Developing a Virtual Flora Portal for Vascular Plants of Saudi Arabia

by

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ABSTRACT

A floristic analysis is essential to understanding the current diversity and structure of community associations of plants in a region. Also, a region's floristic analysis is key not only to investigating their geographical origin(s) but is necessary to their management and protection as a reservoir of greater biodiversity. With an area of 2,250,000 square kilometers, the country of Saudi Arabia covers almost four-fifths of the Arabian Peninsula. Efforts to document information on the flora of Saudi Arabia began in the 1700s and have resulted in several comprehensive publications over the last 25 years. There is no doubt that these studies have helped both the community of scientific researchers as well as the public to gain knowledge about the number of species, types of plants, and their distribution in Saudi Arabia. However, there has been no effort to use digital technology to make the data contained in various Saudi herbarium collections easily accessible online for research and teaching purposes. This research project aims to develop a "virtual flora" portal for the vascular plants of Saudi Arabia. Based on SEINet and the Symbiota software used to power it, a preliminary website portal was established to begin an effort to make information of Saudi Arabia's flora available on the world-wide web. Data comprising a total of 12,834 specimens representing 175 families were acquired from different organizations and used to create a database for the designed website. After analyzing the data, the Fabaceae family ("legumes") was identified as a largest family and chosen for further analysis. This study contributes to help scientific researchers, government workers and the general public to have easy, unlimited access to the plant information for a variety of purposes.

DEDICATION

To My Father and Mother

To My Husband

To My Son Meshari

To My Coming Baby

To My Brothers and Sisters

To My Country, Saudi Arabia

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CHAPTER 1

INTRODUCTION

A floristic analysis is essential to understanding the current diversity and structure of community associations of plants in a region. Also, a region's floristic analysis is key not only to investigating their geographical origin(s) but is necessary to their management and protection as a reservoir of greater biodiversity (Allahdou et al. 2012). According to the Oxford Dictionary a flora is defined as "The plants of a particular region, habitat, or geological period".

In Saudi Arabia, efforts to document the information of the plant flora have resulted in several publications over the last 25 years (Mandaville 1990; Mighaid 1996; Chaudhary 1999, 2000, 2001; Rahman et al., 2004; Thomas et al., 2014). There is no doubt that these studies have helped both the community of scientific researchers as well as the public to gain knowledge about the number of species, types of plants, and their distribution in Saudi Arabia. However, there has been no publication that describes the use of digital technology to make the data contained in herbarium collections easily accessible online for research and teaching purposes; thus, with this technology, scientific researchers, government workers and the general public can have easy, unlimited access to this information for a variety of purposes.

AIM AND OBJECTIVES

This research project aims to develop a "virtual flora" portal for the vascular plants of Saudi Arabia. The following objectives were set up in order to achieve the study's aim:

1. Perform a literature review to highlight the efforts that identify the flora in Saudi Arabia and other countries of the greater Arabian Peninsula. This objective will be discussed in **CHAPTER 1**
2. Review the literature to identify the relevant publications in other countries that have the same scope of this study, which is the development of a virtual flora. This objective will be discussed in **CHAPTER 2**
3. Develop a virtual flora portal for the vascular plants of Saudi Arabia. This objective will be discussed in **CHAPTER 2**
4. Identify and collect data from different resources and use it to populate database that supports the portal. This objective will be discussed in **CHAPTER 2**
5. Select specimen data obtained for the Leguminosae (or Fabaceae) family and analyze it as a case study for this project. This objective will be discussed in **Chapter 3**

LITERATURE REVIEW

The country of Saudi Arabia covers most of the Arabian Peninsula. With an area of 2,250,000 square kilometers, it covers almost four-fifths of the Peninsula (Chaudhary 2001). The landscape comprises many rocky and sandy deserts throughout the central and eastern areas of the country and valleys, with mountains along the western side adjoining the Red Sea. The central part of the country has an elevation range from 200 to 1000 m above sea level, whereas the west and southwest areas are the highest in Saudi Arabia with the elevation reaching up to 3000 m or more (Figure 1). The western

part of the Peninsula is covered with mountain ranges varying in width from 10 to 40 km. The higher peaks in the north reach up to 2700 meters in elevation while the highest point in Saudi Arabia is a mountain in the south, Jabal Soodah in the Asir mountain range, that reaches 3050 m above sea level (Chaudhary 2001).

The temperate zone of Saudi Arabia is mostly found to be arid to semi-arid with warm to hot temperatures that remain for the major part of the year. Most areas have low humidity except for the coastal areas where it reaches over 90%. The average annual temperature is 33.4°C in summer time and 14°C in winter; however, there is a wide difference in the temperatures of different areas. For example, the temperatures inland ranges from less than 0°C at night time to a high of 50°C throughout the summer time. There are very high temperatures in the summertime in the northern part of Saudi Arabia particularly in July. The southeast region has highest temperatures in June and coldest in January (Juneidi and Huss 1978). The average annual rainfall within the north-western part of Saudi Arabia varies from 30 mm to 90 mm, whereas rainfall data for the middle part of Saudi Arabia, in particular in the area of the capital city Riyadh, indicate that average annual rainfall decreases from north to south and from west to east, averaging from 85 to 100 mm. The southwestern region has the highest average annual rainfall according to Almazroui et al (2012). As it is shown in Figure 1, about 30% of the Arabian Peninsula is covered with sand in the form of sand-seas, with the three major bodies of sand the Great Nafud in the north, the Empty Quarter in the south and rather crescent-shaped body of sand known as Dahna connecting the two former bodies of sand. About 33% of the country consists of high sand dunes creating sand deserts.

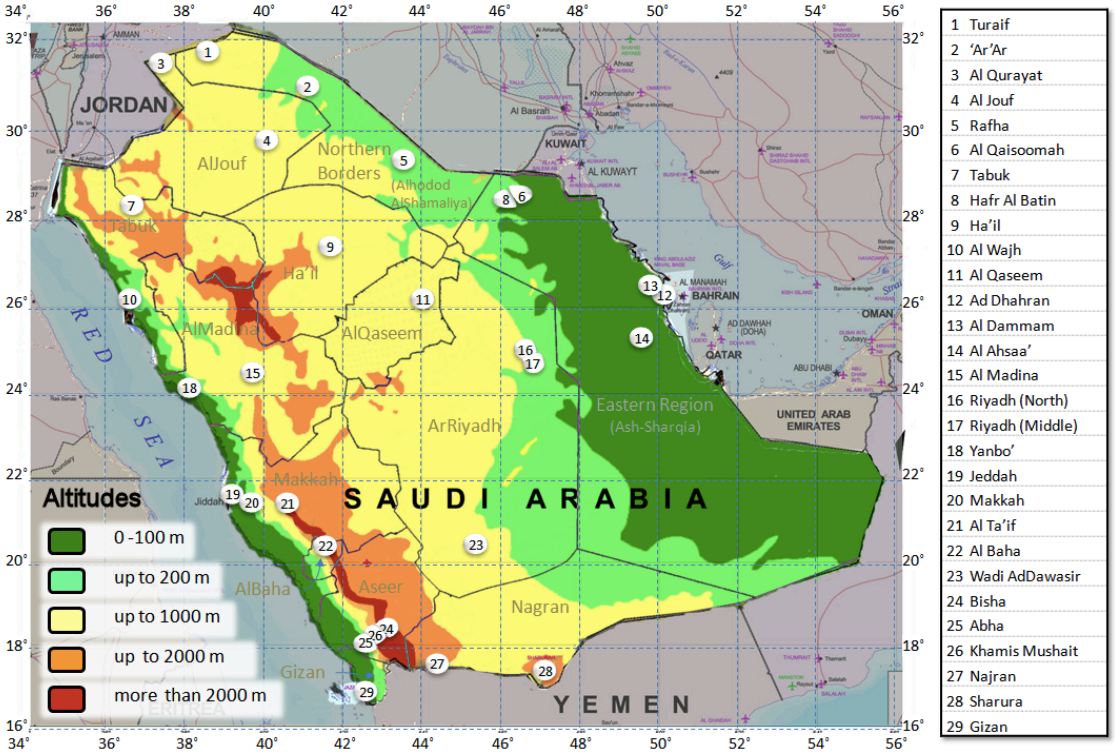

Figure 1. Geographic map of Saudi Arabia (from Elnesr and Alazba 2013).

These are highly unstable as strong winds can shift the sands most of the time. The soil found in the country is rather young having a lack of pedogenic development because of less moisture and continual renewal of the surface by erosion or deposition. The eastern and western coasts have narrow strips of beaches containing sandy soils that stay wet depending on the tidal sweeps and a high water table (Chaudhary 2000).

The Flora of Saudi Arabia

The first detailed written accounts of an entire flora were done by European botanists such as Robert Morison's *Historiae* [1680-1699], Leonard Plukenet's *Phytographia* [1691-1705], and John Ray's *Historia Plantarum* [1686 -1704]. Fredrick Pursh's Flora *Americae Septentrionalis* (1814) was the first attempt to describe the flora for continental North America. A more comprehensive flora of North America was initiated by John Torrey and Asa Gray who published their detailed account of the flora of the area beginning in the 1830s. Several botanists published more regional floras after that, until 1905 when N. L. Britton began publishing the monographic series North American Flora at the New York Botanical Garden (Morin & Spellenberg 2008).

Since then, in developed and developing countries, various floristic studies have continued to be carried out to discover and document the kinds and diversity of species of plants in specific regions (e.g., Kearney and Peebles 1960; Rahman et al. 2004; Kamelin 2007; Angelo and Boufford 2011; Baldwin et al. 2012; Thomas et al. 2014; Badry et al. 2015, Ghazanfar & McDaniel, 2016). In the Middle East, numerous floras have been published since the middle of the 20th century (Migahid and Hammouda, 1974; Mandaville 1990; Al-Turki, 1997; Chaudhary 1999). Ghazanfar & McDaniel (2016) published a study of the flora of Iraq and compared it to that of several other Middle Eastern countries, including Saudi Arabia. Their findings showed that the floras of Turkey and Iran are considered to be the richest in the number of species, with nearly two to three times the number of plant species identified in other Middle Eastern countries (Table 1). For example, according to Ghazanfar & McDaniel (2016), the flora of Iraq is

rich and diverse with about 3300 species. The first efforts to identify the flora of Iraq began in 1966 (Guest and Ali al-Rawi 1966) as a collaborative project between the Ministry of Agriculture in Baghdad and the Royal Botanic Gardens, Kew, England. Between 1966 and 1985, nine volumes were planned and six were published. About 908 genera belonging to 136 families were identified in Iraq. Asteraceae is considered as the largest family with more than 400 species (50 monotypic genera), followed by Fabaceae (393 spp.), Poaceae (264 spp., 35 monotypic genera), Brassicaceae (195 spp., 30 monotypic genera) and Apiaceae (155 spp.). For comparison to a similar, a desert region in North America, Kearney and Peebles (1960) documented the flora of the state of Arizona (USA). Their efforts identified 132 families, 907 genera, and 3370 species. The 10 largest families are as follows: Compositae (543 spp.), Gramineae (369 spp.), Leguminoseae (287 spp.), Scrophulariaceae (112 spp.), Cruciferae (105 spp.), Cyperaceae (100 spp.), Polygonaceae (94 spp.), Euphorbiaceae (84 spp.), Cactaceae (71 spp.), Rosaceae (69 spp.).

Table 1. Approximate number of plant taxa in the countries of the Middle East and the status of their Floras (from Ghazanfar & McDaniel, 2016).

Country	No. of Taxa	Cited Reference(s)
Turkey	9753	Davis (ed.) Fl. Turk., Vols 1–9 (1965– 1985) – complete; Güner et al. (2012; checklist)
Iran	7300	Rechinger (ed.) Fl. Iranica (1963– 2012) – incomplete (see Akhani, 2006)
Syria	3500	Post, Fl. Syria, Palestine & Sinai, Vols 1 & 2 (1932, 1933) – complete but outdated
Iraq	3220	Townsend & Guest (eds) Fl. Iraq (1966– 1985); Ghazanfar & Edmondson (2013)
Yemen	2838	Wood, Fl. Yemen (1997) – complete but not for S Yemen; Al-Khulaidi (2013 – checklist)
Palestine (incl. Israel and eastern Jordan)	2700	Zohary, Fl. Palaestina Vols 1–4 (1966, 1972, 1986)
Lebanon (incl. Syria)	2606	Mouterde (1970)
Jordan	2521	No Flora – incomplete
Saudi Arabia	2281	Chaudhary, Fl. Saudi Arabia Vols 1–3 (1999, 2001) – complete; Mandaville (1990)
Egypt	2145	Boulos , Fl. Egypt Vols 1–4 (1999, 2000, 2002, 2005) & checklist (2009)
Oman	1211	Ghazanfar, Fl. Oman Vols 1–3 (2003, 2007, 2015)
United Arab Emirates	650	Western (1989); Jongbloed (2003); Karim & Fawzi, Fl. United Arab Emirates (2007) – complete
Kuwait	407	Daoud & Al-Rawi, Fl. Kuwait Vol. 1 (1985); Al-Rawi, Vol. 2 (1987) – complete but outdated
Qatar	270	Batanouny, Fl. Qatar (1981); Norton et al. (2009 – checklist); Abdel-Bari (2012) – complete
Bahrain	250	Phillips (1988); Cornes & Cornes, Wild Flow. Pl. Bahrain (1989) –

The flora of the Kingdom of Saudi Arabia, like many countries in the Middle East, shares many species with the East African countries and the Afromontane region to the west, the Mediterranean and Irano-Turanian region in the north and northeast, eastern Iran, Pakistan and India in the southeast, and southern Arabia including Socotra in the south (Chaudhary 2001). The study of plants has been going on in this country for many centuries along with their uses. According to Chaudhary (1999), studies of the flora originally started in 1762 on the Arabian Peninsula by a Swedish explorer, Peter Forsskal, who after studying plants in Egypt and the natural history of Yemen started his plant exploration in Saudi Arabia. His work was published in 1775. Forsskal's work, the first one to be done on this land, was based on modern western (European) science and made use of the Latin binomial nomenclature system created by Carl Linneaus in his *Systema Naturae* (1735).

The second botanist to explore the flora of Saudi Arabia was Ehrenberg in 1825 (sixty years after Forsskal) after which, in 1836, Kotschy and Schimper started their work in the western parts of the country (Chaudhary 1999). There were many other botanists after these who visited this country in the 19th century like Botta in 1839, Anderson in 1859, Pelley in 1865, Balfour in 1880, Schweinfurth in 1888, and Ben, Bornmueller and Deflers in 1893. The 20th century included even more botanists' visits such as Musil in 1909 and Wissman 1927 (Chaudhary 1999). A major contribution was provided by Athelbert Blatter, who published his *Flora Arabica* in six volumes (1919 – 1933) in which he claimed that it had all the plants that could be found in the country.

This book contains data regarding all the native names for plants found in Arabia and Persia even in their regional dialect variants.

Development of the modern knowledge of the plants of Saudi Arabia dates to the 1960s. The major collections from Saudi Arabia seem to have really started with Mandaville (1964), De Marco (1966-67) and Migahid (1966), who published subsequent editions of the *Flora of Saudi Arabia* in 1974, 1978, and 1988. Another comprehensive study of the flora was published by Chaudhary (*Flora of the Kingdom of the Saudi Arabia*), beginning with the first volume in 1999 followed by subsequent volumes in 2000 and 2001. Other publications include one written by Collentette (1999) with the names of 2,250 species, from these, 600 are rare and endangered and 242 are endemic, and illustrations of flowers of Saudi Arabia as well as more regional floras of the Kingdom. These books (published by Chaudhary, Migahid, and Collentette) are now used in education at schools and universities and cited by many researchers. After that, several studies have been published to identify the flora of Saudi Arabia in different provinces such as:

- In the northern region, especially in Hail province, a total of 124 species representing 34 families were recorded. The family Asteraceae is represented by the highest number of species (21 spp.) followed by the Poaceae (17 spp.) and the Brassicaceae (10 spp.) whereas 15 families including Acanthaceae, Convolvulaceae, Moraceae, Nyctaginaceae and Primulaceae, are represented by a single species each (El-Ghanim et al 2010).

- In central region, especially in Riyadh province, Al-Khamis et al. (2012) also conducted a study to identify the perennial plant diversity in the Ibex Reserve, located at the middle of Saudi Arabia, about 180 km south from the city of Riyadh. The study resulted in the identification of six major plant communities. *Haloxylon salicornicum* community was the major plant community followed by the *Rhazya stricta, Ziziphus nummularia*, *Acacia tortilis*, *Rhanterium epapposum*, and *Calotropis prosera* communities, respectively. In addition, Alatar et al. (2012) conducted a study to explore the plants in the Wadi Al-Jufair, near to the city of Riyadh, which identified 157 species, belonging to 133 genera in 40 families. The most represented families found in Wadi Al-Jufair are Poaceae and Asteraceae. "Therophytes" (plants that complete their life cycle in a short period of time and survive harsh conditions as seeds) constituted 81 species (51%) of the total followed by "chamaephytes" (shrubby plants whose buds are on or near the ground) with species (21%) and perennial herbs 31 species (18%). In Qassim province, a checklist was published by Al-Turki (1997), which included 450 species of flowering plants, both wild and cultivated, from 257 genera and 62 families. The systematic list consists of two species of gymnosperms, 362 species of dicotyledons and 86 of monocotyledons. Moreover, El Ghazali et al. (2013) conducted a study to document the weed flora of Qassim region. A total number of 105 weed species were found and Poaceae (21%) was found to be the most dominant family in the area, followed by Asteraceae (13%) and Brassicaceae (12%).

- In the southern region of the country, Al Wadie (2002) identified the flora of Wadi Talha. The study recorded 30 species of vascular plants belonging to 17 families. Chamaephytes constitute 43.3% of the floristic composition followed by phanerophytes at 26.6% and therophytes at 20.1%.
- In the Taif district of the western region, 26 legume species were recorded in the study by Fadl et al. (2015). The study found that *Acacia* was the most common genus with nine species followed by *Astragalus* with four species whereas *Medicago* and *Indigofera* have two species each. Another study in western region by Alsherif et al. (2012) identified 251 plant species belonging to 160 genera and 50 families. The major plant families that contributed to the vegetation of the area in question were Poaceae (42 spp.) followed by Euphorbiaceae and Asteraceae (18 and 15 spp., respectively), while 18 families were represented by only one species. Therophytes exhibited the maximum number of species (41.2%), followed by chasmophytes (31.4%), hemicryptophytes (herbaceous perennials,13.7%) and phanerophytes (perennials with perenniating buds borne above the ground surface, 10%), while the least frequent life form class was geophytes (plants with underground storage organs). The floristic list of the studied area showed 96 spp. with economical importance, 66 spp. used as fodder, 24 spp. as medical and six edible species. Moreover, in 2014 a flora of the city of Mecca was published by Al-Eisawi and Al-Ruzayza. The results identified 184 species. belonging to 44 families and 125 genera. The study identified nine new rare species to the flora of Saudi Arabia which include *Tribulus arabicus* H.

Hosni*, Atriplex farinose* Forssk*., Cyperus rotundus* Benth*., Datura innoxia* Mill*, Emex spinosus* L*., Heliotropium crispum* Desf*., Kohautia caespitosa* Schnizl*., Launaea nudicaulis* (L.) Hook. f*., and Plantago ciliate* Desf. The largest family in Mecca according to the study is Poaceae with 31 spp. (17%) followed by Fabaceae with 22 spp. (13%)

- In the eastern region, a study was published by Mandaville (1990) with the aim of documenting the eastern flora of Saudi Arabia. Table 2 shows the top eight families in the eastern region, which account for over 60% of the total numbers of the species.

Moreover, research on medically relevant species was conducted by Rahman et al. (2003), who showed there were 254 such species in seven families: Solanaceae, Labiatae, Polygonaceae, Amaranthaceae, Apocynaceae, Capparidaceae and Euphorbiaceae. Additional research conducted upon these families revealed that 86 of the 254 medicinal species are being used by the tribal and local citizens. The medicinal healers make use of them to cure nearly 150 ailments. Also the rare plantswas identified in this study. The rare plants include *Euphorbia arabica* Hochst. and Steud. ex Anders., *Euphorbia dracunculoides* Lam., *Carissa edulis* Vahl, *Nerium oleander* L., *Cadaba farinose* Forssk., *Cleome arabica* L., Cleome *brachycarpa* Vahl ex DC., *Cleome chrysantha*Decne., *Acalypha indica* L., *Chrozophora plicata* (Vahl) A. Juss., *Clutia lanceolata* Forssk., *Achyranthes aspera* L., *Amaranthus caudatus* L., *Celosia trigyna* L. and *Adenium arabicum* Balf. *f.*

Table 2. Most diverse families in the Eastern region of Saudi Arabia (Mandaville, 1990)

Name	Number of Genera and Species
Gramineae	(52 genera, 91 spp.)
Compositae	(43 genera, 66 spp.)
Leguminosae	(22 genera, 50 spp.)
Cruciferae	(30 genera, 46 spp.)
Chenopodiaceae	(20 genera, 42 spp.)
Caryophyllaceae	(15 genera, 22 spp.)
Zygophyllaceae	(6 genera, 15 spp.)
Boraginaceae	(8 genera, 14 spp.)

Figure 2. Physical map showing major deserts in Saudi Arabia. (From Ezilon.com - Physical Map of Saudi Arabia)

Similar studies have been conducted to explore the plants in the deserts of Saudi Arabia. As shown in Figure 2, the biggest deserts in the world, the An-Nafud, Ad-Dahna and the Empty Quarter (Rub' al Khali), are found in Saudi Arabia. The Empty Quarter covers most of the southern third of the Arabian Peninsula and is the biggest sand desert in the adjacent area (Vincent 2008). The northern area of Saudi Arabia is taken by the Great Nafud (or An-Nafud), which is linked to the Empty Quarter or Al Rub Al-Khali by the Ad Dahna Desert. The extreme desert conditions can be seen in the central parts of the country having limestone plateaus, mountain ranges, volcanic areas, valleys, shallow

sand covered rocky areas, and alluvial deposits. In short, the central parts of the country are mainly covered by three kinds of steppe vegetation: *Rhanterium* steppe, *Haloxylon salicornicum* steppe and *Salsola* steppe (Chaudhary 2001).

The Red Sea and the Arabian Gulf, or Persian Gulf, form the coastal areas of the country in which the shallow sea beds are full of sea-grass communities consisting of the marine flowering plants *Cymodocea* spp. and *Enhalus acoroides* (L.f.) Royle. The east coast includes the Farasan Islands which are covered with *Avicennia marina* (Forssk.) Vierh. and *Rhizophora mucronata* Lam. while the mangroves on the east coast have only *Avicennia marina*. The western coast along the Red Sea is occupied by the mangroves communities. There are plenty of broad *Acacia commiphora* woodlands and *Acacia* forests having different composition and density due to moisture and soil characteristics on the western coastal plains, as well as the southern and the northern Tihamas and intermountain plains. *Acacia tortilis* (Forssk.), the most common of the *Acacia* species (Chaudhary 2001), has recently been reclassified as *Vachellia tortilis* (Forssk.) Galasso & Banfi.

A number of endemics and endangered species are recorded in the flora of Saudi Arabia. Recently, a group of researchers identified the endemics and endangered species in the different regions in the country (Thomas et al. 2017). According to their study most of the endemics and endangered species were found in the southwestern and southern regions, especially on Shada Mountain, the Faifa Mountains, and the Raydah Escarpment (Table 3).

Recent efforts to make information about the Saudi flora available electronically on the (http://www.plantdiversityofsaudiarabia.info/Biodiversity-Saudi-Arabia/Flora/Flora.htm) have been initiated by Jacob Thomas at the King Saud University herbarium in Riyadh. Thomas' website contains a wealth of information on the plant diversity in different regions in Saudi Arabia, which makes it easy for researchers and other people to find knowledge about the plant diversity in the country. The website also contains information about the topography of each region as well as providing a list of poisonous and weedy species. Images of many species are provided, but detailed descriptions of their geographic distributions are not provided.

Table 3. A comparison of the diversity of endemics and endangered species among different hotspots in Saudi Arabia. From Thomas et al. (2017).

Regions/Hotspot		Area Total (km2)	Total species	Endemics (%)	Endangered species (%)
Southwestern and southern regions	Jabal Shada	68.62	495	60 (12 %)	66 (13.4%)
	Jabal Fayfa	120	537	15 (2.8%)	56 (10.4%)
	Raydah Escarpments	9.33	519	18 (3.4%)	53 (10.2%)
	Southern Tihama (Tihamat Asir	24,000	360	7 (1.9%)	16 (4.4%)
	Island flora (Red Sea Islands)	5408	202	2 (0.9%)	14 (6.9%)
Northwestern and northern regions	Harrat Al-Harra	13,775	218	4 (1.8%)	18 (8.3%)
	Wadi Dessah	160,000	160	4 (2.5%)	21 (13.1%)
	Northern Tihama (Tihamat Al-Hejaz)	10,000	258	4 (1.6%)	6 (2.3%)
Central region	Raudhat Khuraim	45	153	-	4 (2.6%)
	Jabal Aja & Salma	2000	285	4 (1.4%)	18 (6.3%)
	Raudhat Ibex Reserve, Howtha Bani Tamim	1840.9	263	5 (1.9%)	6 (2.3%)
Eastern region	Island flora (Arabian Gulf)	145	85	-	-

According to present estimates, based on Thomas' website (http://plantdiversityofsaudiarabia.info/), Saudi Arabia contains a total of 2282 species, of which 97 are trees (4.25%), 565 are shrubs (24.73%) and about 1,620 are herbaceous (71.02%). The southwestern mountainous regions are densely vegetated, and contain the greatest diversity with about 70% of the flora's species reported from this region. The most species-rich families in the Saudi Arabian flora are (Thomas 2011):

- Poaceae (269 spp.)
- Asteraceae (246 spp.)
- Fabaceae (217 spp.)
- Brassicaceae (87 spp.)
- Caryophyllaceae (74 spp.)
- Lamiaceae (72 spp.)
- Chenopodiaceae (71 spp.)
- Euphorbiaceae (67 spp.)
- Scrophulariaceae (64 spp.)
- Asclepiadaceae (62 spp.)

Overall, the above studies have contributed to our understanding of the flora of Saudi Arabia. Several families such as Poaceae, Fabaceae, and Asteraceae are considered as major families in terms of number of species that are represented in the flora of Saudi Arabia, and are among the most diverse families in many of the countries in the region.

Also, it is clearly seen that according to the literature review, the existing knowledge on the flora of Saudi Arabia is limited to discover a new flora species in different regions. As shown in Figure 3, between 1960 and 2001, extensive studies were conducted by Chundary Migahed, and Collentette who help to identify most of the existing species in the flora and their publications are now used as a benchmark for the flora of Saudi Arabia and used in research and education. Like many other countries, the future of the flora of Saud Arabia should go forward to digitize herbarium records in Saudi Arabia so the flora may be accessible to all. Thus, this thesis presents a virtual flora scheme to align with the global trend. The next chapter will introduce how to develop a virtual flora for Saudi Arabia.

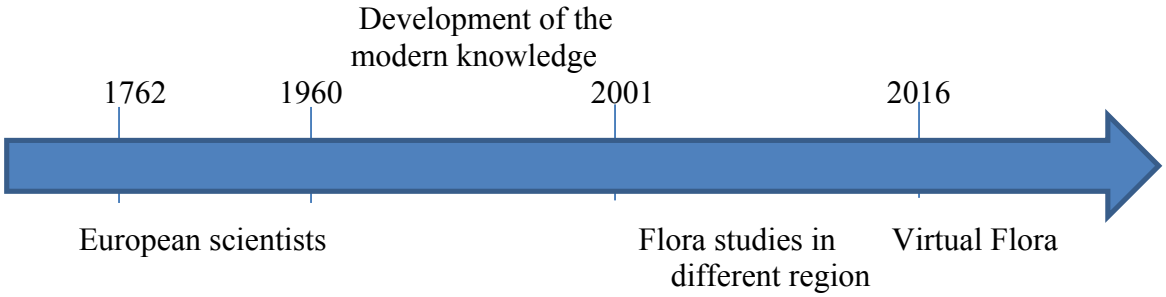

Figure 3: The time line of the floristic studies in Saudi Arabia

CHAPTER 2

LITERATURE REVIEW

Information technology has advanced dramatically in recent years and various approaches have been developed to maximize our access to digital data. In the context of floristic studies, a *virtual herbarium* (a herbarium-based database) is defined by Rao (2012) as "an information system that provides access to data on plant diversity of one or more regions, or on the collection that the herbarium has in its care." There are many organizations that have successfully administered the system of digitizing their herbarium records such as the Consortium of California Herbaria [http://ucjeps.berkeley.edu/consortium/], Utah Valley State College Digital Herbarium [http://herbarium.uvu.edu/virtual/], Herbarium Catalogue of the Royal Botanic Gardens (RBG) [http://apps.kew.org/herbcat/gotoHomePage.do], Plant Database, Northern Ontario [http://www.northernontarioflora.ca/], New York Botanical Garden's International Plant Science Centre [https://www.nybg.org/?gclid=COnQt7T27dUCFQ6dfgodHNkG8w], the SEINet data portal for Arizona and the southwestern United States [http://swbiodiversity.org/seinet/] etc. These websites and digital databases are designed to not only serve and distribute data, but are also used for web-based management of the data (Gries et al. 2004; Schmidt 2007; Thiers 2016). The updated Global Strategy for Plant Conservation (GSPC) of the U.N. Convention on Biological Diversity in 2010 (https://www.cbd.int/gspc/targets.shtml), proposed to create an online flora for all plant specimens as its first target (Target 1). After this initiative, in January 2012 in St Louis,

Missouri, U.S.A., representatives from four institutions, the Missouri Botanical Garden, the New York Botanical Garden, the Royal Botanic Garden, Edinburgh, and the Royal Botanic Gardens, Kew (all members of the Global Partnership for Plant Conservation - GPPC) held a meeting to talk about ways to achieve GSPC Target 1 by 2020. The results of the meeting produced an outline of the scope and content of a World Flora Online along with the content to create an international consortium of institutions and organizations to give the required data by working together (Loizeau & ackson 2017).

Currently, there are numerous efforts being made in different countries to digitize their collections in order to increase the usefulness of the data. For example, the digitization of herbarium specimens at NYBG was determined in the 1990 strategic plan to be an institutional priority. By January 2016, NYBG had nearly 2.5 million specimen records in the Virtual Herbarium database, out of which 1.4 million are included along with an image of the specimen. The largest number of digitized specimens come from the area of the United States of America (900,000 specimens) followed by Brazil and then the Caribbean Region. Of these, the geographic coordinates have been recorded for nearly 861,500 specimens. Type specimens in the database, along with their images, have increased to nearly 150,000 (Thiers et al. 2016).

As another example, the production of a ‘virtual herbarium’ for the state-wide collection of flowering plants in the JCB Herbarium housed at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore was described by Rao et al. (2012). There is a total of about 4,000 flowering plant species in the total plant taxonomic data in the ‘Herbarium JCB’ website [http://florakarnataka.ces.iisc.ac.in/hjcb2/]. This website

was created through standard open-source software on the Linux operating system, including the web server Apache, a MySQL data-base system, and a scripting language, the PHP.

Developing A Virtual Flora Portal for Saudi Flora

The aim of this project is to create a virtual flora as a new source of information and set of tools for the Saudi community, both public and scientific, to enable them to access the herbaria records and related data in Saudi Arabia easily on-line. In addition, students in schools and universities in Saudi Arabia would benefit from such on-line databases and tools when used in courses on the flora of Saudi Arabia.

Saudi Arabia has a good collection of specimens maintained and distributed in several herbaria. According to the New York Botanical Garden Index Herbariorum, there are six herbaria in the country, two at King Saud University (KSUP and KSU), King Abdulaziz City for Science and Technology (MUZ), National Agriculture and Water Research Center (RIY), King Faisal University (KFUH), and Jazan University (JAZUH). Among these herbaria, the first herbarium established in Saudi |Arabia was KSU herbarium in 1965. The total number of plant specimens in this herbarium is more than 25,000. For the other herbaria, the only information found was the number of specimens at each herbarium. The total number of specimens in MUZ is about 25,000, whereas KSUP contain 10,000 specimens. The largest number of specimens was found in the herbarium located in National Agriculture and Water Research Center (RIY), with

specimens about 40,000. The fewest number of specimens are found in JAZUH, with 2,000, and KFUH herbaria, which contain 1,500 specimens.

As mentioned earlier a virtual flora is an interactive, web-based 'encyclopedia' for plant species information, nomenclature, geographic distribution and related biodiversity applications. The current digital efforts often use different methods and means which are better suited for the community that built them for managing collections, digitizing specimens, providing on-line access to the records, or supporting large-scale analyses have been developed for different uses ; for example, Arctos (http://arctosdb.org/), KE Emu (http://emu.kesoftware.com/), SilverBiology (http://www.silverbiology.com/), Specify (http://specifysoftware.org/), or VertNet (http://vertnet.org/) (Gries et al. 2014). One such widely used program is Symbiota (Gries et al. 2014) that can be used to provide portals for biodiversity data has been adopted by different societies and consortia such as SEINet. Societies that may have certain similarities or common goals like taxonomy may work together to achieve better results for digitizing floras and faunas in various areas of the world. To satisfy the needs of such societies, the program Symbiota is a very suitable choice because it can offer a biodiversity information platform that can be configured, customized, and independently managed by the different research communities (Smith et al. 2011).

The long term goal of this project, development of a virtual flora of Saudi Arabia, will be based on the Symbiota software platform with online search engines and tools, to enable the exploration, management, and networking of biodiversity data (http://symbiota.org), and will be set up on computer servers at Arizona State University,

just like the SEINet is. Symbiota is designed to be exclusively web-based and employs a novel data model, information linking, and algorithms to provide highly dynamic customization. Initially the Saudi Arabian flora portal will be in English but the plan is to also develop a parallel Arabic language version of the web interface of it as well. To this end, I have begun to develop a website to be used for the virtual flora of Saudi Arabia, under the guidance and with the assistance of Mr. Edward Gilbert and Dr. Martin Wojciechowski at ASU. **The first phase** in developing a virtual flora portal for Saudi Arabia was to establish a new Symbiota portal website. The portal was given the name "Saudi Arabia Virtual Flora Project" (SAVF Project) and images of some of the local Arabian plants were used to illustrate the home page (Fig. 4). The following steps were undertaken:

- Install Symbiota software from GitHub code repository
    - Symbiota documentation: http://symbiota.org/docs/
    - Code repository: https://github.com/Symbiota/Symbiota
    - Instructions for installing software: http://symbiota.org/docs/symbiota-introduction/establishing-a-regional-flora-or-fauna/
- Build database schema
- Modify Symbiota configuration files
    - Web site header graphics
    - Text and content for main index page
    - Modify header menu
    - DB connection file
    - symbini.php central configuration file

Figure 4. The temporary home page for the Saudi Arabian Virtual Flora Project website (URL: http://hasbrouck.asu.edu/saudiarabia/portal/index.php).

The second phase in this project was to collect electronic collection data on the flora of Saudi Arabia and upload it to the website to create a database of specimen information. In order to achieve the primary goal of this project, which is development of a virtual flora of Saudi Arabia with the existing or most of the existing electronic specimen collection data, the collaborations with Saudi Arabian herbaria are needed. I have tried repeatedly to contact several herbaria in Saudi Arabia by emails, phone calls

and visit to their centers. However, I could not achieve the primary goal of this project because I was not able to gain access to their data, despite repeated attempts at communications with people in Saudi Arabia like Dr. Jacob Thomas to collaborate on this project, and attempts to visit him at the KSU herbarium. Dr. Thomas was only willing to provide 1,000 specimen records from a database of more than 25,000 that is exists in KSU herbarium. The reasons behind this reluctant is not known, but it might due to cultural issues. According to Schmidt (2007), some issues may have to be considered when creating digital collection such as cultural issues; centers and institutions may have different cultural characteristics in terms of ownership of the data, copyright issues, the impact of cost and time constraints. Because of this it was decided that the project would shift to a different goal and that was to analyze the data from the 12,834 specimen records that I had access to and had been incorporated into the SAVF database.

Initially, a list of plant species known from Saudi Arabia was obtained from a website on the Saudi Arabian flora created by Dr. Jacob Thomas, a researcher at the KSU Herbarium at King Saud University in Riyadh (http://www.plantdiversityofsaudiarabia.info/Biodiversity-Saudi-Arabia/Flora/Checklist/Cheklist.htm). With the help of Mr. Gilbert, electronic herbarium collection records of Saudi Arabian species housed in a number of European herbaria were downloaded and used to create and initially populate our database of collection records. Four datasets were identified from the Global Biodiversity Information Facility (http://www.gbif.org/) and included the Missouri Botanical Garden (MO), Museo Nacional de Historia Natural (MNHN), Naturalis Biodiversity Center (NL) - Botany

Leiden (L), Royal Botanic Garden Edinburgh (E). In addition to these collections, the SEINet database (Consortium of US Herbaria) and King Saud University (KSU) were checked for any electronic collection data of Saudi Arabian species. The checklist of names was first verified through the Taxonomic Name Resolution Service (TNRS) http://tnrs.iplantcollaborative.org/ and then linked voucher specimens from occurrence projects to taxon names within checklists http://hasbrouck.asu.edu/saudiarabia/portal/checklists/checklist.php?cl=1. The Prime taxon profile page has the following data:

- Field and specimen images from SEINet
- Species descriptions harvested from SEINet (FNA, Delta World grasses, etc)
  http://hasbrouck.asu.edu/saudiarabia/portal/taxa/index.php?taxauthid=1&taxon=3096&cl=1
  http://hasbrouck.asu.edu/saudiarabia/portal/taxa/index.php?taxauthid=1&taxon=1678&cl=1
- Populated links to Encyclopedia Of Life for each taxon
- Field images harvested from EOL (http://eol.org)

The Harvested taxonomic character data from SEINet to be used within the interactive keys[http://hasbrouck.asu.edu/saudiarabia/portal/ident/key.php?cl=1&proj=&dynclid=0&taxon=All+Species].

CHAPTER 3

RESULTS AND DISCUSSION

Data Collection

The search for collections data of the flora of Saudi Arabia revealed that several organizations maintain specimen collection records of Saudi Arabian species. As mentioned earlier, there are six herbaria in Saudi Arabia. Of these, I was able to obtain only about 1,000 collection records from Dr. Jacob Thomas at KSU. In addition, data from five other different organizations, including the Missouri Botanical Garden (MO), Museo Nacional de Historia Natural (MNHN), Royal Botanic Garden Edinburgh (E-E), SEINet Consortium of US Herbaria (SEINet), and Naturalis Biodiversity Center (NL) Botany Leiden (L), were obtained. The total number of records (12,834) of specimen collection data for Saudi Arabian species from these organizations that we have been able to obtain is presented in Table 4. The collected data is useful as most of the records provide important information such as scientific name of species and family, collection location, date of collection, name and collection number of collector. This specimen data were then used to populate the SAVF database as it is shown in Table 5. On the other hand, some of the specimens either lack specific information or have no information for specimen's location, collector, or the date of collection.

The first step in the analysis process was to determine the number of families found in the collection records database. As it is shown in Figure 5, of the 175 plant families represented in the database, about 80% of the families are angiosperms whereas

only four families are gymnosperms, nine families are ferns and nine families are mosses. The largest and rarest 20 families are listed in Table 6 and Table 7, with the Fabaceae (or Leguminosae, "legumes") having the greatest number of specimens of the identified families (1175). This doesn't necessarily mean that the Fabaceae is the largest, in terms of numbers of species or the most widely distributed family in the flora of Saudi Arabia, since the data is limited to only 12,834 specimens in the database. However, several studies have also determined that Fabaceae is one of the most species rich families in Saudi Arabia (Al-Eisawi and Al-Ruzayza 2015; Thomas et al. 2017).

Table 4. Sources of collection records of species from the flora of Saudi Arabia used in this study.

Name of source	# of specimens
King Saud University (KSU)	994
Missouri Botanical Garden (MO)	847
Museo Nacional de Historia Natural (MNHN)	578
Royal Botanic Garden Edinburgh (E)	7,663
SEINet Consortium of US Herbaria (SEINet)	347
Naturalis Biodiversity Center (NL), Botany Leiden (L)	2,405
Total	12,834

Table 5. Overall information on the SAVF Project database.

Statistics on collection records in SAVF database	**Number**
Total collection records in database	12,834
Total Fabaceae or Leguminosae specimens	1,220
Fabaceae specimens located in Saudi Arabia	1,175
Species of Fabaceae represented	214
Specimens georeferenced	856

Table 6. Largest 20 plant families represented in the SAVF Project database.

Family	Number of Specimens
Fabaceae /Leguminosae	1,220
Asteraceae	1,098
Poaceae	1,067
Lamiaceae	516
Caryophyllaceae	484
Euphorbiaceae	443
Brassicaceae	434
Solanaceae	359
Malvaceae	268
Convolvulaceae	261
Cyperaceae	238
Zygophyllaceae	205
Apocynaceae	201
Apiaceae	183
Plantaginaceae	173
Brassicaceae/Cruciferae	161
Rubiaceae	155
Acanthaceae	150
Geraniaceae	122
Nyctaginaceae	114

Table 7. The rarest 20 plant families represented in the SAVF Project database

Family	Number of Specimens
Viscaceae	1
Vahliaceae	1
Ruppiaceae	1
Podocarpaceae	1
Malpighiaceae	1
Hydnoraceae	1
Cuscutaceae	1
Cruciferae	1
Bignoniaceae	1
Asteliaceae	1
Talinaceae	2
Pinaceae	2
Passifloraceae	2
Ochnaceae	2
Myricaceae	2
Annonaceae	2
Clusiaceae	2
Berberidaceae	2
Cactaceae	2
Velloziaceae	3

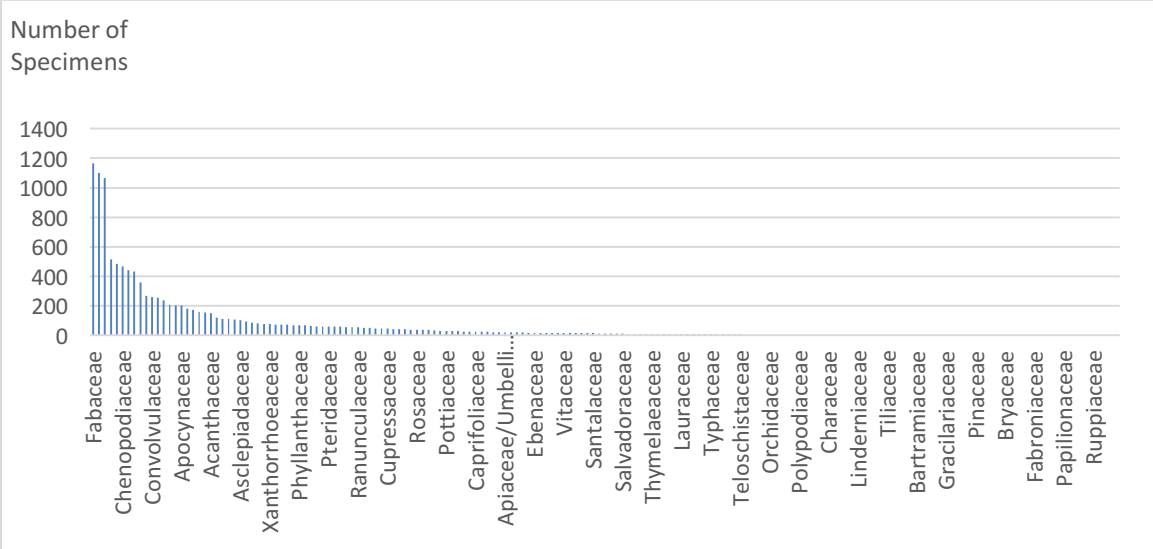

Figure 5: Families represented in the SAVF Project database.

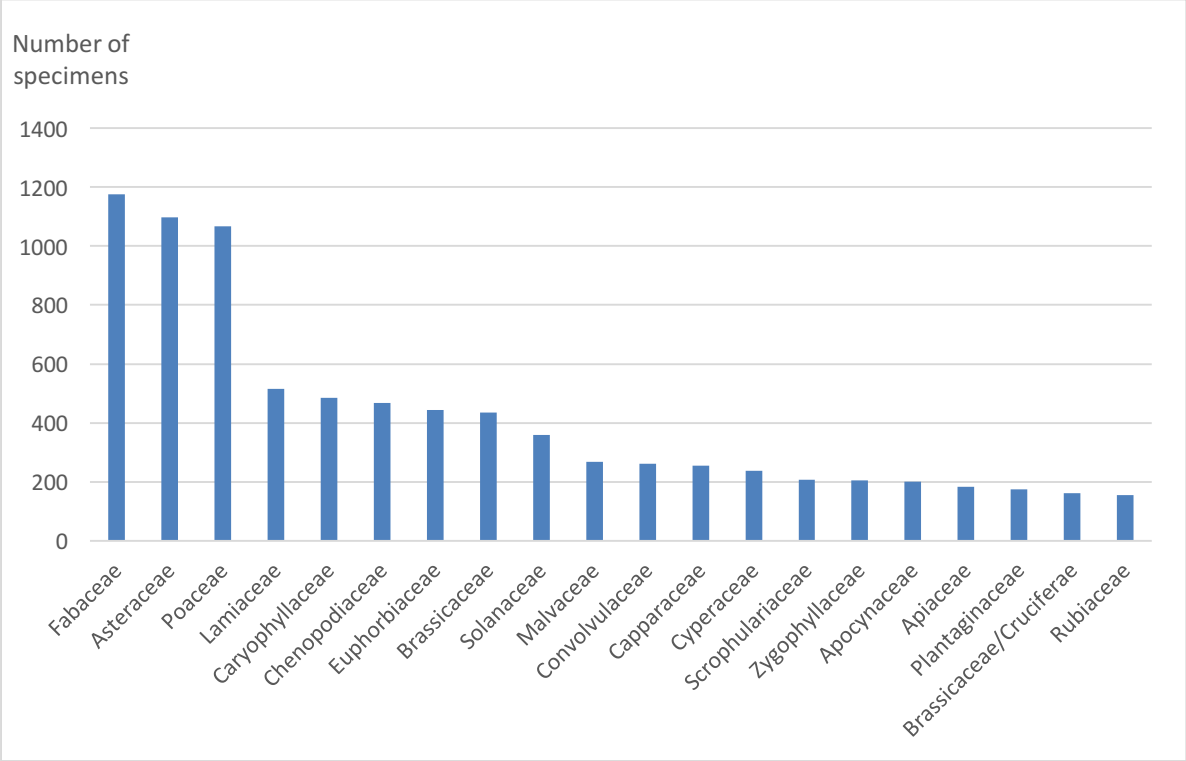

Figure 6: Largest 20 plant families represented in the SAVF Project database.

The specimen data obtained for the Fabaceae family was subsequently selected as a case study for further analysis as part of this project. With this information we were able to ask a number of questions about the species of Fabaceae and their distribution in Saudi Arabia.

First, the specimen collection data was compared with the data presented by Jacob Thomas on his website (http://www.plantdiversityofsaudiarabia.info/Biodiversity-Saudi-Arabia/Flora/Flora.htm). It was found that the majority of the species of Fabaceae identified from Thomas' website (219 spp.), about 156 species are the same as those listed on our list (214 spp.). However, as presented in Figure 7, there are some species that are included in Thomas' list and are not found in our list, and at the same time, there are some species in our list for this study, but are not included in Thomas' list. The total number of species that overlap or are the same in the both lists is 159, and include species such as *Acacia asak* (Forssk.) Willd., *Alhagi graecorum* Medik., *Astragalus annularis* Forssk., and *Indigofera Arabica* Jaub. & Spach. There are 60 species found in Thomas' list, such as *Acacia raddiana* Savi, *Alysicarpus rugosus* Willd., *Astragalus asterias* Steven, and *Indigofera spicata* Forssk., that are not found in our list. On the other hand, there is a total of 55 species that exist on our list but are not found in Thomas' list, such as *Indigofera leptocarpa* Eckl.& Zeyh., *Acacia edgeworthii* T.Anderson , *Acacia horrida* (L.) Willd., and *Hippocrepis ciliate* Willd. There are probably a few reasons why our lists of these species are not identical. First, the differences may due to the lack of accurate synonymy for many of the taxa or the lack of recent updates to the list on the Thomas website.

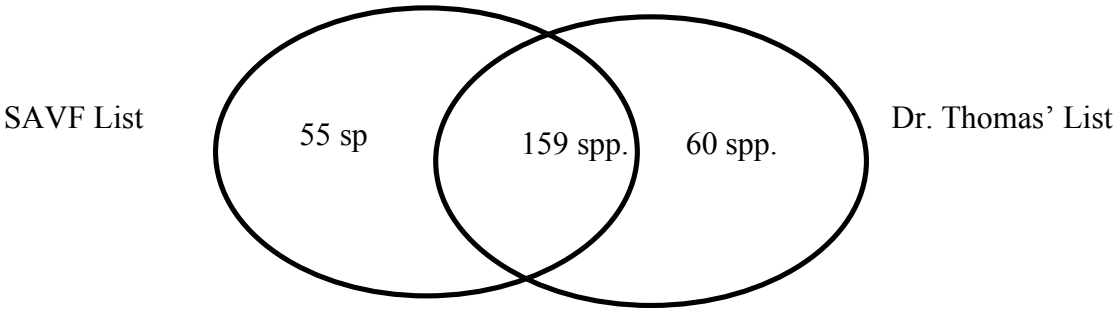

Figure 7. Comparison of Fabaceae species in SAVF database to that compiled by Jacob Thomas on his Saudi Arabian Flora website.

In addition, the timeline for the collection of legume specimens in the SAVF database was analyzed, beginning with the early 1800s and continuing to the present. About 18.6 % of the records (219) have no identified date of collection. As shown in Table 8, the most active collection period was from 1971 to 2000 with a total of 819 specimens.

One of the most important and useful kinds of data that can be obtained from specimen collection records is the geographic location of the collection site. Using the collection location information from the specimens, I was able to determine the geographic coordinates for each geo-referenced specimen on a map of Saudi Arabia. Because there are some specimens, about 309 which either have incomplete information or no information at all regarding their collection location, only 856 specimens in Fabaceae were georeferenced and thus could be located on the map in the website, as shown in Figure 8.

Table 8. Time-line of specimen collections of Fabaceae species in Saudi Arabia based on SAVF project database.

Timeline	Number
Before 1820	15
1819 - 1830	0
1831 - 1840	99
1841-1850	0
1851 - 1860	4
1861 - 1870	0
1871 - 1880	1
1881 - 1890	1
1891 - 1900	1
1901- 1910	4
1911-1920	0
1921-1930	0
1931 - 1940	1
1941- 1950	1
1951 - 1960	2
1961 -1970	3
1971-1980	222
1981- 1990	493
1991- 2000	104
2001 - 2010	2
2011- 2020	3

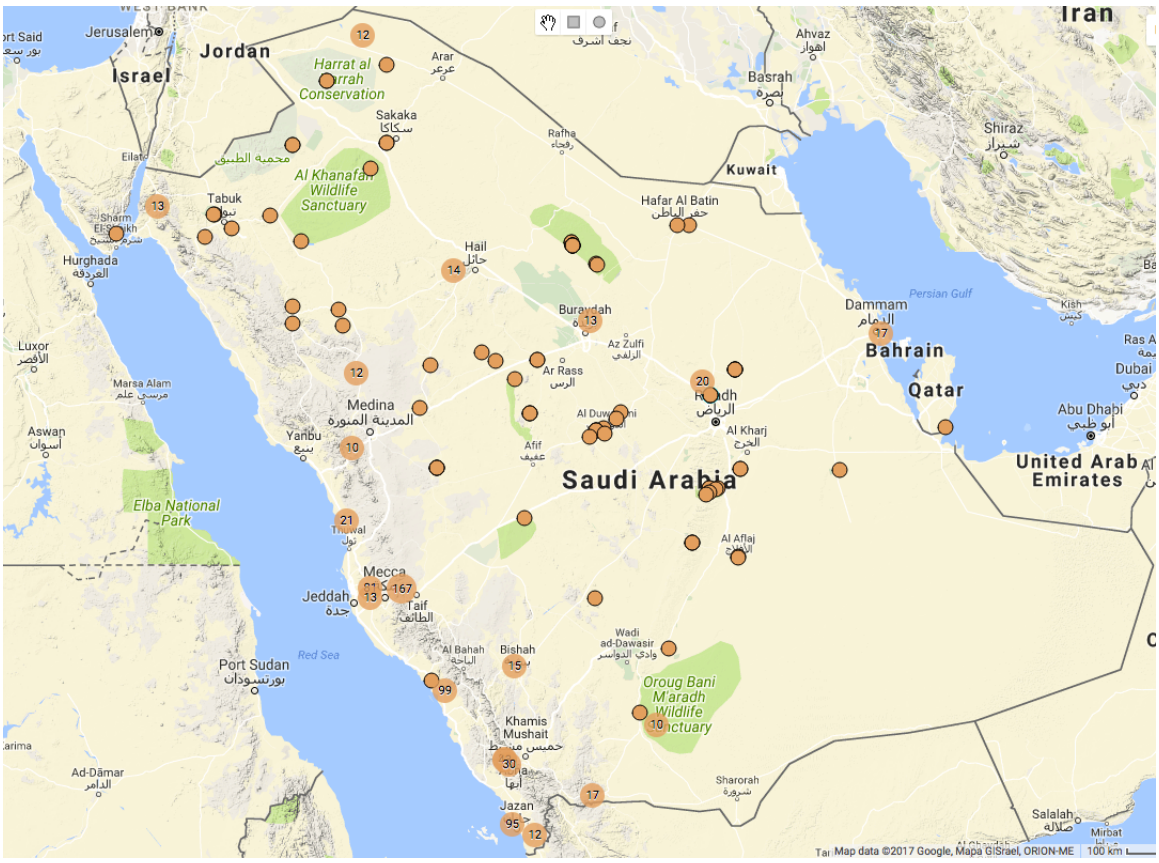

Figure 8: Distribution map of georeferenced Fabaceae specimens in SAVF database.

Additional analyses were undertaken to answer the following questions about the legume flora of Saudi Arabia based upon the SAVF database:

1. What are the largest (species richness) and most widely distributed genera in Fabaceae in Saudi Arabia?
2. Where are these genera localized in Saudi Arabia?
3. What is the most frequently collected species of Fabaceae in Saudi Arabia based on the SAVF Project database?
4. Which region of Saudi Arabia contains the highest number of collected Fabaceae specimens?
5. For each region in Saudi Arabia, what are the three most frequently collected species of Fabaceae?

As is shown in Figure 9, Saudi Arabia consists of 13 provinces and the capital city is Riyadh located in the central region. The analysis of the distribution of Fabaceae family was conducted based on these regions.

To answer the first question, the analysis showed that the most species rich genus distributed in Saudi Arabia is *Acacia* L., with 182 specimens. According to Chaudhary (2001) *Acacia* sensu lato include around 1100 species in which 830 were found in Australia and 120 in Africa, while Lewis et al. (2005) estimate there are at least 1450 species of *Acacia* worldwide with some 1050 alone in Australia. The second most species rich genus is *Astragalus* L. (161 specimens.) followed by *Indigofera* L. (136 specimens.), and *Tephrosia* Pers. (81 specimens.), and *Crotalaria* L. (72 specimens). These findings

agree with other studies conducted on the flora of Saudi Arabia. According to Al-Turki and Al-Olayan (2003), the largest genera identified in Wadi Rimah at the region of Hail are *Acacia* and *Senna* Mill. Also, Al-Eisawi and Al-Ruzayza (2015) reported in their study that the most widely distributed plants in Saudi Arabia are *Aloe*, L. *Caralluma* R. Br., and *Acacia*. In addition, Fadl et al. (2015) conducted a study in the Taif district and determined that *Acacia* was the largest genus in the area followed by *Astragalus.*

Figure 9: Provinces in Saudi Arabia

As it is shown in Table 9, the most frequently collected species of Fabaceae in Saudi Arabia is *Crotalaria microphylla* M. Vahl with (31 specimens) followed by *Lotononis platycarpa* (Viv.) Pic.Serm. (23) *Acacia johnwoodii Boulos* (22) *Indigofera leptocarpa* Eckl. & Zeyh. (22) and *Indigofera spinosa* Forssk. (21), and *Argyrolobium arabicum* (Decne.) Jaub. & Spach (20). About 50% of the specimens of *Crotalaria microphylla* Vahl*., Lotononis platycarpa* (Viv.) Pic.Serm*., Acacia johnwoodii* Boulos*,*

Indigofera leptocarpa Eckl. & Zeyh. , and *Indigofera spinose* Forssk. are collected from the western region of Mecca province, whereas, 50% of *Argyrolobium arabicum* (Decne.)Jaub. & Spach specimens were found in the South region in the provinces of Asir, Albaha, and Nejran. More details on the distribution of the specimens of these and other species are provided in Appendix A. An example of using the website portal to know the location of the specimens on the map for the top three distribution specimens are shown in Figures 10, 11 and 12.

Table 9. Most frequently collected specimens of Fabaceae in Saudi Arabia based upon SAVF project database.

Species	# of specimens	Most frequent collection province
Crotalaria microphylla	31	Mecca
Lotononis platycarpa	23	Mecca
Acacia johnwoodii	22	Mecca
Indigofera leptocarpa	22	Mecca
Indigofera spinosa	21	Mecca
Argyrolobium arabicum	20	Asir
Tephrosia spp.	19	Mecca
Acacia asak	18	Mecca
Astragalus eremophilus	17	Mecca
Tephrosia apollinea	17	Mecca
Acacia ehrenbergiana	15	Mecca
Hippocrepis constricta	15	Mecca
Indigofera hochstetteri	15	Mecca
Tephrosia arabica	14	Mecca
Astragalus atropilosulus	13	Jazan
Astragalus tribuloides	13	Hail

Figure 10. Collection localities for *Crotalaria microphylla*.

Figure 11. Collection localities for *Lotononis platycarpa*.

Figure 12. Collection localities for *Acacia johnwoodii*.

Table 10. Distribution of specimens in SAVF database based on province.

Province	Number of specimens present
Albaha	66 (46 spp.)
Aljouf	4 (4 spp.)
Asir	137 (64 spp.)
Eastern Province	24 (17 spp.)
Hail	29 (21 spp.)
Jazan	122 (62 spp.)
Mecca	299 (97 spp.)
Medina	37 (29 spp.)
Nejran	30 (19 spp.)
Northern Province	17 (11 spp.)
Qassim	14 (12 spp.)
Riyadh	58 (40 spp.)
Tabuk	19 (13 spp.)

The objective of the fourth question was to identify which province(s) has the highest number of legume species. As shown in Table 10, Mecca province, which is located in the western part of the country, is considered the region that has the largest number of species (97) represented by 299 (25.5 %) of the Fabaceae specimens. Several studies have shown similar results (Al-Eisawi & Al-Ruzayza, 2015; Fadl et al 2015).

The second province with the most species was Asir with (64 species, 137 specimens) followed by Jazan (62 species, 122 specimens) and Albaha (46 species, 66 specimens). These three regions have the same topographic characteristics of Mecca. Thus, it is predictable for these regions to contain a high number of species. According to the Thomas website data, most of the Saudi flora is found in the southwestern region due to the climate and topography conditions. After analyzing Fabaceae family distribution,

this study agreed with Thomas finding and showed that most of Fabaceae species are located in southwestern of Saudi Arabia. The province with the fewest legume species was Aljouf, with only 4 species (4 specimens). These numbers have to be taken with a little skepticism because the data are only based on a very limited number of collected specimens in the database (856).

For the last question, the three most frequent species (based on specimen numbers) in each province in Saudi Arabia were identified (Table 11). For the Northern province, the top three species were *Astragalus trachoniticus*, *Astragalus schimperi*, and *Medicago laciniata*. This finding agrees with the study done by Osman et al. (2014) who recorded that 13 species out of 29 species of *Astragalus* identified in Saudi Arabia are located in the northern region. In addition, in the provinces of Aljouf and Tabuk located in the northern region of Saudi Arabia, *Astragalus* spp. are commonly identified in these areas. This finding is similar to that reported by Thomas et al. (2013) who stated that most of the Astragalus species are exist in the northern provinces (Tabuk and Al-Jouf).

In Riyadh province, the central region, the top three species identified are *Astragalus sieberi* DC., *Astragalus bombycinus* Boiss., and *Astragalus corrugatus* Bertol.. These species are also reported in Thomas data website as a common species that are exist in central region. Riyadh region characterised by sands and many valleys. Also, there are many Raudhatus (Meadow), which the *Astragalus* species can be found in these areas. Another reason why the *Astragalus* species are common in Riyadh is that there are a high number of population of people live in this region and they use *Astragalus* for medicine.

Table 11. The three most commonly collected species in each of the provinces according to the SAVF database

Location	Three most frequently collected species in each province		
	First	Second	Third
Riyadh	*Astragalus sieberi*	*Astragalus bombycinus*	*Astragalus corrugatus*
Mecca	*Crotalaria microphylla*	*Lotononis platycarpa*	*Acacia johnwoodii*
Medina	*Acacia etbaica*	*Acacia tortilis subsp. raddiana*	*Tephrosia purpurea*
Asir	*Dorycnopsis abyssinica*	*Argyrolobium arabicum*	*Medicago lupulina*
Jazan	*Acacia johnwoodii*	*Acacia ehrenbergiana*	*Crotalaria incana*
Alqassim	*Trigonella hamosa*	*Lotononis platycarpa*	*Onobrychis ptolemaica*
Albaha	*Lotus quinatus*	*Faidherbia albida*	*Acacia asak*
Nejran	*Alhagi maurorum*	*Lotus quinatus*	*Astragalus sieberi*
Hail	*Acacia pachyceras var. najdensis*	*Astragalus tribuloides*	*Astragalus bombycinus*
Northern Province	*Astragalus trachoniticus*	*Astragalus schimperi*	*Medicago laciniata*
Eastern Province	*Alhagi maurorum*	*Lotus garcinii*	*Taverniera spartea*
Tabuk	*Argyrolobium arabicum*	*Astragalus spinosus*	*Astragalus caprinus*
Aljouf	*Astragalus spinosus*	*Astragalus sinaicus*	*Acacia mellifera*

In the southern region, the three top species identified in the Asir province were *Dorycnopsis abyssinica* (A.Rich.)V.N.Tikhom. & D.D.Sokoloff*, Argyrolobium arabicum* (Decne.)Jaub. & Spach, and *Medicago lupulina* L.. Whereas, in Jazan province, *Acacia* is the most common genus and the most common species are *Acacia johnwoodii* Boulos and *Acacia ehrenbergiana* Hayne. For Nejran province, the most commonly collected species were *Alhagi maurorum* Medik*., Lotus quinatus* (Forssk.) J.B.Gillett, and *Astragalus sieberi* DC. On the other hand, one of the top three species in the Eastern

Province was *Alhagi maurorum* Medik. This species is used in traditional medicine and was recognized as one of the most commonly distributed species according to (Mandaville 1990). Also, *Lotus garcinii* DC., and *Taverniera spartea* (Burm.f.)DC. were identified as common species in this region.

Overall, species of the genera *Acacia*, *Alhagi*, and *Astragalus* were the most frequently collected in the provinces of Saudi Arabia, with representatives of genera from primarily distributed in both temperature regions of the northern hemisphere, such as *Astragalus*, *Lotus*, and *Medicago*, and temperate regions of the southern hemisphere, such as *Argyrolobium*, *Crotalaria*, and *Indigofera*, present. Also, the analysis of the distribution of species by provinces shows that the southwestern region - the Hejaz Mountains and Asir that run along with the Red Sea - are the most species rich. The species richness was predicted because the climate in these regions is suitable for plant growth. Another reason behind the richness plants in Mecca is that there are a large number of people who live in this region. Also, many people, around 3 million, are visiting Mecca every year to do Hajj and Umrah. Topography conditions are considering as another reason since there are many mountains and valleys existing in Mecca region. In comparing with other middle eastern countries such as Yemen, Iraq, Ghazanfar & Mcdaniel (2015) reported that 40% of the total flora in Iraq is exist in the mountain region that located in the northern regions of the country. Also, Ghazanfar & Mcdaniel (2015) and Townsend (1974) have found that *Astragalus is considered as* one of the largest legume genera in Iraq. For the *Acacia* and *Indigofera* genera, it is found that there are some of species such as *Acacia asak* (Forssk.), *Acacia tortilis* (Forssk.) Hayne,

Indigofera spinose Forssk, *Indigofera articulate* Gouan, and *Indigofera oblongifolia* Forssk. are exist in the mountains located in the west of Yemen (Al-Hawshabi & El-Naggar, 2015).

CHAPTER 4

CONCLUSION & RECOMMENDATIONS

A review of the literature showed that there is an intense and growing effort in many countries to digitize their floras in order to increase the usefulness of plant information to the general public, professional researchers, and students (Schoeninger et al. 2002; Schmid 2007; Rao et al. 2012; Gilbert & Gries 2014; Thiers et al. 2016). Several countries have started to achieve this objective such as USA, India, and many European countries. The international Global Biodiversity Information Facility (GBIF) has become a successful open-source, collaborative network to provide free access to data for all types of life on Earth. This organization has helped researchers worldwide, and anyone who has interest to know the biodiversity in many countries.

With this trend in mind, this study is the first to propose to create a virtual flora for Saudi Arabia. Based on SEINet and the Symbiota software used to power it, a preliminary website portal was established to begin an effort to make information of Saudi Arabia's flora available on the world-wide web. Data comprising a total of 12,834 specimens representing 175 families were acquired from different organizations and used to create a database for the designed website. The top five families found after analyzing these data were Fabaceae (1,220 specimens) followed by Asteraceae (1098 specimens), Poaceae (1067 specimens), Lamiaceae (516 specimens), and Caryophyllaceae (484 specimens). One family, Fabaceae, was chosen for further study. It is important to keep in mind that the results of analyses presented here are gleaned from a rather limited number of collected specimens that were obtained. Based on estimates, some 100,000 specimens of Saudi Arabian plants reside in principal herbaria in Saudi Arabia, and perhaps a

similar number are to be found in collections in herbaria around the world. Unfortunately, we were only able to access a small number of these specimens for this project.

The analyses conducted here were based on the geographic distribution of the 862 specimens among the regions of Saudi Arabia, of which the georeferenced specimens are plotted on Figure 5. The results showed that Mecca province contains the largest number of Fabaceae species (97 species, 299 specimens) followed by Asir province (64 species, 137 specimens) and Jazan province (62 species, 122 specimens). At the generic level, *Astragalus* was represented by the largest number of species (28), followed by *Acacia* (25), *Indigofera* (17), and *Crotalaria* (13), *Lotus* (10) and *Tephrosia* (9).

Challenges Experienced During This Study

During the course of working on this research project, several challenges have faced the author. One of these issues was getting access to the basic specimen collection data from the principal herbaria in Saudi Arabia. Out of the six herbaria operating in Saudi Arabia, only two of them indicated any interest in helping the author by providing some of the data that they have about the flora of Saudi Arabia. The cost was another issue; the author offered to purchase a digital camera imaging system in order to generate digital images of the many species housed in the herbaria as an incentive to collaboration on this project. Unfortunately, the educational support that the author received during her two years at ASU could not be used to cover the cost of the required equipment and

materials. Moreover, the time was also another factor since the researcher had a limited time to conduct the research and complete the requirements for the masters' degree.

Recommendations

The following recommendations are proposed:

- Continue maintaining and expanding the virtual flora of Saudi Arabia web portal that is proposed and initiated in this study by securing more collection locality data for the database.
- Obtain high quality images of species present in the flora of Saudi Arabia and create an image database for the portal.

Study Limitation

There is a limitation of this study that has to be declared. This limitation is that the collection data that was obtained for this study may not be representative of all the information on the flora of Saudi Arabia. For example, there are differences in the list of species that has been compiled by Jacob Thomas for his website compared to the one presented here. This mean that the analyses conducted in this study represent a preliminary survey on the flora of Saudi Arabia.

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APPENDIX A

THE DISTRIBUTION OF FABACEAE SPECIMENS AS COMPILED IN THIS STUDY

Provinces are as follows. R: Riyadh; M: Mecca; D: Medina; A: Asir; J: Jazan; Q: Qassim; B: Albaha; A: Najran; H: Hail; N: Northern Province; E: Eastern Province; T: Tabuk; F: Aljouf

Genus	#	Scientific Name	#	R	M	D	A	J	Q	B	A	H	N	E	T	F	Unknown
Abrus	4	Abrus bottae	4					3		1							
Acacia	181	Acacia spp.	12	1	2		2			4	3						
		Acacia asak	18		7		2	1		2							6
		Acacia edgeworthii	1														
		Acacia ehrenbergiana	16	2	6			5		1			1	1			
		Acacia etbaica	12		3	3	2			1							3
		Acacia etbaica subsp. uncinata	2														2
		Acacia farnesiana	3	2													1
		Acacia gerrardii	6	1			1			1					1		2
		Acacia hamulosa	9		6	1		2									
		Acacia hockii	2					1									1
		Acacia horrida	3	1	1							1					
		Acacia hunteri	1														
		Acacia johnwoodii	22		12		2	5		2							1
		Acacia laeta	9		2		3			2	1						1
		Acacia mellifera	3					1								1	1
		Acacia oerfota	9		2	1		4		1	1						
		Acacia oerfota var. brevifolia	1														1

		Acacia origena	12				4			2							6
		Acacia pachyceras	5		2		2			1							
		Acacia pachyceras var. najdensis	9	2		1			1	2		3					
		Acacia raddiana	1	1													
		Acacia salicina	1	1													
		Acacia senegal	1		1												
		Acacia seyal	6	1				4									1
		Acacia tortilis	12	1	2	2	1	1		1							3
		Acacia tortilis subsp. raddiana	4			3											1
		Acacia yemenensis	1														1
Alhagi	10	Alhagi graecorum	1											1			
		Alhagi maurorum	9	1							3			3			2
Alysicarpus	5	Alysicarpus glumaceus	5				1	2									2
Anagyris	8	Anagyris foetida	8		1		2			2	1						2
		Argyrolobium sp.	1														1
Argyrolobium	26	Argyrolobium arabicum	20		4		5	2		1	2				3		3
		Argyrolobium bottae	2														2
		Argyrolobium confertum	3				3										
Astracantha	3	Astracantha echinus	2												2		
Astracantha	3	Astracantha echinus subsp. arabica	1														1

Astragalus	160	Astragalus spp.	9			1	3				2						3
		Astragalus asterian	1			1											
		Astragalus annularis	3	1								1		1			
		Astragalus atropilosulus	13		2		3	4		2							2
		Astragalus bombycinus	9	3					1			2	1				2
		Astragalus caprinus	4									1			2		1
		Astragalus caprinus subsp. caprinus	1														1
		Astragalus collenetteae	2			1						1					
		Astragalus corrugatus	8	3		1			1				1				2
		Astragalus dactylocarpus	1														1
		Astragalus eremophilus	17	2	7	2											6
		Astragalus eremophilus subsp. eremophilus	1														1
		Astragalus fasciculifolius	1											1			
		Astragalus hamosus	1									1					
		Astragalus hauarensis	9	2	1		2					2	1	1			
		Astragalus kahiricus	2									1		1			
		Astragalus mareoticus	1										1				
		Astragalus palaestinus	1														1

		Astragalus pelecinus	2														2
		Astragalus radiatus	1				1										
		Astragalus schimperi	8	2	1							2	3				
		Astragalus sieberi	10	3	1				1	1	2	1		1			
		Astragalus sinaicus	3	1								1				1	
		Astragalus sparsus	6		1		2			2							1
		Astragalus spinosus	6	2										1	2	1	
		Astragalus trachoniticus	4										4				
		Astragalus tribuloides	13	1	2	1			1	1		3	1		1		2
		Astragalus vogelii	13		6	1	3			1							2
		Astragalus vogelii subsp. fatimensis	10		3												7
Cadia	9	Cadia purpurea	9				3				1						5
		Caesalpinia spp.	1		1												
Caesalpinia	2	Caesalpinia pulcherrima	1														1
Cassia	3	Cassia spp.	3		3												
		Cicer sp.	1		1												
Cicer	2	Cicer cuneatum	1		1												
		Clitoria sp.	1								1						
Clitoria	4	Clitoria ternatea	3					2									1
Colutea	2	Colutea abyssinica	2												2		
		Crotalaria spp.	12	3	1		2	1			1						
		Crotalaria aegyptiaca	3		1		1	1									

		Crotalaria emarginella	6		4	1	1										
		Crotalaria incana	4					4									
		Crotalaria leptocarpa	3														3
		Crotalaria leucoclada	3					3									
		Crotalaria microphylla	31	1	16			1			1						12
		Crotalaria pallida	1				1										
		Crotalaria plowdenii	1														1
		Crotalaria pycnostachya	1					1									
Crotalaria	72	Crotalaria quartiniana	2					1									1
		Crotalaria retusa	1					1									
		Crotalaria senegalensis	1		1												
		Crotalaria thebaica	3	1					1								1
Cullen	11	Cullen plicatum	11	1	8			1									1
Cyamopsis	3	Cyamopsis senegalensis	3		2												1
Cytisus	1	Cytisus arabicus	1														1
Delonix	7	Delonix elata	7		3			1		1							2
Desmodium	1	Desmodium gangeticum	1					1									
Dichrostachys	4	Dichrostachys cinerea	4					2									2
Dolichos	3	Dolichos trilobus	3					2									1
Dorycnopsis	10	Dorycnopsis abyssinica	10				6	3		1							

Fabaceae	34	Fabaceae	34		3		17	3			4						7
Faidherbia	4	Faidherbia albida	4							3							1
Glycyrrhiza	1	Glycyrrhiza glabra	1											1			
		Hippocrepis arenaria	3		1												2
		Hippocrepis areolata	3				1							2			
		Hippocrepis ciliata	1			1											
Hippocrepis	25	Hippocrepis constricta	15	2	4	1									1		7
		Hippocrepis unisiliquosa	3									1					2
		Indigofera spp.	20		7	1	2	5			1		2				2
		Indigofera amorphoides	4				1										3
		Indigofera arabica	2				1										1
		Indigofera argentea	8		1			2									5
		Indigofera arrecta	2					2									
		Indigofera articulata	3							1							2
		Indigofera coerulea var. coerulea	1					1									
		Indigofera coerulea var. occidentalis	3		1			1		1							
		Indigofera colutea	4		2			2									
Indigofera	136	Indigofera hochstetteri	15		4		1			1							9
		Indigofera leptocarpa	22		9												13
		Indigofera oblongifolia	11		4		1	2									4

		Indigofera semitrijuga	8		1			2									5
		Indigofera sessiliflora	2		2												
		Indigofera spiniflora	3		2												1
		Indigofera spinosa	21	1	10		1			1							7
		Indigofera trita	4		2			2									
		Indigofera trita var. subulata	3														3
Inga	1	Inga edulis	1	1													
Lablab	3	Lablab purpureus	3					1									2
		Lathyrus cicera	1							1							
		Lathyrus pratensis	2				2										
Lathyrus	6	Lathyrus pseudocicera	1														1
		Lathyrus saxatilis	2		1										1		
Lens	5	Lens culinaris	5		2		1			1							1
Lotononis	23	Lotononis platycarpa	23		11	1	3	2	1			1			1		3
		Lotus spp.	5		2					1	1						1
		Lotus arabicus	3														3
		Lotus corniculatus	3				2				1						
		Lotus garcinii	4		1									3			
Lotus	50	Lotus glinoides	7		5				2								
		Lotus halophilus	5	1					1			1		1			1
		Lotus hebranicus	3		3												
		Lotus lalambensis	5		2	1				2							

		Lotus laricus	1														
		Lotus quinatus	11		4		1	1		3	2						
		Lotus schimperi	3		1												2
Macrotyloma	2	Macrotyloma axillare var. axillare	1														1
		Macrotyloma uniflorum	1					1									
		Medicago spp.	3				3										
		Medicago laciniata	3										1				2
		Medicago laciniata var. brachyacantha	4						1			2					1
		Medicago lupulina	4				4										
Medicago	28	Medicago minima	5		1		1			1							2
		Medicago monspeliaca	2														2
		Medicago orbicularis	2	1						1							
		Medicago polymorpha	4	1	1		1			1							
		Medicago truncatula	1														1
Melilotus	4	Melilotus albus	2				2										
		Melilotus indicus	2		1		1										
		Microcharis disjuncta	2	1	1												
Microcharis	7	Microcharis tritoides	2		2												
		Microcharis tritoides subsp. tritoides	3		3												
Neonotonia	3	Neonotonia wightii	3		1			2									

Onobrychis	7	Onobrychis ptolemaica	7	1			1		1	1		1			1		1
Ononis	8	Ononis sp.	1														1
		Ononis natrix	1												1		
		Ononis reclinata	3		2					1							
		Ononis viscosa	3			1						1					1
Pisum	2	Pisum sativum	1														1
		Pisum sativum subsp. arvense	1				1										
Pithecellobium	1	Pithecellobium dulce	1		1												
Podlechiella	4	Podlechiella vogelii subsp. fatmensis	4														4
Prosopis	10	Prosopis cineraria	2	1										1			
		Prosopis farcta	1	1													
		Prosopis juliflora	7					3						1			3
Retama	1	Retama raetam	1												1		
Rhynchosia	39	Rhynchosia spp.	8		1	1	4	1			1						
		Rhynchosia elegans	1														1
		Rhynchosia malacophylla	7		3		1	1		1							1
		Rhynchosia minima	5				1	3		1							
		Rhynchosia pulverulenta	2		1		1										
		Rhynchosia schimperi	11		7		1										3
		Rhynchosia totta	2							2							

		Rhynchosia usambarensis	2					2									
		Rhynchosia variegata	1				1										
		Senna alexandrina	13		2			3									8
		Senna alexandrina var. alexandrina	3		3												
		Senna holosericea	13		6		1										6
		Senna italica	8	1			4	1									2
Senna	55	Senna italica subsp. arachoides	1														1
		Senna italica subsp. italica	6	2	1	1											2
		Senna italica subsp. micrantha	1			1											
		Senna obtusifolia	3				1	1				1					
		Senna occidentalis	7		1		1	1									4
		Sesbania leptocarpa	5		3												2
Sesbania	6	Sesbania sesban	1		1												
Sophora	1	Sophora gibbosa	1		1												
Stylosanthes	1	Stylosanthes fruticosa	1														1
		Tamarindus sp.	1		1												
Tamarindus	11	Tamarindus indica	10		1			3									6
		Taverniera aegyptiaca	3		2												1
Taverniera	17	Taverniera cuneifolia	1														1
		Taverniera lappacea	8		2												6

		Taverniera spartea	5	1										3			1
		Tephrosia spp.	19		11		1	2									5
		Tephrosia apollinea	17		5	2					1						8
		Tephrosia arabica	14		9												5
		Tephrosia desertorum	6		1												5
		Tephrosia heterophylla	1														1
Tephrosia	81	Tephrosia nubica	11		4											1	6
		Tephrosia pumila	1					1									
		Tephrosia purpurea	9		7	2											
		Tephrosia subtriflora	2		1												1
		Tephrosia uniflora	1					1									
		Teramnus labialis	2				1	1									
		Teramnus labialis subsp. arabicus	1														1
Teramnus	7	Teramnus repens	3		1			2									
		Teramnus repens subsp. gracilis	1														1
		Trifolium spp.	3				3										
		Trifolium arvense	4		1		1			2							
		Trifolium campestre	4		1		3										
Trifolium	15	Trifolium fragiferum	1				1										
		Trifolium scabrum	2							1							1
		Trifolium tomentosum	1							1							
Trigonella	13	Trigonella sp.	1														1

		Trigonella anguina	1	1													
		Trigonella cylindracea	1														1
		Trigonella foenum-graecum	1							1							
		Trigonella hamosa	6	2					2				1				1
		Trigonella stellata	3			1								1			1
Vermifrux	1	Vermifrux sp. (syn. Dorycnopsis)	1				1										
		Vicia monantha	3			1		1				1					
Vicia	22	Vicia peregrina	9		4	1											4
		Vicia sativa	10		3	1	4			2							
		Vigna sp.	1														1
		Vigna aconitifolia	2					2									
Vigna		Vigna heterophylla	1					1									
	10	Vigna membranacea	5					3		2							
		Vigna membranacea subsp. membranacea	1														1
Totals			1175	58	299	37	137	122	14	66	30	29	17	24	19	4	309

APPENDIX B

THE FABACEAE SPECIES COMPILED BY DR.THOMAS AS LISTED ON HIS WEBSITE

Number	Taxon Name
1	*Abrus bottae* Defl.
2	*Abrus precatorius* L.
3	*Acacia abyssincia* Hochst.
4	*Acacia asak* (Forssk.) Willd.
5	*Acacia ehrenbergiana* Hayne
6	*Acacia etbaica* Schweinf.
7	*Acacia etbaica* ssp. *uncinata* Brenan
8	*Acacia gerrardii* var. *najdensis* Chaudhary
9	*Acacia gerrardii var. negevensis* Zoh.
10	*Acacia hamulosa* Benth.
11	*Acacia laeta* R.Br.
12	*Acacia mellifera* var. *mellifera* Vahl
13	*Acacia mellifera* var. *almakkiana* S.A. Chaudhary
14	*Acacia oerfota* var. *brevifolia* Boulos
15	*Acacia oerfota* var. *oerfota* (Forssk.) Schweinf.
16	*Acacia origena* Asfaw
17	*Acacia raddiana* Savi
18	*Acacia seyal* Del.
19	*Acacia tortilis* (Forssk.) Hayne
20	*Alhagi graecorum* Boiss.
21	*Alysicarpus glumaceus* (Vahl) DC.
22	*Alysicarpus rugosus* Willd.
23	*Anagyris foetida* L.
24	*Argyrolobium arabicum* (Decne.) Jaub. & Spach.
25	*Argyrolobium confertum* Polhill
26	*Argyrolobium crotalarioides* Jaub. & Spach.
27	*Astragalus abyssinicus* ssp. *abyssinicus* Steud. ex A. Rich.

Number	Taxon Name
28	Astragalus annularis Forssk.
29	Astragalus asterias Steven
30	Astragalus atropilosus (Hochst.) Bunge
31	Astragalus bombycinus Boiss.
32	Astragalus caprinus ssp. caprinus L.
33	Astragalus collenettiae Hedge & Podl.
34	Astragalus crenatus Schult.
35	Astragalus dactylocarpus ssp. acinaciferus (Boiss.) Ott.
36	Astragalus echinus ssp. arabica (Hedge & Podl.) Chaudhary
37	Astragalus eremophilus Boiss.
38	Astragalus fruticosus Forssk.
39	Astragalus hamosus L.
40	Astragalus hauarensis Boiss.
41	Astragalus intercedens Sam. ex Rech..f.
42	Astragalus kahiricus DC.
43	Astragalus mareoticus Del.
44	Astragalus pelecinus (L.) Barneby
45	Astragalus schimperi Boiss.
46	Astragalus schimperi var. subsessilis
47	Astragalus sieberi DC.
48	Astragalus sparsus Del. ex Decne.
49	Astragalus spinosus (Forssk.) Muschl.
50	Astragalus trachoniticus Post
51	Astragalus tribuloides Del.
52	Astragalus tribuloides var. minutus Boiss.
53	Astragalus tribuloides var. thapsacenus Hand.-Mazz
54	Astragalus vogelii var. vogelii (Webb) Bornm.

Number	Taxon Name
55	*Astragalus vogelii* var. *fatmensis* Maire
56	*Cadia purpurea* (Picc.) Ait.
57	*Canavalia virosa* (Roxb.) Wight. & Arn.
58	*Chamaecrista mimosoides* (L.) Greene
59	*Chamaecrista nigricans* (Vahl) Greene
60	*Cicer arietinum* L.
61	*Cicer cuneatum* Hochst. ex A. Rich.
62	*Clitoria ternatea* L.
63	*Colutea istria* Mill.
64	*Crotalaria aegyptiaca* Benth.
65	*Crotalaria emarginella* Vatke
66	*Crotalaria incana* L.
67	*Crotalaria leptocarpa* Balf.f.
68	*Crotalaria microphylla* Vahl
69	*Crotalaria mucronata* Desv.
70	*Crotalaria persica* (Burm.f.) Merril
71	*Crotalaria pycnostachya* Benth.
72	*Crotalaria quartiniana* A. Rich.
73	*Crotalaria retusa* L.
74	*Crotalaria senegalensis* (Pers.) DC.
75	*Cyamopsis senegalensis* Guill. & Perr.
76	*Delonix elata* (L.) Gamble
77	*Desmodium gangeticum* (L.) DC.
78	*Dichrostachys cinerea* (L.) Wight & Arn.
79	*Dolichos trilobus* L.
80	*Faidherbia albida* (Del.) A. Chev.
81	Glycine wightii ssp. longicauda (Schweinf.) Verdc.

Number	Taxon Name
82	*Glycyrrhiza glabra* L.
83	*Hippocrepis areolata* Desv.
84	*Hippocrepis constricta* Kunze
85	*Hippocrepis unisiliquosa* ssp. *bisiliqua* (Forssk.) Bornm.
86	*Indigofera amorphoides* Jaub. & Spach.
87	*Indigofera arabica* Jaub. & Spach.
88	*Indigofera argentea* Burm.f.
89	*Indigofera arrecta* Hochst. ex A. Rich.
90	*Indigofera articulata* Gouan
91	*Indigofera brachyphylla* Al-Turki
92	*Indigofera coerulea* var. *coerulea* Roxb.
93	*Indigofera coerulea* var. *occidentalis* Gillet & Ali
94	*Indigofera colutea* (Burm.f.) Merr.
95	*Indigofera hochstetteri* Bak.
96	*Indigofera intricata* Boiss.
97	*Indigofera linifolia* (L.f.) Retz.
98	*Indigofera oblongifolia* Forssk.
99	*Indigofera schimperi* Jaub. & Spach.
100	*Indigofera semitrijuga* Forssk.
101	*Indigofera sessiliflora* DC.
102	*Indigofera spicata* Forssk.
103	*Indigofera spiniflora* Hochst. & Steud.
104	*Indigofera spinosa* Forssk.
105	*Indigofera tinctoria* L.
106	*Indigofera trita* var. *maffeii* (Chiov.) Ali
107	*Indigofera trita* var. *scabra* (Roth) Ali
108	*Indigofera trita* ssp. *subulata* (Vahl ex Poir.) Ali

Number	Taxon Name
109	*Indigofera volkensii* Taub.
110	*Lablab purpureus* (L.) Sweet
111	*Lathyrus aphaca* L.
112	*Lathyrus cicera* L.
113	*Lathyrus pratensis* L.
114	*Lathyrus saxatilis* (Vent) Vis.
115	*Lens culinaris* Medik
116	*Lens orientalis* (Boiss.) Hand-Mazz.
117	*Lotononis platycarpa* (Viv.) Pichi.- Serm.
118	*Lotononis stolzii* Harms
119	*Lotus arabicus* L.
120	*Lotus corniculatus* L.
121	*Lotus garcinii* DC.
122	*Lotus glinoides* Del.
123	*Lotus goetzei* Harms
124	*Lotus halophilus* Boiss. & Sprun.
125	*Lotus lanuginosus* Vent.
126	*Lotus quinatus* (Forssk.) Gillette
127	*Macrotyloma axillare* var. *axillare* (E. Mey.) Verdc.
128	*Medicago laciniata* var. *laciniata* (L.) Mill.
129	*Medicago laciniata* var. *brachyacantha* Boiss.
130	*Medicago lupulina* L.
131	*Medicago minima* (L.) L.
132	*Medicago orbicularis* (L.) Bart.
133	*Medicago phyrgia* (Boiss. & Balansa) E.Small
134	*Medicago polymorpha* L.
135	*Medicago sativa* L.

Number	Taxon Name
136	*Medicago truncatula* ssp. *longiaculeata* Urb.
137	*Melilotus albus* Medik
138	*Melilotus indicus* (L.) All.
139	*Microcharis disjuncta* (Gillette) Schrire
140	*Microcharis tritoides* (Bak.) Schrire
141	*Onobrychis ptolemaica* (Del.) DC.
142	*Ononis natrix* L.
143	*Ononis reclinata* L.
144	*Ononis serrata* Forssk.
145	*Ononis sicula* Guss.
146	*Pisum sativum* var. *arvense* (L.) Poir.
147	*Prosopis cineraria* (L.) Druce
148	*Prosopis farcta* (Banks & Sol.) Macbr.
149	*Prosopis juliflora* (SW.) DC.
150	*Prosopis koelziana* var. *puberula* J. Leonard
151	*Psoralea bituminosa* L.
152	*Psoralea plicata* Del.
153	*Pterolobium stellatum* (Forssk.) Brenan
154	*Retama raetam* (Forssk.) Webb.
155	*Rhynchosia buramensis* Hutch. & Bruce
156	*Rhynchosia malacophylla* (Spreng.) Boj.
157	*Rhynchosia minima* var. *minima* (L.) DC.
158	*Rhynchosia minima* var. *nuda* (DC.) Kuntze
159	*Rhynchosia minima* var. *prostrata* (Harv.) Meikle
160	*Rhynchosia pulverulenta* var. *memnonia* Delile
161	*Rhynchosia pulverulenta* var. *pulverulenta* Stocks
162	*Rhynchosia schimperi* Hochst. ex Boiss.

Number	Taxon Name
163	*Rhynchosia totta* (Thunb.) DC.
164	*Rhynchosia variegata* (Def.) JRI Wood
165	*Rhynchosia velutina* Wight. & Arn.
166	*Scorpiurus muricatus* L.
167	*Senna alexandrina* Miller
168	*Senna holosericea* (Fresen) Greuter
169	*Senna italica* Miller
170	*Senna obtusifolia* (L.) Irwin & Barneby
171	*Senna occidentalis* (L.) Link.
172	*Senna tora* (L.) Roth.
173	*Sesbania leptocarpa* DC.
174	*Sesbania sericea* (Willd.) Link
175	*Sophora gibbosa* (DC.) Yakovlev
176	*Stylosanthes fruticosa* (Retz.) Alston
177	*Tamarindus indica* (DC.) Yakovl
178	*Taverniera aegyptiaca* Boiss.
179	*Taverniera cuneifolia* (Roth) Arn.
180	*Taverniera lappacea* (Forssk.) DC.
181	*Taverniera spartea* (Burm.f.) DC.
182	*Tephrosia desertorum* Scheele
183	*Tephrosia heterophylla* Vatke
184	*Tephrosia nubica* (Boiss.) Bak.
185	*Tephrosia pumila* (Lam.) Pers.
186	*Tephrosia purpurea* ssp. *apollinea* (Del.) Hosni
187	*Tephrosia purpurea* ssp. *leptostachya* var. *leptostachya* (DC.) Bru.
188	*Tephrosia purpurea* ssp. *leptostachya* var. *pubescens* (Bak.) Bru.
189	*Tephrosia quartiniana* Cuf.
190	*Tephrosia subtriflora Hochst. ex Bak.*

Number	Taxon Name
191	*Tephrosia uniflora* ssp. *petrosa* (Blatt. & Hall.) Gillet & Ali
192	*Tephrosia villosa* (L.) Pers.
193	*Teramnus labialis* ssp. *arabicus* Verdc.
194	*Teramnus repens* ssp. *gracilis* (Chiov.) Verdc.
195	*Trifolium arvense* L.
196	*Trifolium campestre* Schreb.
197	*Trifolium fragiferum* L.
198	*Trifolium retusum* L.
199	*Trifolium scabrum* L.
200	*Trifolium semipilosum* Fresen.
201	*Trifolium tomentosum* L.
202	*Trigonella anguina* Del.
203	*Trigonella cylindracea* Desv.
204	*Trigonella foenum-graecum* L.
205	*Trigonella hamosa* L.
206	*Trigonella monantha* C.A. Mey
207	*Trigonella monspeliaca* var. *monspeliaca* L.
208	*Trigonella stellata* Forssk.
209	*Vermifrux abyssinica* (A. Rich.) Gillett
210	*Vicia monantha* Retz.
211	*Vicia peregrina* L.
212	*Vicia sativa* var. *angustifolia* L.
213	*Vicia sativa* ssp. *nigra* var. *nigra* (L.) Ehrh.
214	*Vicia sativa* ssp. *sativa* L.
215	*Vigna aconitifolia* (Jacq.) Marechal
216	*Vigna ambacensis* Welw.
217	*Vigna macrorhyncha* (Harms) Milne-Redhd.
218	*Vigna membranacea* ssp. *caesia* A. Rich.
219	*Vigna membranacea* ssp. *membranacea* A. Rich.