Citrullus colocynthis, Peganum harmala, Verbesina encelioides, Acacia gerradii* and *Fagonia indica*).

The life form spectra of the vegetation in the study area indicated that, chamaephytes had the highest contribution in the study area (47.3% of the total recorded species), followed by therophytes (27.3%), phanerophytes (12.7%) and Gephytes (7.3%). While hemi-cryptophytes were the lowest with a total relative value of 5.5% (Figure 3).

Forty eight species of the recorded species in this area (87.3% of the total species) have at least one aspect of the potential or actual economic uses (Table 2). Thirty one species have ≥ 3 (out of 5) economic aspects, of them 5 species have 5 economic aspects. These are*: Withania somnifera*, *Phoenix dactylifera, Peganum harma*la, *Senna italiaca* and *Indigofera spinos.* Thirty nine species (70.9% of total recorded species) are medicinal, 38 species (69.1% of total recorded species) are grazing, 16 species (29.1% of total recorded species) are edible by man, 30 species (54.5% of total recorded species) used as fuel and 22 species (40.0% of total recorded species) used as other economic uses (Figure 4). The economic uses of the recorded species could be arranged descendingly as follows: grazing → medicinal→ fuel → other uses→human food. On the other hand, 43 species of the total recorded species are common (78.2%), 8 species are rare (14.5%) and 4 specie (7.3%) are very rare (Figure 5).

Regarding the global phyto-geographical distribution, the mono-regional species were the highest (30 species = 54.5%), followed by pluri-regional species (13 species = 23.6%). The bi-regional (9 species = 16.4%) and cosmopolitans (3 species = 5.5%) were the lowest (Figure 6A). Ten of the mono-regional species (13.6%) are Sudano-Zambezian species and 6 species are belonging to Saharo-Arabian and Mediterranean regions (Figure 6B).

The application of TWINSPAN on the cover estimates of 55 species recorded in 75 stands during the study period, led to the recognition of 18 groups at the 6^{th} level of classification and 7 vegetation groups (communities) at 4^{th} level (Figure 7A). The application of DECORANA on the same set of data indicates a reasonable segregation among these groups along the ordination plane of axes 1 and 2 (Figure 7B). The vegetation groups are named after the first and occasionally the second dominant species (Table 3) (the species that have the highest presence percentage and / or the highest visual cover). The vegetation groups (communities) are associated with *Calotropis procera* are: A: *Themeda triandra* group, B: *Cynodon dactylon* group, C: *Commicarpus ambiguus* group, D: *Amaranthus viridis* group, E: *Acacia tortilis* group, F: *Argemone ochraleuca* group, and G: *Verbesina encelioides* group).

The soil analysis according to vegetation groups (communities) was presented in (Table 4). It was indicated that the soils of *Argemone ochraleuca* group (F) have the highest of pH (7.74±0.17), salinity (138.00±66.90 µmhos/cm), organic carbon (2.59±1.84%), organic matter (4.46±3.18%), and bicarbonate (0.05±0.01%). The soils of *Acacia tortilis* group (E) have the lowest of organic carbon (1.16±1.05%) and organic matter (1.99±1.81%), but the soils of *Amaranthus viridis* group (D) have the lowest of bicarbonate (0.02±0.00%). The soils of all vegetation groups were characterized by low chlorides (0.01%).

As indicated in (Table 5), the soils of the altitude of 1500-1700m a.s.l. have the highest values of all estimated soil variables: pH (7.74±0.11), salinity (314.96±477.14 µmhos/cm), chlorides (0.03±0.05%), and organic carbon (3.29±0.93%), organic matter (5.67±1.60%), and bicarbonate (0.06±0.01%). The altitude of <1300 a.s.l. have the lowest values of organic carbon (0.66±0.23%), organic matter (1.14±0.39%), and bicarbonate (0.03±0.01%) and the high altitudes (>1700 m a.s.l.) have the lowest of pH (7.33±0.17) and salinity (42.49±5.90 µmhos/cm). On the other hand, the depression spot habitat have the highest values of all estimated soil variables: pH (7.74±0.11), salinity (314.96±477.14 µmhos/cm), chlorides (0.03±0.05%), and organic carbon (3.29±0.93%), organic matter (5.67±1.60%), and bicarbonate (0.06±0.01%). The high altitudes (>1700 m a.s.l.) have the lowest of pH (7.33±0.17), salinity (42.49±5.90 µmhos/cm) and bicarbonate (0.03±0.00%), while the sand flats habitat has the lowest of chlorides (0.01±0.00%), and organic carbon (0.69±0.28%) and organic matter (1.20±0.48%).

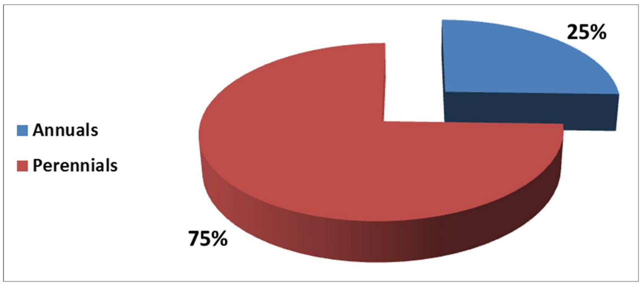


Figure 2. *Percentage of habits of the recorded species associated with Calotropis procera. at the study area.*

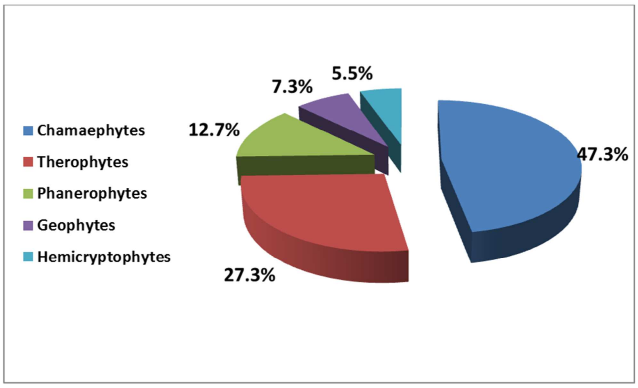


Figure 3. *Life form spectra of the recorded species associated with Calotropis procera at the study area.*

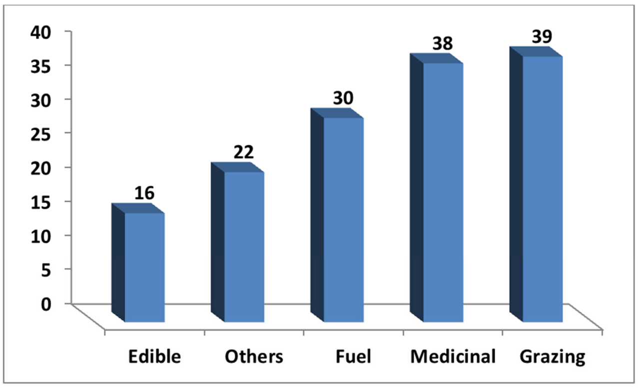


Figure 4. *Ascending arrangement of the economic uses of the recorded species associated with Calotropis procera in the study area.*

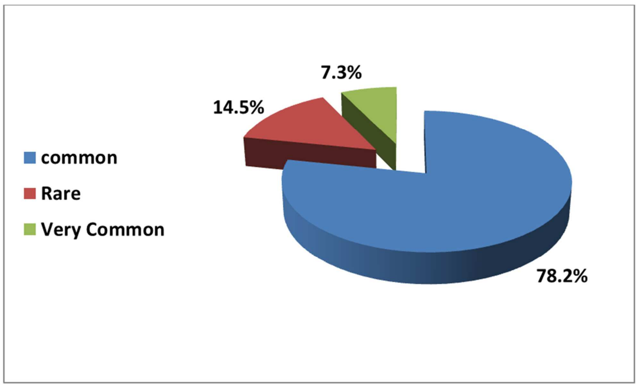
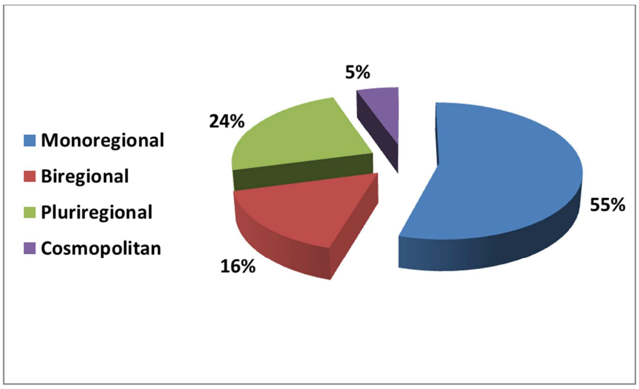


Figure 5. *Abundance spectra of the recorded species associated with Calotropis procera in the study area.*



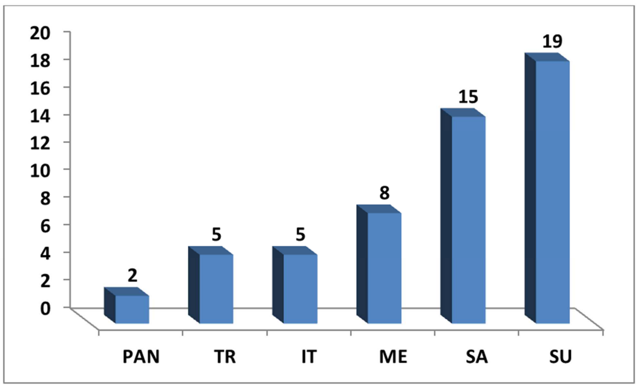


Figure 6. *Chorotype spectra the recorded species recorded species associated with Calotropis procera in the study area.*

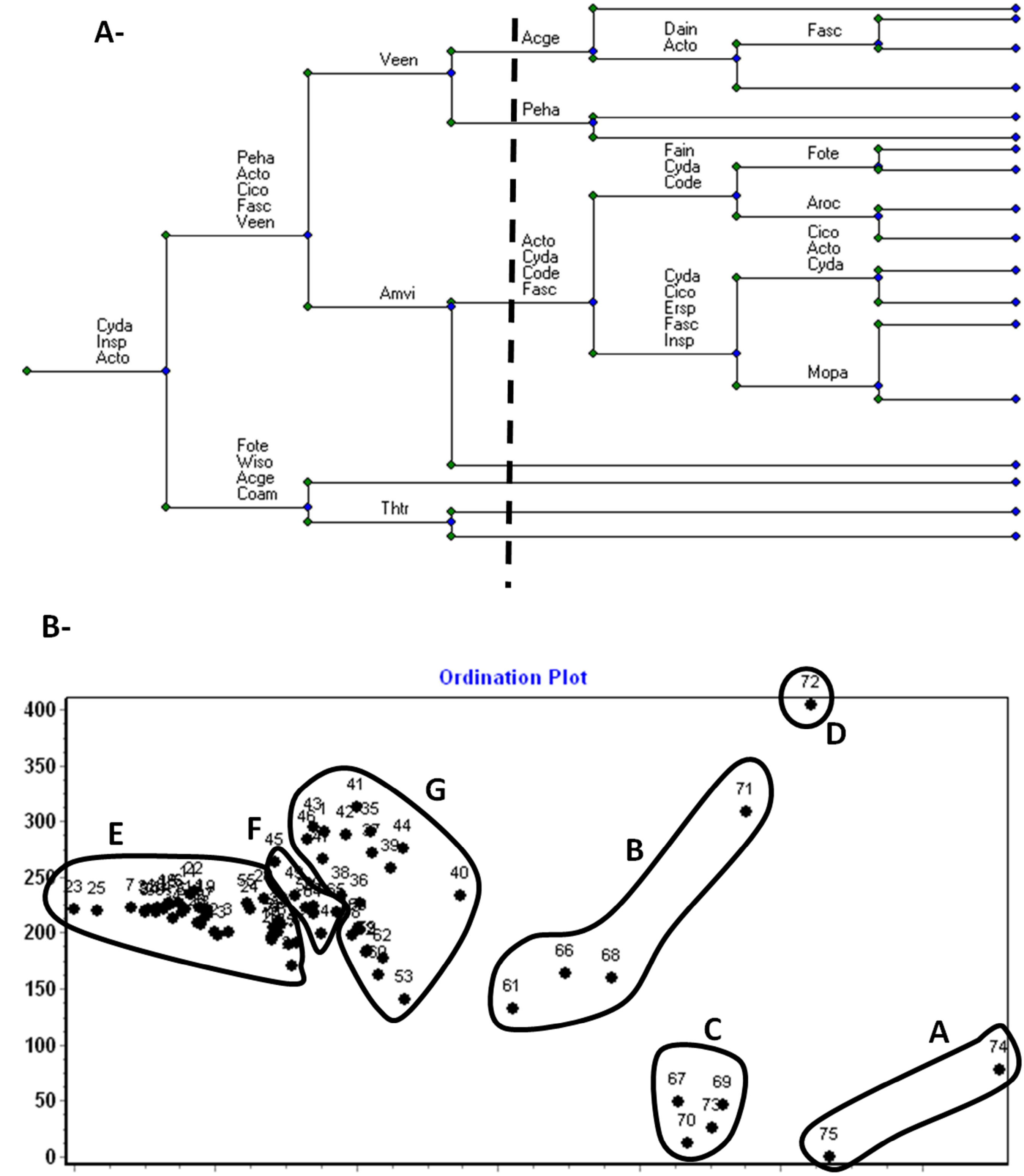


Figure 7. A: Dendrogram of the 7 vegetation groups derived after application of TWINSPAN classification technique. B: Cluster centroids of the 7 vegetation groups derived after application of DECORANA ordination technique on the associated species with C. procera in the study area. The vegetation groups are: A: Themeda triandra, B: Cynodon dactylon, C: Commicarpus ambiguus, D: Amaranthus viridis, E: Acacia tortilis, F: Argemone ochraleuca, and G: Verbesina encelioides groups).

Table 2. *Floristic composition of the community dominated by calotropis procera forests at study area. The life forms are: Ch: chamaephytes, He: hemicryptophytes, Gh: geophytes–helophytes, Ph: phanerophytes, Th: therophytes. Chorotypes are: SA: Saharo-Arabian, SU: Sudano-Zambezian, IT: Irano-Turanian, ME: Mediterranean, TR: Tropical, COSM: cosmopolitan, and PAN: Panotropic. The abundance are: r: rare, c: common and cc: very common. The uses: Me: medicinal, Gr: grazing, Ed: edible, Fu: fuel and O: other uses. The vegetation groups are: A: Themeda triandra, B: Cynodon dactylon, C: Commicarpus ambiguus, D: Amaranthus viridis, E: Acacia tortilis, F: Argemone ochraleuca and G: Verbesina encelioides groups).*

Species	LF.	VG	Chorotype	Abundance	Uses				
					Me	Gr	Ed	Fu	O
Acanthaceae									
Blepharis ciliaris (L.) Burtt	Ch	E	SA	r	-	-	-	+	-
Aizoaceae									
Aizoon canariense L.	Th	A	Pluri	c	-	+	-	-	-
Amaranthaceae									
Aerva javanica (Bunn.f.) Juss.ex Schulta	Ch	F	TR	c	+	+	-	+	-
*Amaranthus hybridu*s L.	Th	B, G	TR	c	+	+	-	+	-
Amaranthus viridis L.	Th	B, D	Pluri	c	+	+	+	-	+
Anacardiaceae									
Pstiaca falcata Becc. ex Mart.	Ph	D	ME	c	-	-	-	+	-
Apocynaceae									
Rhazya stricta Decne	Ch	E	SA	c	+	+	-	+	-
Asparagaceae									
Asparagus stipularis Forrsk.	Ch	C	ME	r	+	+	-	+	+
Asteraceae									
Centaurea sinaica DC.	Th	C, E, F	ME	r	-	+	-	-	+
Echinops spinosus	He	G	IT	c		+			
Pulicaria crispa (Forssk.) Oliva	Ch	P, E, F	PAN	c	+	+	+	+	-
Verbesina encelioide (Cav.) Booth.& Hookfil ex. A. Grays	Th	G	PAN	c	-	-	-	-	-
Boraginaceae									
Heliotropium arbianese Fresen	Ch	E	SA	c	+	-	-	+	+
Brassicaceae									
Farsetia aegyptia Turra	Ch	G	SU	c	+	+			
Morettia parviflora Boiss.	Ch	E	SU	c	+	+		+	
Capparaceae									
Maerua crassifolia Forssk.	Ph	G	SA	c	-	+	+	+	+
Caryophyllaceae									
Minuartia hybrida (Vill.) Schisch.	Th	E	Pluri	r					
Polycarpaea repens (Forssk.) Asch. & Schweinf.	He	F, G	SU	c		-			
Chenopodiaceae									
Salsola imbricata Forssk.	Ch	E, F	SA+SU	r	-	+	-	+	+
Salsola kali L.	Th	A, B, C	Pluri	c	+	+	-	+	+
Salsola spinescens Moq.	Ch	E, G	SA+SU	c	-	+	-	+	-
Cucurbitaceae									
Citrullus colocynthis (L.) Schard.	He	E, F, G	SA	c	+	+	+	-	-
Cupressaceae									
Juniperus procera Hochst. ex Endl.	Ph	A	COSM	c	+	+	-	+	+
Euphorbiaceae									
Chrozophora oblingifolia (Del.) Spreng.	Ch	E, G	SU	c	+	+	-	+	-
Euphorbia granulata Forssk.	Th	E, F, G	SA+SU	c	+	-	-	-	+
Pergularia temenusa L.	Ch	E	SU	c	+	+	-	+	+
Fabaceae									
Acacia gerradii Rech f.	Ph	A, B, C, G	SA	c	+	+	-	+	+
Acacia tortilis (Forssk.) Hayne	Ph	E, F, G	SU	c	+	+	-	+	+
Indigofera spinosa Forssk.	Ch	E, F, G	TR	c	+	+	+	+	+
Senna italica Mill.	Ch	E, F, G	SU	c	+	+	+	+	+
Geraniaceae									
Erodium laciniatum (Cav.) Willd.	Th	E, F, G	ME	r	+	+	-	-	+
Lamiaceae									
Lavandula pubescens Decne	Th	B	SA+SU	r	+	+	+	-	+
Nyctaginaceae									
*Commicarpu*s *stenocarpus* (Chiov.) Cuf.	Ch	G	IT	c					
Commicarpus ambiguus R. D. Meikle	Th	C	SU	cc					
*Commicarpus sinuatu*s Meikle	Ch	A	SU	cc					
Palmae									
Phoenix dactylfera L.	Ph	B, C, E, G	Pluri	cc	+	+	+	+	+
Papaveraceae									
Argemone ochroleuca Sweet.	Th	B, E, G, F	TR	cc	+	-	-	-	+
Poaceae									
Cenchrus ciliaris L.	Ch	C	Pluri	c	+	+	-	-	-
Centropodia forsskalii (Vahl.) Cope	Ch	G	Pluri	c	-	+	-	-	-

Species	LF.	VG	Chorotype	Abundance	Uses				
					Me	Gr	Ed	Fu	O
Cynodon dactylon (L.) Pers.	Gh	A, B, C, D, E, F, G	COSM	c	+	+	-	-	-
Panicum turgidum Forssk	Gh	E	ME+SU+IT	c	+	+	+	+	-
Themeda triandra Forssk.	Gh	A	COSM	c	-	+	-	+	-
Portulacaceae									
Portulaca oleracea L	Th	B	Pluri	c	+	+	+	-	+
Resedaceae									
Ochradenus baccatus Del.	Ch	C, G	SA+SU	c	+	+	-	-	-
Solanaceae									
Datura innoxia Mill.	Ch	G	Pluri	r	+	-	+	+	-
Solanum incanum L.	Ch	B, E, G	SU	c	+	+	-	+	+
Solanum nigrum L.	Th	D	ME	c	+	+	+	+	-
Solanum schimperianum Hochst. ex A. Rich.	Ch	G	ME	c	+	+	+	+	-
Withania somnifera (L.) Dunal	Ch	A, C	IT+ME+TR	c	+	+	+	+	+
Tiliaceae									
Corchorus depressus (L) stocks	Ch	E, F, G	SA+IT	c	+	-	-	-	-
Urticaceae									
Forsskaolea tenacissima L.	Ch	B, C, E, G	SA+SU	c	-	-	-	-	-
Zygophyllaceae									
*Fagonia schweinfurthi*a Hadidi	Ch	E, G	SA+SU	c	+	-	-	-	-
*Fagonia indic*a Bunn.	Ch	B, E, F, G	SA+SU	c	+	-	-	+	-
*Peganum harmal*a L.	Ch	B, E, F, G	Pluri	c	+	+	+	+	+
Tribulus terrstris L.	Th	B	Pluri	c	+	+	+	-	-

Table 3. *Characteristics of 7 vegetation groups derived after the application of TWINSPA. The groups are named as follows: A: Themeda triandra group, B: Cynodon dactylon, C: Commicarpus ambiguous, D: Amaranthus viridis, E: Acacia tortilis, F: Argemone ochraleuca, G: Verbesina encelioides groups.*

Veg.	location				habitat				
	Al-Seil Road	Baha Road	Riyadh Road	Al-Hada	wadi beds	Mountain Slopes	Sand flats	Depression spot	High altitude
A				100					100
B			25	75				25	75
C				100					100
D				100					100
E	75	5	21		52	11	16	21	
F		33	67				33	67	
G		100			71		28		

Table 3. *Continued.*

Veg.	First	P	Second	P
A	*Themeda triandra*	100	*Withania sominifera*	100
B	*Cynodon dactylon*	100	*Acacia gerradii*	50
C	*Commicarpus ambiguus*	75	*Cynodon dactylon*	75
D	*Amaranthus viridis*	100	*Solanum nigrum*	100
E	*Acacia tortilis*	96	*Indigofera spinosa*	80
F	*Argemone ochraleuca*	100	*Acacia tortilis*	100
G	*Verbesina encelioides*	100	*Indigofera spinosa*	64

Table 4. *Mean ± standard deviation of the soil characters in relation to vegetation groups identified after application of TWINSPAN to associated species with Calotropis procera population in the study area. The vegetation groups are: A: Themeda triandra group, B: Cynodon dactylon group, C: Commicarpus ambiguus group, D: Amaranthus viridis group, E: Acacia tortilis group, F: Argemone ochraleuca group, and G: Verbesina encelioides group).*: P < 0.05, **: P < 0.01, ***: P <0.001.*

VG	pH	EC	Cl	C	OM	HCO_3	AX1	Ax2
A	7.34±0.11	48.10±1.98	0.01±0.00	1.50±0.16	2.59±0.27	0.03±0.00	595.00±84.85	39.00±55.15
B	7.51±0.27	55.90±36.52	0.01±0.00	2.05±1.47	3.53±2.53	0.04±0.02	379.00±70.71	191.25±79.78
C	7.23±0.14	41.93±6.69	0.01±0.00	1.45±0.37	2.50±0.65	0.03±0.00	443.25±14.64	33.50±17.71
D	7.43±.0.00	48.00±.0.00	0.01±.0.00	1.43±.0.00	2.47±.0.00	0.02±.0.00	522.00±.0.00	404.00±.0.00
E	7.58±0.20	138.88±288.97	0.01±0.03	1.16±1.05	1.99±1.81	0.04±0.01	110.75±55.51	208.84±19.93
F	7.74±0.17	138.00±66.90	0.01±0.00	2.59±1.84	4.46±3.18	0.05±0.01	180.67±20.67	213.33±17.53
G	7.52±0.12	101.11±64.26	0.01±0.00	2.18±2.37	3.75±4.09	0.04±0.01	197.50±32.69	270.79±25.74
Total mean	7.55±0.20	118.53±225.10	0.01±0.02	1.54±1.49	2.65±2.57	0.04±0.01	182.97±131.67	208.55±66.18

Table 5. *Mean ± standard deviation of the soil characters in relation to altitudes and habitat of Calotropis procera population in the study area. *: P < 0.05, **: P < 0.01, ***: P <0.001.*

Variable		pH	EC	Cl (%)	C (%)	OM (%)	HCO_3	AX1	Ax2
Altitudes	<1300	7.54±0.20	71.18±39.76	0.01±0.00	0.66±0.23	1.14±0.39	0.03±0.01	88.30±40.10	215.03±14.11
	1300-1500	7.55±0.15	94.78±57.92	0.01±0.00	1.84±2.17	3.17±3.75	0.04±0.01	190.17±33.40	258.33±33.59
	1500-1700	7.74±0.11	314.96±477.14	0.03±0.05	3.29±0.93	5.67±1.60	0.06±0.01	192.57±47.25	189.00±28.49
	>1700	7.33±0.17	42.49±5.90	0.01±0.00	1.42±0.30	2.45±0.52	0.03±0.00	469.00±86.60	124.90±136.10
Total mean		7.55±0.20	118.53±225.10	0.01±0.02	1.54±1.49	2.65±2.57	0.04±0.01	182.97±131.67	208.55±66.18
F-value		11.63***	5.26**	4.71**	17.62***	17.62***	47.6***	158.22***	14.15***
Habitat	Wadi beds	7.53±0.19	85.62±57.87	0.01±0.00	1.28±1.70	2.21±2.93	0.03±0.01	121.67±69.27	233.18±30.21
	Mountain Slopes	7.57±0.06	65.50±7.64	0.01±0.00	0.74±0.39	1.28±0.67	0.04±0.01	108.40±53.56	206.80±22.62
	Sand flats	7.59±0.20	69.39±16.21	0.01±0.00	0.69±0.28	1.20±0.48	0.04±0.01	136.92±43.47	232.08±33.00
	Depression spot	7.74±0.11	314.96±477.14	0.03±0.05	3.29±0.93	5.67±1.60	0.06±0.01	192.57±47.25	189.00±28.49
	High altitude	7.33±0.17	42.49±5.90	0.01±0.00	1.42±0.30	2.45±0.52	0.03±0.00	469.00±86.60	124.90±136.10
Total mean		7.55±0.20	118.53±225.10	0.01±0.02	1.54±1.49	2.65±2.57	0.04±0.01	182.97±131.67	208.55±66.18
F-value		9.13***	3.9**	3.5*	9.51***	9.51***	33.1***	61.5***	8.1***

4. Discussion

From the biodiversity viewpoint, the present study can conclude that this area seems to be the richest area of the kingdom taking into account its relatively small area comparing with the area of kingdom (it represent about 0.05% of the total area of kingdom). One of the main characteristics of the vegetation cover of Saudi Arabia is its low floristic diversity. The number of plant species that recorded in the country is 2172 species, many of which are in the wetter areas of its south-western part. Which include Sarrawat mountains these species belong to 840 genera and 149 families 47]. The number of species increased to 2250 by adding subspecies, extinct and species that have not been identified yet [28]. Numbers of families, genera, and species are very low compared to Saudi Arabia's vast land area, which is probably, the result of the harsh environmental conditions that prevail in the Saharo-Arabian region which covers vast area of the country. The greatest plant diversity, approximately 74% of the total plant species of Saudi Arabia, is found in the mountainous western area which include the study area due mainly to a greater rainfall [48]. The recorded species associated with *Calotropis procera* in the present study (55 species) is too low as compared with that associated with *Juniperus spp.* [49]. This mean that this species may be produce allellopathic components to the associated species.

It is evident that the families Fabaceae, Poaceae, Solanaceae have the highest contributions to the total flora (9.1%of the total species), followed by the Asteraceae and Zugophyllaceae (7.3%). These results similar to the whole flora of Saudi Arabia where the highest families in the Whole flora are Poaceae (262 species = 12.1%), Asteraceae (233 species = 10.7%), and Fabaceaee (210 species= 9.7%) which represented by 705 species or 32.5% of the total plant species in the Kingdom. Also, similar trend to the flora of other similar studied region in the kingdom such as Mosallam [50] on his comparative study on the vegetation of protected and non-protected areas, Sudera, Taif, Saudi Arabia (Table 6); Abdel Fattah and Ali [51] on the study of vegetation-environment relations in Taif, Saudi Arabia; Al-Turki [52] on his study of the flora of Jabal Fayfa in the south western Saudi Arabia; Al-Turki and Al-Olayan [53] on the study of flora of Hail region; Al-Zahrani [54] on his study on the vegetation and ecosystem of Bani Saad mountains, south [of Taif city. As in most tropical and subtropical deserts, the most plant species of Saudi Arabia belong to a limited number of plant families, for example, 1586 species belong to 23 families or 15.4% of the total families. These plant species represent 73% of the total species in the Kingdom [48]. 46 families or 30% of the families in the country such as *Aloaceae*, *Celastraceae, Commelinacea*e, and *Burseraceae* are found only in Sarrawat mountains [47].

Table 6. *The comparison between some floristic variables in the present study and the previous studies.*

Floristic Variables	The present study	Al-Sodany *et al.* (2014)	Mosallam (2007)	Al-Turki (2004)	Al-Turki & Al-Olayan (2003)	Al-Zahrani (2003)	Collenette (1999)
Recorded Species	55	191	234	537	338	75	2172
Perennials	41	133	123	340	149	53	-
Annuals	14	56	111	197	189	22	-
Families	27	56	57	85	61	27	149
Genera	48	145	168		221	65	840
Asteraceae	7.3	14.1	9.4	8.6	18.6	20.0	10.7
Poaceae	9.1	7.9	15.8	8.8	9.8	6.7	12.1
Fabaceae %	9.1	6.3	5.6	9.5	5.9	12.0	9.7
Solanaceae	9.1	5.8	3.0	2.1	1.5	6.7	1.5

An outstanding feature of floristic composition of the flora of the study area is that about half of the families are of importance floristically. Among 27 families, 16 families or 61.5% of the total number of families are represented by one species per family (Examples: Acanthaceae, Aizoaceae, Apocynaceae, Asparagaceae, Cucurbitaceae, Cupressaceae, Lamiaceae and Papaveraceae). Two families, or 7.7% of the total number of families are represented by two species per family. Comparing to the whole flora of Saudi Arabia where among 149 families, 68 families or 45.6% of the total number of families are represented by single genus per family. 36 families, or 24.2% of the total number of families, are represented by one species per family. The number of genera appears to be very high compared to the number of species. This is a common feature of desert flora. It is an indication that only a few of the large number of species that belong to these old plant families have adapted and survived in this harsh environment. Other species that could not survive have become extinct [48].

The life form spectrum indicated that chamaephytes were the most represented followed by therophytes. These results agree with that of Heneidy and Bidak [55] on Bisha, Asir region in southwestern of Saudi Arabia, El-Demerdash *et al*. [56] in the southern region and El-Yasi [49] in his study on *Juniperus* spp. the same study area. They concluded that the dominance of chamaephytes and therophytes over other life forms in that region would seem to be the hot dry climate, topography variations and biotic influence. Also, Chamaephyte life form is able to withstand water logging, high salinity levels and a wide range of temperature variability [57, 58]. On the other hand, the results of the present study disagree with other studies in the same region [50] which indicated that therophytes had the highest contribution. This may be due to the sampling in the present study was during season in which many annuals are dead. Moreover, he indicated that the loss of chamaephytes was due to overgrazing in that area.

From the phyto-geographical viewpoint, the present study indicated that the Sudano-Zambezian elements (10 species) are the most represented chorotype, followed by the Saharo-Arabian elements (6 species), while the other elements had a minor representation. This trend is similar to that of Al-Sodany *et al*. [59] in the same study area. Comparing with the other related studies, Al-Nafie [48] reported 180 species in the flora of Saudi Arabia are belongs to Saharo-Arabian Region and 88 ones to Sudanian Region. Unfortunately, the boundaries of these two regions in Saudi Arabia are still debatable, ill-defined and very difficult to delimit. The delimitation of the frontier between the two regions in the Arabian Peninsula in its southern part has always created some difficulties for a few bio-geographers as well as phyto-geographers who have studied the region. These difficulties arise from the fact that the southern parts of the Saharo-Arabian region are occupied by very dry, hot and vegetationless deserts such as Al Rub Al- Khali, as well as the much more vegetated sand dunes of the Dahna and the Great Nafud. Zohary [60] suggested that these deserts could support Sudanian species as a result of their hot climate, but are too dry to support such vegetation. In addition, many of the Saharo-Arabian elements are derived and developed from the neighboring regions, mainly the Sudanian region in the south, and the Mediterranean and Irano-Turanian regions in the north and north-west, respectively they are developed gradually but discontinuously under the increase of aridity since the Middle Miocene, which is believed to be a transitional period climatically between the humid early Tertiary and the arid Late Tertiary and Quaternary environments [61]. The most dominant Sudano-Zambezian elements are *Pergularia temenus*a, *Commicarpus ambiguous, Morettia parviflora, Farsetia aegyptia, Polycarpaea repens, Senna italiaca, Acacia tortilis, Solanum incanum, Chrozophora oblingifolia,* and *Commicarpus sinuatu*s. while the Saharo-Arabian elements in the flora of study area include: *Maerua crassifolia, Heliotropium arbianese, Rhazya stricta, Acacia gerradii, Blepharis ciliaris*and *Citrullus colocynthis*, On the other hand the Saharo-Arabian and Sudanian elements are: *Euphorbia granulat, Salsola imbricate, Lavandula pubescens, Salsola spinescen, Ochradenus baccatus, Forsskaolea tenacissima, Corchorus depress*) , *Fagonia indica* and *Fagonia schweinfurthi*a.

On the other hand, the present study recorded 16 species are Pluriregional, three of them are cosmopolitan species. According to Al-Nafie [48], Pluriregional species that grow in many regions and widely spread all over the world such as: Himalayan Mountain, Deccan plateau, Canary Islands, Namib desert, and South Africa are represented in the Saudi Arabian flora. The presence of these plant species from different regions is an indication on the relationship between the Arabian Peninsula and these regions. Some of these species might reached the Arabian Peninsula as a result of the climatic changes which the world witnessed a long time ago, or as a result of the distribution by human and animals specially birds which carry seeds for a long distances. Examples found in the present study include: *Amaranthus viridis, Aizoon canariense, Phoenix dactylifera, Cenchrus ciliaris, Centropodia forskalii, Tribulus terrstris, Portulaca oleracea, Peganum harmala* and *Datura innoxia*.

It has to be mentioned that the activities of few research projects have been implemented in the area of the Kingdom. Little work has been done in Taif region. Consequently little data is available about the medicinal plants and their status as natural resources for potential use by local inhabitants in this region [62]. About eighty seven percent of the total recorded species by the present study have at least one aspect of the potential or actual economic uses. Thirty nine species (70.9% of total recorded species) are medicinal, 38 species (69.1% of total recorded species) are grazing, 16 species (29.1% of total recorded species) are edible by man, 30 species (54.5% of total recorded species) used as fuel and 22 species (40.0% of total recorded species) used as other economic uses. So, the economic uses of the recorded species could be arranged descendingly as follows: grazing → medicinal→fuel → other uses→human food. This trend similar to that recorded by Heneidy and Bidak [55] in Bisha, Asir region who recorded 75% as medicinal, 83% as grazing, 17% as edible by human and animals, 40% as fuel wood and 72% of them as other uses; and El-Yasi [49] who indicated that one hundred twenty-three species (64.4%) are medicinal, 139 species (72.4%) are grazing, 54 species (28.3%) are edible by man, 92 species (48.2%) used as fuel and 130 species (68.1%) used as other economic uses. However, there is a shortage of information about the multipurpose uses of natural species. Many substances that we use in our daily lives are plant products, although there are a lot of uses of plant species still unknown. Numerous medicines, many industrial products are derived of plant products. Most of all are edible plant products that form the food base of human culture (Heneidy and Bidak) [55]. On the other hand, Mossa *et al*. [39] recorded 149 plant species as a medicinal plants in the Saudi Arabia. Generally, the various activities have different impacts as (e.g. telecom, crop expansion, overgrazing, overcutting). There are direct and indirect causes for ecosystem degradation and species impoverishment in the study area. The direct causes are related to mainly to the ways in which man has used and misused the natural resources since its early history. More recent, land use activities are even more devastating. Evaluation of the effects of the environmental factors threatening the wild life should be taken in consideration. So it is important to construct a representative reserve (protected natural areas) for conservation of the natural.

The application of TWINSPAN on the cover estimates of 55 species recorded in 75 stands during the study period, led to the recognition of 18 groups at the 6th level of classification and 7 vegetation groups (communities) at 4th level associated with *Calotropis procera*. These vegetation groups (communities) are: A: *Themeda triandra* group, B: *Cynodon dactylon* group, C: *Commicarpus ambiguus* group, D: *Amaranthus viridis* group, E: *Acacia tortilis* group, F: *Argemone ochraleuca* group, and G: *Verbesina encelioides* group). This groups are totally different with that associated with *Juniperus* spp. in the same study area [49] who indicated that three of the vegetation groups (communities) are associated with *Juniperus phoenicea* (*Capparis spinosa* group, *Colchicum schimperi* group, and *Juniperus procera* group), and four vegetation groups associated with *Juniperus procera (Lavandula dentata* group, *Lavandula dentata-Juniperus phoenicea* group, *Psiadia punctulata* group, and *Solanum incanum* group) and to that were described by Abdel Fattah and Ali [51] and Mosallam [50] in the Taif region. This may due to the differences in habitat types with El-yasi [49] that carried out in high altitudes; and the methods of identification of plant communities in other both studies.

On the other hand, a complete differences between plant communities recognized by the present study and other related studies in the other areas of the kingdom ([63-67]). They concluded that, on the Asir highlands (above 2500 m) discontinuous plant communities exist on discrete habitat types. This appears to represent slope and exposure effects at the high elevation. In contrast, the transitional range between 500–2500 m is characterized by continuity in vegetation change from one altitudinal belt to the next, with broad transitional areas and overlap between low and high altitude vegetation. Similar results and observations were described by Kassas [68] in Sudan, Vesey-Fitzgerald [69] in Saudi Arabia, Kassas [70] in Egypt, Beals [71] in Ethiopia, Brooks and Mandil [72] in Saudi Arabia and Ghazanfar [73] in Oman. Moreover, Moustafa [74] in St. Catherin (Sinai Peninsula area) found that the organization of community types or associations is the net result of the behavior of species in response to environmental conditions. Ayyad *et al.,* [75] in Sinai Peninsula recorded that the extent of species replacement or biotic change between different land forms reveals that the high values between habitats may reflect rapid and ecologically significant change and may also reflect the large extent of biotic change of different habitats.

The present study suggested that this plant may naturalized in all habitats in the kingdom of Saudi Arabia and will effect on the vegetation of these habitats. This may be due to the fact that *Calotropis* has (a) a large number of small seeds capable of wind-dispersal and speedy germination-juvenile traits (b) a strong competitive ability and (c) a large size (see results) - adult traits. Shipley *et al*. [76] argued that the concept of r-K strategists predisposes an association between juvenile and adult traits. In Grime's C-S-R ordination triangle of plant strategies (1977) this association between juvenile and adult traits is not found. Rather than conforming to a set type of life-history strategy, the results in the present investigation may describe *Calotropis* as (a) a perennial (b) a stress-tolerant ruderal [77, 78] and (c) a weed.

On the other hand, the observation during the present study indicated that *Calotropis procera* had little grows at high altitudes and grow well in the urban habitats with high human impact. The fact that reduction in growth in high altitude of *C. procera* plants, could be due to the effects of severity of drought or the sensitivity of *C. procera* plants to wet conditions. Growth rates observed in plants grown under moderate water stress were nearly two-fold and three-fold higher than the growth rates of plants grown under severe water conditions and wet conditions, respectively [6]. However, Altaf [79] indicated that *Calotropis procera* can be a useful botanical monitor of pollution. The variations found in the concentrations of Br, Mn, Se, Cr and Zn between urban and suburban samples suggests that the plant has a good potential for the determination of these elements when it is exposed to them from any source. Br, Mn and Zn concentrations in the plant were found greater in the urban area than in controls which emphasizes the assumption that they are resulting from traffic pollution.

In desert environments, the plant's reaction to the different sort of stresses might be worth studying for itself, as the mechanisms behind stress tolerance are not fully understood [80]. On the hand, the results of such studies are vital for extending the range of cultivation of economically important plants, such the medicinal plant *C. procera*. Because no detailed studies on the ecology of *C. procera* have been conducted, a study of this type is needed to enhance the conservation efforts for this plant species [6]. In contrast to crop plants, growth of desert plants under controlled conditions is less understood. For example, most studies on *Calotropis procera* are focusing on the pharmacological and medical aspects. Studies of this type are very limited. Due to the importance of *C. procera* in medicine, pharmacology and desert environment, further studies on effects of different climate conditions on growth performance and other physiological and biochemical aspects are encouraged. The climate conditions that need to be investigated might include drought, heat and salinity. Such studies will help in understanding the favorable growth conditions of this plant species, for regeneration and to preserve soils with less plant cover in semi-arid and arid conditions, where the plant is subjected to deterioration by number of means, such as harsh growing conditions and grazing. The preliminary results presented in this study suggest that *C. procera* grows better under moderate water availability conditions due to human impact.

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