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Full Length Research Paper

Diversity and frequency of *Acacia* spp. in three regions in the Kingdom of Saudi Arabia

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This study was carried out to assess the diversity and frequency of *Acacia* spp. and to determine the effect of soil texture on the frequency of *Acacia* spp. The study sites were selected after field visits to the Al Madinah, Aseer and Al Baha areas. The selection was done on the basis of the natural distribution and density of *Acacia* spp. Both Aseer and Al Baha are in the semiarid zone, and Al Madinah is in the arid zone according to Emberger. Measurements of trees were carried out inside 0.1 ha sample plots. Diameter frequency histograms were drawn for all locations as a measure of stand structure. There were great differences between species in relation to diameter distribution. The study shows the scarcity of large diameter trees and also in some cases, medium and small trees, which necessitated urgent intervention by transplanting and protection during regeneration periods to attain sustainability. *A. ehrenbergiana* and *A. tortilis* were the species common to all the three regions studied. *A. origena, A. etbaica, A. asak and A. gerrardii* were restricted to Al Baha and Aseer, possibly due to differences in climate (semi-arid) as compared to Al Madinah (arid). There were significant differences in soil texture associated with the various species, with some apparently preferring sandy soils and others clay rich soils.

Key words: *Acacia*, diversity, soil texture, diameter at breast height (DBH) classes.

INTRODUCTION

Saudi Arabia, with an area of 2.25 million km^2 comprises mainly desert and semi-desert areas besides the mountains of the south-west region, scattered valleys and the western and eastern coasts (Chaudhary, 1983; Aref and El-Juhany, 2000). The Arabian shield is formed of igneous and metamorphic rocks of the Precambrian age, which have been uplifted and tilted eastwards. The second group of rocks, composed of unaltered, younger sedimentary rocks, is represented by escarpments, ridges etc. About 30% of the Arabian peninsula is covered with sand. The major sand bodies are the great Nafud in the north, the Empty Quarter in the south and the crescent bodies of sand known as Dahna. The sandy soil is stable wherever the area is thickly vegetated. In arid lands, plants play a major role in the productivity and stability of the desert environment (Hassan and Farraj, 1989). *Acacia sensu lato* species (hereafter referred to as *Acacia*) are of great economic importance in Saudi Arabia as they yield wood that is used as fuel and timber. They are also a good source of gum, tannins and forage. In addition, *Acacias* form a good habitat for honeybees that produces good quality honey (Aref et al., 2003). The shape of the diameter distribution of uneven-sized and uneven-aged forest is often a reversed J-curve. This kind of distribution is commonly characterized by the ‘q’ coefficient (also called ‘q’ ratio), which is the ratio between tree frequencies in two adjacent diameter classes (Cancino and Gadow, 2002). The ‘q’ ratio is often considered constant through the whole distribution, ranging from 1.2 to 2.0 between adjacent 4 cm wide diameter classes, but it may also vary within the range of diameters

The *Acacia* population in Saudi Arabia is threatened because of their narrow genetic diversity and geographical range, small population size and low density, extreme environmental conditions, and indiscriminate cutting of trees, despite the fact that they have a high reproductive capacity. The objective of this study was to determine the diversity and size frequency of some *Acacia* spp. in Aseer, Al Baha (Southwestern Saudi

Figure 1. Study locations in Aseer.

Arabia) and Al Madinah (western) regions, and to assess the effect of soil texture on species occurrence.

MATERIALS AND METHODS

The study area

The study was conducted in locations in Al Madinah, Al Baha and Aseer regions representing variable topography, soil, climate and terrain, where most of *Acacia* spp. under investigation are distributed. Latitude, longitude and altitude of the study areas were recorded using a GPS device (Garmin 5). Study sites, and the *Acacia* spp. present at each are shown in Figures 1 to 3.

Maps of the study area

Maps of the study areas in the three regions were prepared by locating the recorded coordinates for each location on the relevant map, latitude, longitude and altitude of the study areas, and were recorded using GPS. Maps were drawn for the different study areas (Figures 1 to 3).

Climate of the study areas

Meteorological data were collected and analyzed for successive years from the meteorological stations within or in the vicinity of the study areas. The climate classification was based on the pluviometric index of Emberger (1971) as follows:

$$Q^2 = \frac{2000\,P}{M^2 - m^2}$$

where, P is the annual average rainfall (mm); M is the average temperature of the hottest month (°C); m is the average temperature of the coldest month (°C) and Q^2 is the coefficient index. These parameters were fitted into a climate curve to classify each region of the study areas.

Sampling of *Acacia* spp.

Circular sample plots (0.1 ha) were laid out using a plastic rope (17.8 m radius). The rope was fixed to a peg at the centre of the sample plot and moved around 360°. All trees inside the circle were marked using a paint sprayer. Depending on species distribution and density, a number of sample plots were laid out in the study locations in Al Madinah, Al Baha and Aseer region. The Diameter at breast height (DBH) was determined for all plants within the plots, and size frequency histograms were drawn for all locations as an indicator of sustainability of harvesting. Stem diameter has been considered an indicator of the forest structure, especially at the stand level (Rubin et al., 2006).

Soil field study and laboratory analysis

Soil profiles representing the marked out areas of each location

Figure 2. Study locations in Al-Baha.

were studied. Soil profiles were morphologically described following the terminology outlined by the Soil Survey Division Staff (1993). Representative soil samples were collected, air dried, ground gently and then sieved through a 2 mm sieve, and the fractions less than 2 mm were kept for laboratory analyses. Particle size distribution was determined according to Gee and Bauder (1986). The data was statistically analyzed by analysis of variance (ANOVA) and means were separated by LSD at P = 0.05.

RESULTS

Climate of the study areas

Temperature, rainfall and elevation are summarized in Table 1. Both Al Baha and Aseer fall within the highland zone, with altitudes 1652 and 2093 m a.s.l (above sea level), respectively. However, Al Madinah falls within the flat land zone (635 m a.s.l). Consequently, the former were characterized by moderate temperature and more rainfall, whereas the latter had high temperature and less rainfall (Table 1). The climate analysis according to Emberger (1971) showed that Al Baha is at the top margin of the semi-arid climate and Aseer falls at the bottom margin of this zone. Nevertheless, Al Madinah falls at the bottom margin of the arid zone close to the very arid zone (Figure 4).

Distribution of *Acacia* spp.

The following species were recorded namely: *Acacia tortilis* (Forssk.) Hayne subsp. *tortilis, A. tortilis* subsp. *raddiana* (Savi) Brenan*, A. gerrardii* Benth.*, Acacia asak* (Forssk.) Willd., *A. etbaica* Schweinf and *A. origena* R.B. The species recorded in each study site are given in Table 2. The species common to the three regions were *A. tortilis* and *A. ehrenbergiana* whereas; *A. origena, A. gerrardii, A. asak,* and *A. etbaica* were restricted to Al Baha and Aseer regions and not found in Al Madinah region. Hence, climate appears to have had a considerable effect on the distribution and diversity of *Acacia* spp. in Saudi Arabia. It is worth noting that *A. origena* is common in the highlands and it is the only *Acacia* spp. at high altitudes, even occuring with a conifer

Figure 3. Study locations in Al-Madinah.

(*Juniperus procera* Hochst. ex Endlicher). It is also evident that *A. tortilis* is a common specie in Saudi Arabia as it thrived in semi-arid and arid zones in the study areas.

Diameter distribution

Al Baha

Generally, most forests in Al Baha lack some diameter classes especially the relatively large ones (25 to 30 cm). In the majority of these forests and woodlots, the diameters ranged between 5 to 10 cm. Diameter distribution of Acacias in most locations is a typical reverse J-shape (Figures 5 to 7). However, in some locations the DBH distribution is extremely irregular.

Al Madinah

Diameter distribution of Acacias in some locations is a typical reverse J-shape (Figure 8). Nevertheless, other locations were characterized by irregular DBH classes and the domination of small diameter trees and scarcity of mature large trees. However, the curvature of the reverse-J is sometimes flat, indicating the scarcity of large trees (Figure 9).

Aseer

The situation is no different from Al Baha and Al Madinah where extremely irregular patterns of diameter distribution were recorded. In many locations, large trees were scarce and small trees were dominant (Figures 10 and 11).

Effect of soil texture on distribution of *Acacia* spp.

Al Madinah

Soil texture under *A. ehrenbergiana*, *A. tortilis tortilis* and *A. tortilis raddiana* was significantly different in terms of sand, clay and silt contents (Table 3). With regard to

Table 1. Climate in the study areas (2000 to 2011).

Region	Temperature (°C)			Rainfall (mm)		Elevation (m a.s.l)
	Monthly mean maximum	Monthly mean minimum	Mean monthly	Monthly mean maximum	Mean monthly	
Aseer	31.2	7.6	19.2	115.2	11.8	2093.35
Al Baha	36.1	9.9	23.2	132.3	9.2	1651.88
Al Madinah	44.3	11.3	28.9	63.4	2.9	635.6

Source: National Metrological and Environmental Center, Presidency of Meteorology and Environmental Protection, Ministry of Defense and Aviation, Kingdom of Saudi Arabia (2000 to 2011).

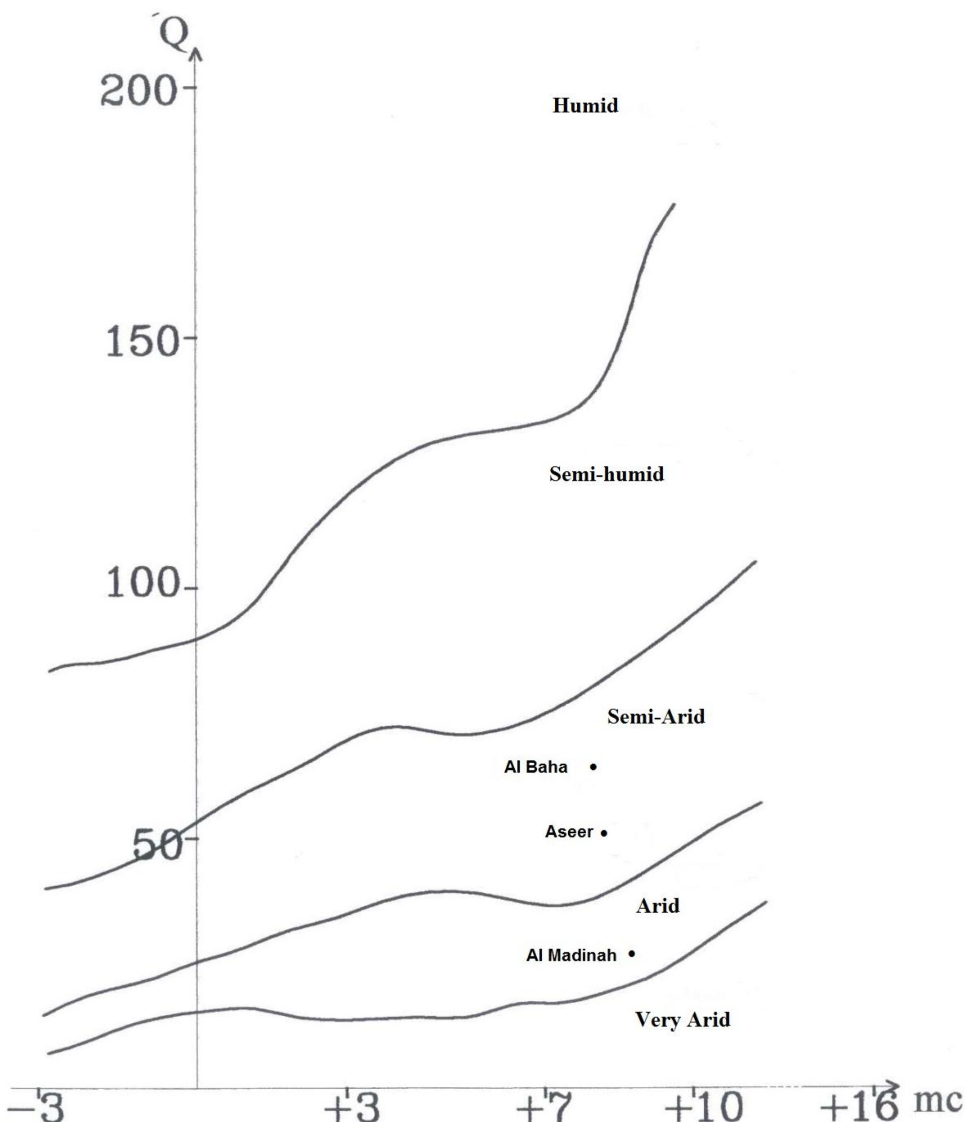

Figure 4. Climate of the study regions.

sand, it was significantly higher under *A. tortilis tortilis* (93.2%) (Table 3) and least under *A. tortilis raddiana* (81.5%) and *A. ehrenbergiana* (69.3%). Clay content was significantly greater under *A. ehrenbergiana* (8.5%) and *A. tortilis raddiana* (6.1%), whereas it was least under *A. tortilis tortilis* (2.4%). As for silt, the trend was similar to

Table 2. Distribution of *Acacia* spp. in the study areas.

Region	Location	Coordinates	Species
Al Madinah	Wadi Sedara	N 2411109 E 391323	A. T + A. R
	Wadi Al Gareed	N 2418659 E 0392328	A. R
	Wadi Al Rimth	N 2415389 E 3916936	A. R + EH
Al Baha	Al Ageeg Al Matar road	N 1949613 E 4134380	A. ET
	Al Gimda	N 1949613 E 4135280	A.O
	Al Mekhwa	N 50530 E 4136476	A. A
	Kara Al ageeg road	N 1946432 E 4137133	A.R + A.EH + A.G
	Wadi Batat Namira road	N 1953413 E 4137175	A. T + A.EH
Aseer	Al Marbaa park	N 1754055 E 4226511	A. G
	Al Masgaa park	N 1764055 E 4228523	A. O
	Beesha park	N 1752056 E 4224511	A. R
	Tihama-Ghtan	N 1749165 E 4224422	A. ET + A. A

A.T = *Acacia tortilis* subsp. *tortilis,* A.R = *Acacia tortilis* subsp. *raddiana,* A.G = *Acacia gerrardii,* A.A. = *Acacia asak,* A.O = *Acacia origena, A.*EH = *Acacia ehrenbergiana,* A.ET. = *Acacia etbaica.*

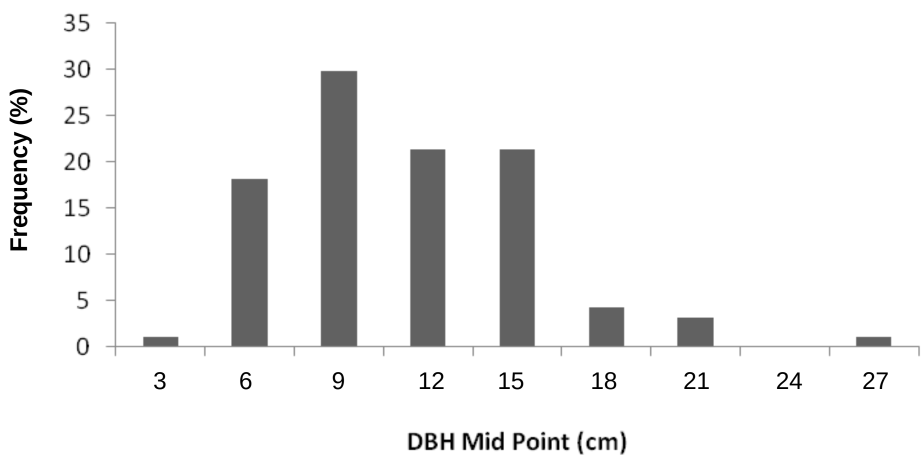

Figure 5. DBH distribution in Al Baha (Al Ageeg-Airport road).

clay. Silt content was significantly greater under *A. ehrenbergiana* (22.2%) and *A. tortilis raddiana* (12.5%), whereas it was least under *A. tortilis tortilis* (4.3%).

Aseer

It is apparent that *A. ehrenbergiana, A. asak, A. gerrardii* and *A. tortilis raddiana* were more abundant in sandy soils (Table 4), whereas *A. gerrardii* and *A.origena* were more frequent in clay soils.

Al Baha

In Al Baha, all *Acacia* spp. tended to be more abundant in soils where sand was predominant, with the exception of *A.origena* which prefers more clay and silt soils (Table 5).

DISCUSSION

It is apparent that climate had a considerable effect on the distribution of *Acacia* spp. This is in agreement with the study of Hnatiuk and Maslin (1988) who reported that the area of the highest density of *Acacia* spp. in Australia was the south-west corner of the continent, especially adjacent to the major boundary separating the arid zone from the more humid south west botanical province. The second major centre of richness of *Acacia* spp. occurred in eastern Australia south of the Tropic of Capricorn along the topographically heterogeneous Great dividing

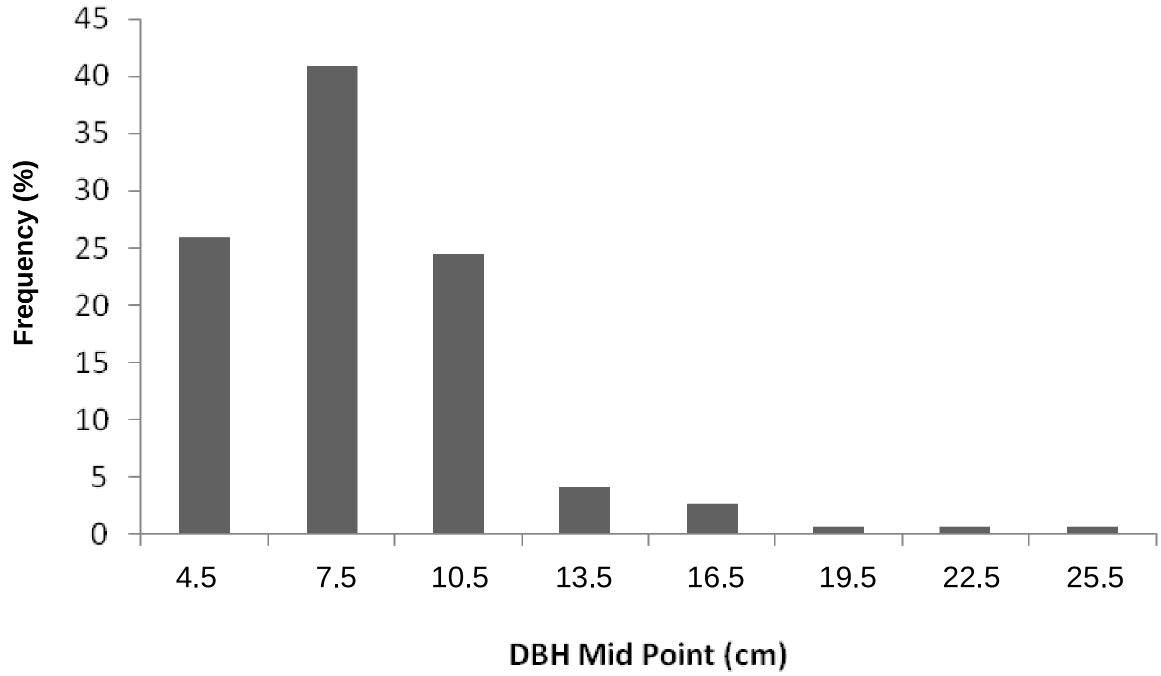

Figure 6. DBH distribution in Al Baha (Al Gimda).

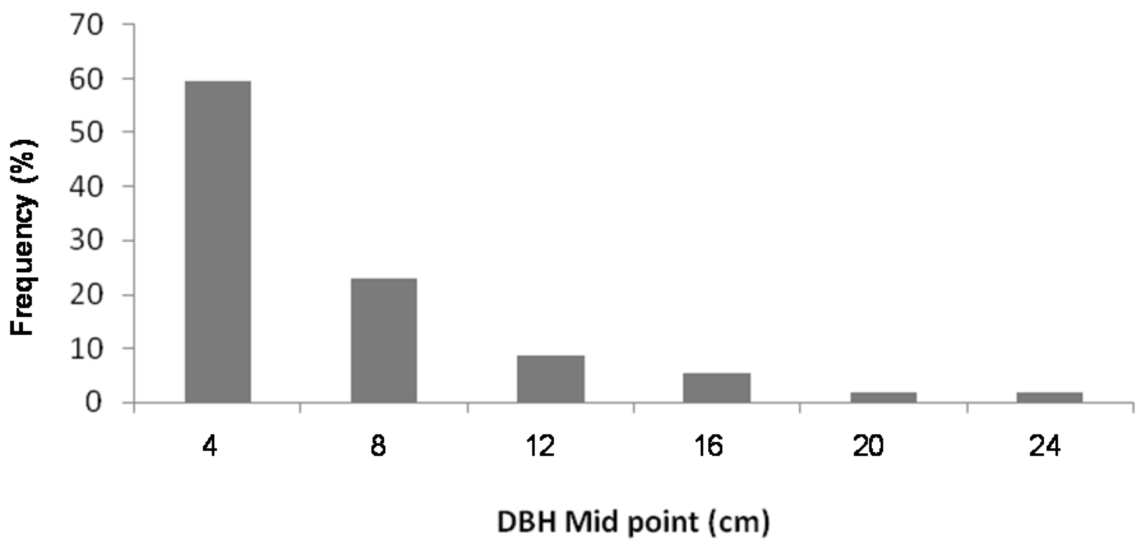

Figure 7. DBH distribution in Al Baha (Kara Al Matar road plot 1).

range. Secondary centres of species-richness occurred in northern and north-eastern Australia, a number of rocky tablelands of the arid zone and in western Victoria. The principal species-poor areas were located in sandy and some riverine areas of the arid zone, in temperate forests of Tasmania and in coastal areas of the north of the continent. The scarcity of large diameter trees is probably an indication of illicit felling and over grazing and the later had produced extremely stunted trees. This scarcity of large diameter trees in most locations is of concern. Rouvinen and Kuuluvainen (2005) reported that the lack of large trees would likely reduce the ability to sustain high biodiversity.

Internationally, stands with a reverse J-shaped diameter distribution have been the most prevalent (Lahde et al., 1991, 1999; Zackrisson et al., 1995). This kind of stand structure seems to have been a result of natural disturbances and dynamics of forests. However,

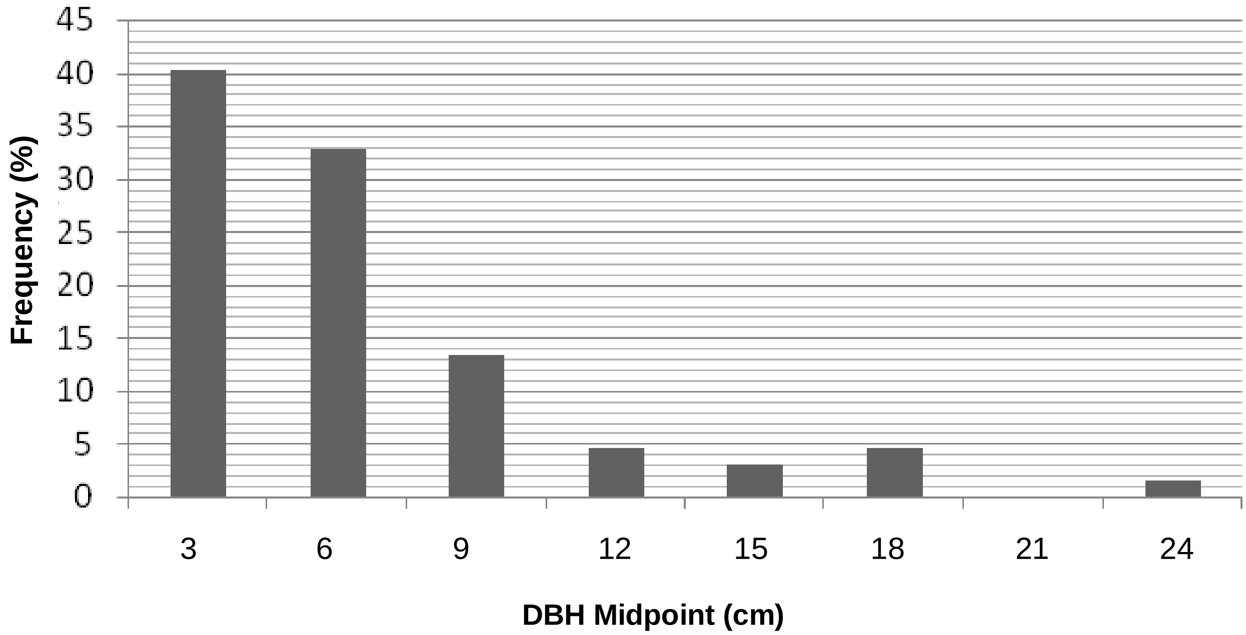

Figure 8. DBH distribution in Al Madinah Wadi Sedara (*A. tortilis*).

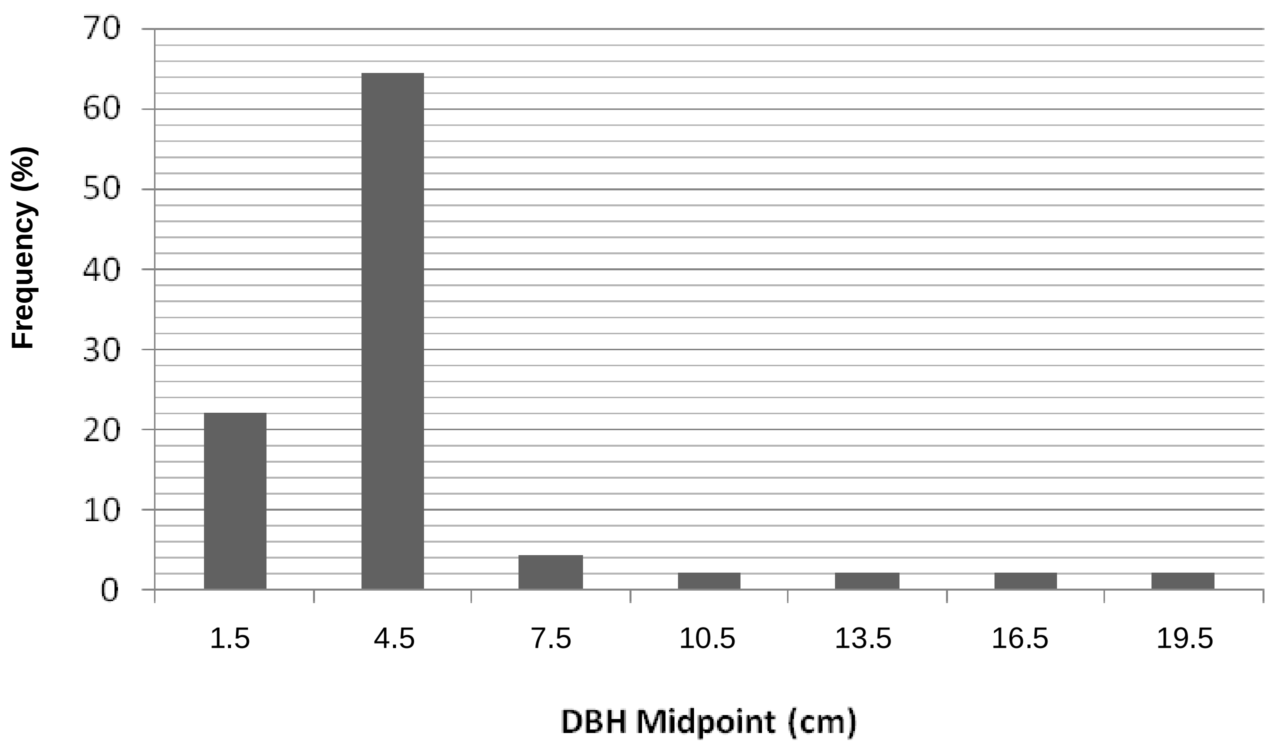

Figure 9. DBH distribution in Al Madinah Wadi Al Rimth (*A. tortilis*).

the reverse J-shaped curve is not the only applicable model for describing virgin uneven-sized forests. The distribution may also resemble a rotated sigmoid or bi-modal curve (Westphal et al., 2006). Diameter class distribution was considered as detrimental to forest structure and sustainability (Rubin et al., 2006). In the present study, the scarcity of large diameter trees and other DBH classes might be attributed to illicit felling, high

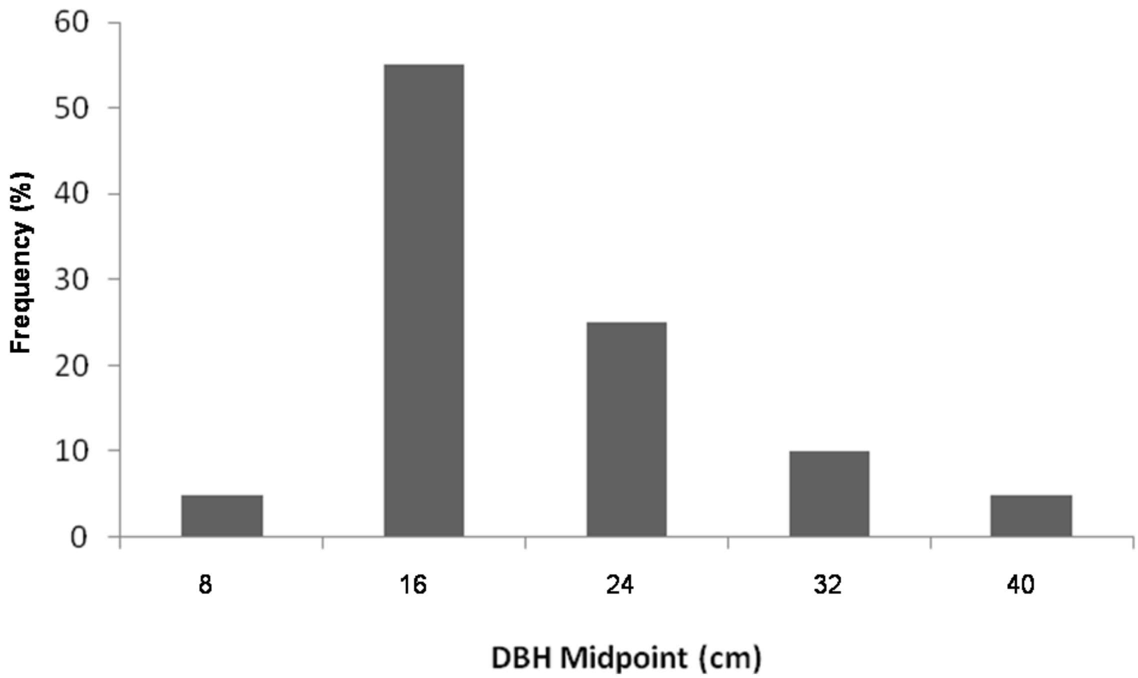

Figure 10. DBH distribution of *A. origena* in Aseer (Al Marbaa park plot 1).

Table 3. Soil texture under different *Acacia* spp. in Al Madinah.

Parameter	Value
Sand (%)	
A. tortilis tortilis	93.2[a]
A. tortilis raddiana	81.4[b]
A. ehrenbergiana	69.3[b]
Clay (%)	
A. ehrenbergiana	8.5[a]
A. tortilis raddiana	6.1[a]
A. tortilis tortilis	2.4[b]
Silt (%)	
A. ehrenbergiana	22.2[a]
A. tortilis raddiana	12.5[ab]
A. tortilis tortilis	4.3[b]

Means followed by the same letter are not significantly different at P = 0.05.

Table 4. Soil texture under different *Acacia* spp. in Aseer.

Parameter	Value
Sand (%)	
A. ehrenbergiana	79.4[a]
A. asak	78.3[a]
A. gerrardii	76.1[a]
A. tortilis raddiana	74.0[a]
A. etbaica	61.0[b]
A.origena	52.0[c]

Table 4. Continued.

Clay (%)	
A. origena	18.0[a]
A. gerrardii	14.1[b]
A. asak	9.1[c]
A. tortilis raddiana	8.4[b]
A. ehrenbergiana	8.3[c]
A. etbaica	8.3[c]
Silt (%)	
A. etbaica	30.7[a]
A. ehrenbergiana	14.3[b]
A.origena	30.0[a]
A. asak	12.6[b]
A. gerrardii	9.8[c]
A. tortilis raddiana	9.0[c]

Means followed by the same letter are not significantly different at P = 0.05.

Table 5. Soil texture under different *Acacia* spp. in Al Baha.

Parameter	Value
Sand (%)	
A. asak	76.4[a]
A. gerrardii	78.5[a]
A. tortilis tortilis	82.1[a]
A.origena	32.2[b]
A. ehrenbergiana	80.2[a]
Clay (%) (Not significant)	
A.origena	13.8
A. gerrardii	8.5
A. asak	7.9
A. tortilis tortilis	8.4
A. ehrenbergiana	8.2
Silt (%)	
A. tortilis tortilis	9.5[b]
A.origena	54.0[a]
A. asak	15.6[b]
A. gerrardii	13.0[b]
A. ehrenbergiana	12.9[b]

Means followed by the same letter are not significantly different at P = 0.05.

intensity of grazing and fire. Therefore, intervention by planting as well as protection is recommended at least during regeneration periods to enrich these forests and woodlots, so as to attain sustainability. It is evident that soil texture had a significant effect on the occurrence of *Acacia* spp. This is in agreement with the study of Fterich et al. (2011) who reported a close link between *A. tortilis raddiana* and soil texture.

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